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MEMORANDUM



**Atlantic Inflow Experiment,
GIN Sea
Cruise '86**

**Data Report
Part II: Circulation**

T.S. Hopkins,
P. Giannecchini, L. Gualdesi
and P. Zanasca

March 1990

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Pages	Total
i-vi	6
1-43	43
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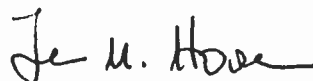
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Executive Summary: This memorandum provides a data summary of the Atlantic Inflow Experiment in the form of an oceanographic data report. Its purpose is to provide a complete data summary that serves as a reference for the experiment itself and for subsequent interpretive analyses in accordance with the scientific objectives of the GIN Sea Project.

The Atlantic Inflow Experiment was designed to provide information on the entrance of Atlantic waters to the Arctic Ocean through the Faeroe-Shetland Channel. The sampling design was unique and the instrumentation was more advanced technologically than that used in previous oceanographic samplings of the area.

Detailed sampling of the oceanographic environment provides information on three levels: exploration of the environment in both space and time frames not yet observed; confirmation of our understanding of the physical processes governing the ocean environment; and utilisation of both these data and laws in quantitative assessments (models) that allow environmental prediction. These descriptions and assessments of the ocean environment are a primary requirement for ASW research.

The data report for the 1986 portion of the Atlantic Inflow Experiment is divided into Part I: Hydrography (reporting on the shipboard sampling of water properties) and Part II: Circulation (reporting on the sampling conducted from moored and free-floating instruments). Included in this memorandum are the data obtained from seven currentmeters on three moorings, two subsurface acoustic floats, and one ARGOS drifting meteorological/thermistor chain buoy. These were positioned in the Faeroe-Shetland Channel in a spatial arrangement that would provide information on the inflow, its recirculation in the Channel, and the outflow of the deeper waters.

SACLANTCEN SM-231

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Part II: Circulation**

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Abstract: As the initial field effort of the Atlantic Inflow Experiment, three instrumented moorings were deployed in the Faeroe-Shetland Channel during June 1986. The purpose of the array was to monitor the inflow, and to track the movement of two subsurface floats deployed beneath the inflow in the sound velocity minimum at ~ 600 m. For this purpose a triangular array was deployed with two moorings placed within the main inflow stream and one on the western outflow side. Each mooring had two principal currentmeters at ~ 125 and 230 m and a listening station at ~ 600 m. All three moorings performed well resulting in a ~ 25 -day time series of flow in the Channel to accompany the hydrographic cruise taken over the entire inflow area. The results of a drifting ARGOS meteorological buoy, placed within the array of current meters, is also included in this report. The data are presented in the form of time-series plots, progressive-vector diagrams, velocity stick diagrams, and tables of statistics.

Keywords: acoustic doppler profile \circ Arctic Ocean \circ Atlantic Inflow \circ circulation \circ current measurement \circ Faeroe-Shetland Channel \circ GIN Sea \circ Greenland-Iceland-Norwegian Sea \circ hydrography \circ meteorology \circ Norwegian Atlantic Current \circ outflow

Contents

1. Introduction	1
1.1. <i>GIN Sea project</i>	1
1.2. <i>Atlantic Inflow Experiment</i>	1
1.3. <i>Collaboration</i>	2
2. Instrument deployment locations	4
3. Methods	6
3.1. <i>Data acquisition systems</i>	6
3.2. <i>Data processing</i>	11
4. Data presentation	15
4.1. <i>Statistics</i>	17
4.2. <i>Time-series plots</i>	25
4.3. <i>Progressive vector diagrams</i>	37
4.4. <i>Stick diagrams</i>	39
References	43

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1.1. GIN SEA PROJECT

The GIN Sea observational programme was initiated to acquire an extensive set of oceanographic data in the Greenland–Iceland–Norwegian Sea from which state-of-the-art quantitative analyses could be conducted to serve the purposes of SACLANTCEN and the NATO scientific communities. During the field experiments, an attempt was made to employ as many different techniques as feasible in order to maximize the potential for interpretive assessment. The observational programmes utilize a core of standard instrumentation (CTD, currentmeters) complemented by experimental instrumentation (e.g. acoustic doppler profilers, subsurface floats, drifting meteorological buoys) and augmented by biochemical sampling (e.g. chemical tracers, planktonic observations).

The SACLANTCEN GIN Sea Project proposed two major observational experiments: the Atlantic Inflow Experiment in 1986–87 and the Icelandic Boundary Current Experiment in 1988–89. The first deals with the water mass input to the GIN Sea via the Faeroe–Shetland Channel and its subsequent transitions northward within the Norwegian Atlantic current system. The second deals with the large-scale forcing controlling the Icelandic Current which transports waters of the Denmark Strait to the Faeroes Channel and which establishes the dynamic boundary forming the Iceland–Faeroe Front. The two experiments together are designed to provide a more complete understanding of the physical dynamics that control the exchanges with the Atlantic Ocean, the formation of the Arctic Front, and the origin of the significant meso-scaled variability in the southern GIN Sea.

1.2. ATLANTIC INFLOW EXPERIMENT

The Arctic Ocean draws in the North Atlantic surface waters in large quantities, $\sim 4\text{--}8$ Sv. Most of this inflow derives from a portion of the North Atlantic Current which enters the Arctic Ocean over the Wyville–Thompson Ridge and through the Faeroe–Shetland Channel. Smaller inflows arrive via the Iceland–Faeroe Ridge and the Denmark Strait. Virtually all of the salt and heat input to the Arctic Ocean enters with this input. Although considerable observational effort has been spent in attempting to quantify this input, the results have not been particularly consistent nor have they been in accord with the input values deduced from thermohaline balances of the Arctic Ocean (see Hopkins, 1988). In part, these results

have been explained by the historical need to rely on the dynamic method, with its uncertainty of an unknown reference level, i.e. Tait (1957). The more recent use of currentmeters has provided better direct information on the flow field (i.e. Dooley and Meincke, 1981), but a comprehensive data set does not yet exist that provides a satisfactory description of the inflow and its temporal variability. A review of the observational attempts to establish this inflow and its general relevance to the Arctic Ocean oceanography can be found in Hopkins (1988).

The GIN Sea Project has undertaken the observational task of enhancing the body of data concerning the behaviour of this input water within the southern portions of the GIN Sea (Norwegian Sea) in order that the interface between this water mass and the Arctic Waters can be better described. We have called this observational effort the 'Atlantic Inflow Experiment'. The cruise also served as an introductory cruise in an engineering sense, that is, in the sense of deploying SACLANTCEN hardware into northern waters for the first time.

This data report summarises the data from the 1986 expedition, which concentrated on the Faeroese Channel region. Data from the hydrographic casts and from the deployed instrumentation have been summarised as Part I: Hydrography (Hopkins, 1989) and Part II: Circulation, respectively.

1.3. COLLABORATION

The GIN Sea Project is unclassified and open to collaboration with oceanographic research institutions of NATO member nations. This policy is intended to encourage participation and scientific exchange within the NATO community. In both the hydrography and mooring phases of the GIN Sea Cruise '86, the GIN Sea Project was assisted by collaborating institutes, summarized as follows:

- *Institute of Oceanographic Sciences (UK)*
 - participation of I. Waddington and G. Phillips
 - deployment of IOS moorings 1, 2, and 3 (J. Gould, principal investigator)
 - loan of 2 Aanderaa currentmeters for SACLANTCEN mooring 1
- *Dutch Royal Navy Hydrographic Office (NL)*
 - participation of M. Scheffers
 - administrative Support
- *Stazione Zoologica di Napoli (IT)*
 - participation of M. Ribera
 - loan of fluorometer, centrifuge, and vacuum pump

SACLANTCEN SM-231

- *Istituto Scienze Ambientali Marine (IT)*
 - participation of P. Povero
 - loan of filter apparatus for POC and heavy metal analysis
- *Deutsches Hydrographisches Institut (FRG)*
 - participation of Z. Vogel
- *University of Bergen (NR)*
 - phytoplankton sample counts (T. Johnsen)
 - oxygen-18 sample analysis (T. Johannessen)
 - *Institute of Environmental Physics, University of Heildleberg (FRG)*
 - tritium sample analysis
- *Netherlands Institute for Sea Research (NL)*
 - additional silicate analysis (J. van Bennekom)

2

Instrument deployment locations

The location of the three SACLANTCEN moorings in the Faeroe–Shetland Channel and the three IOS moorings on the Faeroe continental shelf are indicated in Fig. 1. Also shown is the deployment position of the meteorological buoy and the accompanying CTD stations of Leg I.

SACLANTCEN SM-231

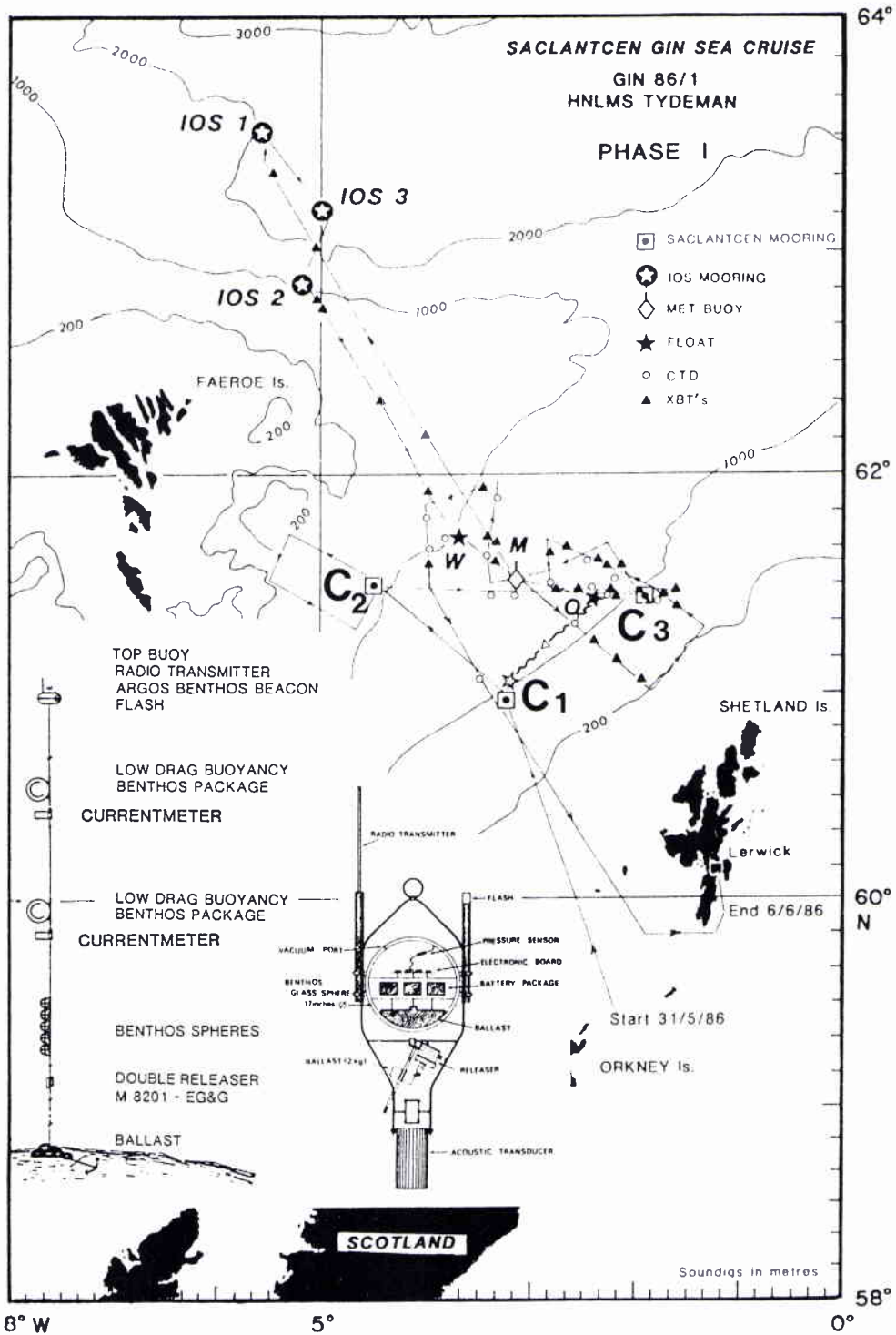


Figure 1 Location chart for the Mooring Leg of GIN '86 cruise. (The insert displays the mooring configuration and the OED float design.)

3

Methods

3.1. DATA ACQUISITION SYSTEMS

3.1.1. Array and mooring design

A triangular array of moorings (Fig. 1) was deployed as a compromise between providing good spatial configuration for observing the movements of the subsurface floats and providing observations of the inflow through the Faeroe–Shetland Channel. As this was the first use of SOFAR floats in the region, a conservative spacing of ~ 100 km was used between the moorings. Two of the moorings were located on the Shetland side of the Channel where the Atlantic Inflow is known to be concentrated. From the mean-flow estimates of the core of the Atlantic Water (Gould, personal communication) and the known energy peak in the 2–5 day band, it was estimated that the 100-km spacing would be within the alongshore coherence length scale of major flow events. Each of the moorings were placed at the 800-m isobath, to facilitate dynamical comparisons between the different currentmeter records by minimizing the effects of bathymetry.

All three moorings were single-point, taut-wire, subsurface moorings and were deployed by free-fall and recovered by acoustic release. The mooring design is shown in the insert of Fig. 1, and the instrument depths are given in Table 1. Note that the IOS moorings are also included for information; for more detail see Saunders and Gould (1988).

3.1.2. Currentmeters

As indicated in Table 1, four different types of currentmeters were used among the total of eight currentmeters used on the three SACLANTCEN moorings:

- Neil Brown Instrument Systems (NBIS) vector averaging acoustic currentmeter, model ACM-2 (two-axis). The instrument measures the doppler phase difference, created by water flowing past the instrument, between a pair of high-frequency (1.6 MHz) sound transducers. The phase difference is converted to a frequency, which is counted and stored for each orthogonal component. Absolute orientation is achieved by a flux-gate type compass. The average values of the orthogonal components are recorded on a data cassette along with the corresponding instrument temperature at the recorded time interval.

SACLANTCEN SM-231**Table 1** *Currentmeter deployment data*

	Mooring 1 ¹			Mooring 2 ²			Mooring 3 ³	
	RCM 4	VACM	NBIS	RCM 4	VACM	NBIS	VACM	VMCM
Depth (m)	110	131	236	695	127	230	123	228
Start time	day	151	151	151	151	152	152	152
	hour	14	14	14	14	08	08	17
	minute	20	20	20	20	13	13	24
End time	day	175	175	175	175	176	176	176
	hour	11	11	11	11	08	08	16
	minute	15	15	15	15	20	20	42
Sampling interval (min)	5	3.75	4	5	3.75	4	3.75	4
Variables	speed	×	×	×		×	×	×
	direction	×	×	×		×	×	×
	<i>T</i>	×	×	×	×	×	×	×
	<i>S</i>	×			×			
	<i>P</i>	×			×			

¹ Latitude: 60° 58.00'N; longitude: 03° 12.60'W.

² Latitude: 61° 29.90'N; longitude: 04° 30.75'W.

³ Latitude: 61° 26.45'N; longitude: 01° 53.75'W.

- EG&G vector averaging currentmeter (VACM), model 610B. This instrument utilises a Savonius-type rotor to determine the speed and a vane in conjunction with a flux-gate type compass to determine direction. The number of rotor counts and the direction values (taken 8 times per rotor revolution) are used to calculate vector components for subsequent storage on a cassette.
- Davis Weller, vector measuring currentmeter (VMCM), model 630. This instrument uses a pair of orthogonal propellers for the speed sensor and a flux-gate type compass for sensing the direction (of the pressure case). An internal microprocessor calculates the north and east components for storage on a cassette.
- Aanderaa instruments currentmeter model, RCM 4. This instrument uses a Savonius-type rotor to record the water speed and a magnetic compass to obtain the orientation of the pressure case relative to a large vane. By means of potentiometers, both sensors outputs are converted to a binary code by an electromechanical encoder which dumps to a data tape at the end of every sampling interval.

Information associated with the deployment and recovery of the currentmeters is given in Table 1.

3.1.3. Subsurface float system

Listening station The subsurface floats are tracked by means of time-delay signals recorded by listening stations attached to the moorings (see Table 2). In this application, they were located at the mean depth of the sound velocity minimum. A listening station consists of a 4-hydrophone array, an amplifier, a microprocessor with a correlator and a tape recorder. The amplifier has automatic gain control and amplifies the received signal to a level equal to the reference level. It continuously receives acoustic signals and makes correlations with a dummy reference signal that matches that of the floats. During this process, a heterodyne mixer converts the transmission frequency range of 1562.5–1572.5 Hz to a 1–10 Hz range. The microprocessor orders the correlations on the criterion of best correlation and earliest time delay between the two signals. Every four minutes the four highest correlated signals are stored in a data block along with housekeeping information. The listening stations (see Table 3) also have an acoustic transmitter and this transmits the correlation information from the memory register of the microprocessor every 4 min; the transmitter information can be received by a normal echo-sounding receiver tuned to 12 kHz.

Table 2 *Float deployment data*

	Float 7 (OED)	Float 0 (Webb)
Start time {	155	155
day		
hour	21	14
minute	30	0
Start position {	61°25.71'N	61°42.76'N
	02°25.49'W	03°42.58'W
End time {	175	not
day		recovered
hour	10	
minute	00	
Start depth (m)	600	950
Sound velocity (m/s)	1500	1500
Clock shift (s)	0.7	not observed

Shipboard acoustic receiver A shipboard receiver, which is similar in electronic design to the moored listening stations but is connected and lowered via the ship's CTD cable, was employed to monitor the transmitted float information. The correlations and their arrival times are printed out and plotted on board. This receiver was used just after deployment of a float to monitor its depth, and was used during float recovery to provide range and monitor arrival at the surface.

SACLANTCEN SM-231**Table 3** *Deployment information on float listening stations*

		Station number		
		1	2	3
Start time	day	151	152	152
	hour	14	08	17
	minute	20	13	24
End time	day	175	176	176
	hour	11	08	16
	minute	15	20	42
Position	{	60°58.00'N 03°12.60'W	61°29.90'N 04°30.75'W	61°26.45'N 01°53.75'W
Depth (m)		593	590	585
Clock shift(s)		-0.154	+0.278	-0.140

Subsurface acoustic floats Two types of subsurface acoustic floats were deployed. The first type was constructed by the SACLANTCEN Oceanographic Engineering Department (OED) which was designed after the Swallow-type SOFAR floats described by Tillier (1980). A more complete description of the SACLANTCEN design can be found in Pistek (1987); Pistek, de Strobel and Montanari (1984).

The second type was manufactured by Webb Research Corporation and has the following specifications:

- Autonomy: 3 months.
- Power: 18 W (acoustic).
- Max depth: 2000 m.
- Accuracy: $T = 0.01$ °C, $P = 1\%$ F.S.

These floats are equipped with acoustic pingers housed in 50-cm glass spheres. The spheres also contain transducers which monitor pressure and temperature. The OED floats are further equipped with an acoustic release for recovery and with flashing light and radio transmitter to fix location after release (Fig. 1). These floats are designed to remain at constant pressure, but due to an indeterminacy of the compressibility of the rubber and plastic components, some variation in depth usually occurs during the first six hours or so after deployment. The pressure adjustment data are given below with the data results in Figs. 18 and 19. As can be seen, the Webb float greatly overshoot its intended depth of 600–940 m and for unexplained reasons returned to 700 m. The pressure adjustment of the OED float was close to that expected, falling within the first three days to ~ 625 m.

3.1.4. Meteorological buoy

A special-design meteorological-thermistor chain buoy was constructed by the Polar Research Laboratory under the supervision of the US National Data Buoy Center. The buoy itself was the same as those employed in the TOGA Project, i.e. using standard meteorological sensors with a satellite transmitter. The basic modification was the addition of a 300-m thermistor chain. The distribution of the sensors is given in Table 4. Sensor data were organised into 32 8-bit words. The data were stored as 8-min running data averages and compiled for transmission every minute to the TIROS satellite. The data and buoy positions were available through the Service ARGOS receiving station, Toulouse, France.

Table 4 *Sensor description of met. buoy, no. 4126*

Channel	Depth	Sensor	Data
1	–	none	–
2	–1	air temperature	Y
3	0	water temperature	Y
4	–1	air temperature	Y
5	130	pressure	N
6	–1	wind speed	Y
7	–1	wind speed	Y
8	300	pressure	N
9–15	–	none	–
17	2	temperature	N
18	5	temperature	Y
19	8	temperature	N
20	11	temperature	Y
21	15	temperature	N
22	20	temperature	Y
23	35	temperature	N
24	50	temperature	Y
25	70	temperature	N
26	100	temperature	Y
27	130	temperature	N
28	160	temperature	Y
29	200	temperature	N
31	250	temperature	Y
32	300	none	N

3.2. DATA PROCESSING

3.2.1. Currentmeters

Data reduction The raw data format was determined by the currentmeter type. The particular data parameters for each type and the sampling interval are given in Table 1. The raw-data cassettes were transferred to a 16-track magnetic tape and read into the Centre's UNIVAC to create a raw-data file. The file was searched for gaps, missing sampling points, spikes, and sampling points with excessive values. The gaps were generally only one or two samplings wide ($\sim 2\Delta T$) and were replaced by linear interpolations. The gaps have been generated during data transfer and were not caused by a malfunctioning of the sensor. The spikes were removed and replaced by interpolated values.

The files were then transferred to the UNIVAC MINIFILE system, where the remainder of the data reduction was performed. Raw-data time-series plots were used, together with the deployment information, to determine the start and end times of the 'good data'. A clean time-series was then created for each currentmeter record in a Julian-day timeframe that included the original raw parameters, and additional calculated or derived variables, such as the filtered velocity components. The entire time series of all the currentmeter variables returned 'good data'.

The UNIVAC system was dismantled in late 1986 and a VAX 8600 system installed. During 1987 and 1988 a MicroVAX software currentmeter processing package (CURMET) was brought on line and the data were reprocessed with that system. The data presented here represent a mix of these two processing packages. The data have been transferred from the MicroVAX to an oceanographic database on the VAX.

Calibration A brief description of the calibration and adjustment procedures used for the different types of currentmeter sensors is given below:

- Type 1: Neil Brown acoustic: two- and three-axis. The major advantage of this type of currentmeter, relative to the others, is that the use of a tow-tank or calibration standard is not necessary. This is because the output is dependent only on the acoustic frequency, the transducer integrity, and the spacing (or distance) between transducers. An accurate electronic check and adjustment is available to guarantee the proper functioning of the currentmeter within the operating range. The fixed parameters were: calibration factor $K = 0.94$ (depending on the electrical and mechanical transducer characteristics); the two-axis spacing $D = 11.4$ cm; and the acoustic excitation frequency $f = 1.605$ MHz. Prior to each cruise, the following adjustments were made: full-scale range ± 2.5 m/s = ± 2000 mV output at half-scale; zero off-set stability $\leq +2$ mV. The zero stability on the velocity output was observed during 24 h or more and continuously adjusted as necessary. The instrument sensors were submerged, in 1 m³ of still, bubble-free fresh water. Compass output, clock and timing, and temperature conversion, were also accurately verified according to

the operating and instruction manual. All the above information was easily displayed and converted through the use of the test-set data readout feature. The data were also recorded on cassette tape and transferred to a Hewlett-Packard computer (HP-21MX) via the Memodyne cassette reader for final verification.

- Types 2 and 3: VACM vector averaging rotor, Savonius type, and VMCM dual orthogonal propeller, Davis-Weller type. To assure the minimum friction and 'free rotation', all the bearings were replaced and lubricated before each deployment. It was assumed that the factory standard calibration factors applied.
- VACM (*Savonius*). Rotor constant $K = 34.6$ cm (the water flow needed for one complete rotor revolution; valid for water currents with flows between 2.8 and 32.1 cm/s). The rotor threshold was ~ 2.6 cm/s.
- VACM (*Davis-Weller*). Rotor constant $K = 9.363$ cm (the water flow per instrument count). The threshold speed was 0.9 cm/s.

Particular care was taken in the verification of the propeller R1 and R2 counts by using the test-set binary unit for the Savonius-type rotor and the diagnostic 20 mA loop interface and HP-85 computer for the Davis-Weller-type. In parallel with this 'in-line' checking procedure, all the data were recorded on cassette tape and translated to the Hewlett-Packard computer (HP-21MX) via the Sea Data model 12 reader for the final verification.

A post-cruise inspection of all the currentmeters was conducted to check the condition of the mechanics, the crystals, the rotors and the propeller movements. An electronic check of all the sensors was conducted to verify that they still functioned according to specification.

3.2.2. Floats

Raw float data and treatment After recovery, the listening station data was transferred from the original cassette tapes to the UNIVAC. This raw data information contains the four highest-valued correlations and is formatted into a data clock containing 20 number-coded fields covering the station number, experiment number, day, hour, and the time for each of the four correlations in minutes, seconds, and milliseconds.

The floats transmitted for 20 s every 1 h. The times of transmission for the two floats were separated by 30 min. In order to identify the data from individual floats, a program created separate data files for each float according to whether the correlation times were within -1 to $+13$ min of the individual float transmission times. For each float, the highest correlation time was chosen on the condition that it fell within a reasonable range of time delays, in order to exclude spuriously

SACLANTCEN SM-231

high correlations. The selected time delays for each float were then used to create another file which constituted a time series for each float of the distance to each of the listening stations. The transmission interval for temperature Webb float interval was every 24 h every 48 h alternating each 24 h between temperature and pressure. The data transmission intervals are given Table 5.

Table 5 *Sampling intervals (in h) for float data*

Float	Distance	Temperatures	Pressure
OED	1	24	24
Webb	1	48*	48*

* Alternating every 24 h.

Float fix computation To compute the sequence of fixes for a given float, an interactive program was used. The previous positions of each float and the distance arcs from the individual listening stations were displayed on a 12×12 n.mi Mercator grid:

- For three arcs, an area was defined in which the operator fixed a point with a cursor. A new file was then created with a time series of latitudes and longitudes. The operator chose the median position unless one arc was unreasonably located relative to the previous fix.
- For two arcs, the point was again taken within reasonable limits.
- For those cases where there was only one arc, the fix was placed on the intersection of an extension of the float track and the arc.

Clearly, more reliable fixes were obtained when there were three arcs to a listening station.

The number of valid arcs tended to degenerate as the distance from the listening station increased. To edit the fixes resulting from this treatment, we took the mean and standard deviation of the incremental changes in latitude and longitude between sequential fixes (Table 6). Points changing more than three standard deviations were replaced by an increment in latitude or longitude equal to three standard deviations. After this treatment, the data were considered as edited raw data, i.e. a time-series of latitudes and longitudes. These were converted to cartesian coordinates and a time-series of east–west and north–south components constructed. In addition, the data were filtered with a tidal filter (Groves, 1955) having a half-energy point at 40 h. A discussion of error in the float fixes is given in Hopkins and Zanasca (1988).

Float calibration For deep-water deployments, where the density stratification is very slight, precise measurements of the density of the floats is required in order

Table 6 Mean and standard deviation of incremental changes in latitude and longitude between sequential fixes and the number of points beyond the three standard deviation limit

Float	Latitude change		Points ¹		Longitude change		Points ¹		Total ²
	mean	st. dev.	no.	%	mean	st. dev.	no.	%	
OED	0.004	0.0042	7	1.5	0.008	0.0062	5	1.1	469
Webb	0.004	0.0038	1	0.2	0.005	0.0043	2	0.4	500

¹ Outside limit. ² Number of points.

to ensure stabilization at the desired depths. A method of calibration has been developed by OED in which an empirical curve of the float density *vs* depth is constructed. In order to be within ± 20 m of the required deployment depth, the precision in the density of the surface float must be of the order of 2×10^{-5} g/cm³. This was obtained by:

- Weighing the float in air with an accuracy of ± 0.02 g on an electronic balance (Sauter model K.120). The OED float weighed 48.23 kg and the Webb 44.85 kg.
- Weighing the float totally submerged (in a specially designed tank filled with seawater) to an accuracy of better than ± 0.2 g (with the same electronic balance).
- Accurately measuring the tank seawater density to an accuracy of 0.8×10^{-5} g/cm³ with a temperature/conductivity standard (Neil Brown Instrument Systems).

The density of the float was then calculated from the formula

$$\rho_{\text{float}} = \left[\frac{m}{M - m} + 1 \right] \rho_{\text{water}},$$

where m is the weight in seawater, M the weight in air, ρ_{float} the density, and ρ_{water} the density of seawater computed from S, T for $P = 0$. More details and a discussion on error are given in Pistek, de Strobel and Montanari (1984).

4

Data presentation

The data are presented in Figs. 2–30. For reference, a summary plot of the current-meter progressive vector diagrams and the met. buoy trajectory is shown to scale in Fig. 2. The figures are organised in a sequential way by mooring and depth, starting with mooring 1 top sensor and ending with mooring 3 bottom sensor. Following the data from the moored currentmeters is given that of the floats and the met. buoy. Each figure has a self-explanatory legend; the following notes are given as a supplement.

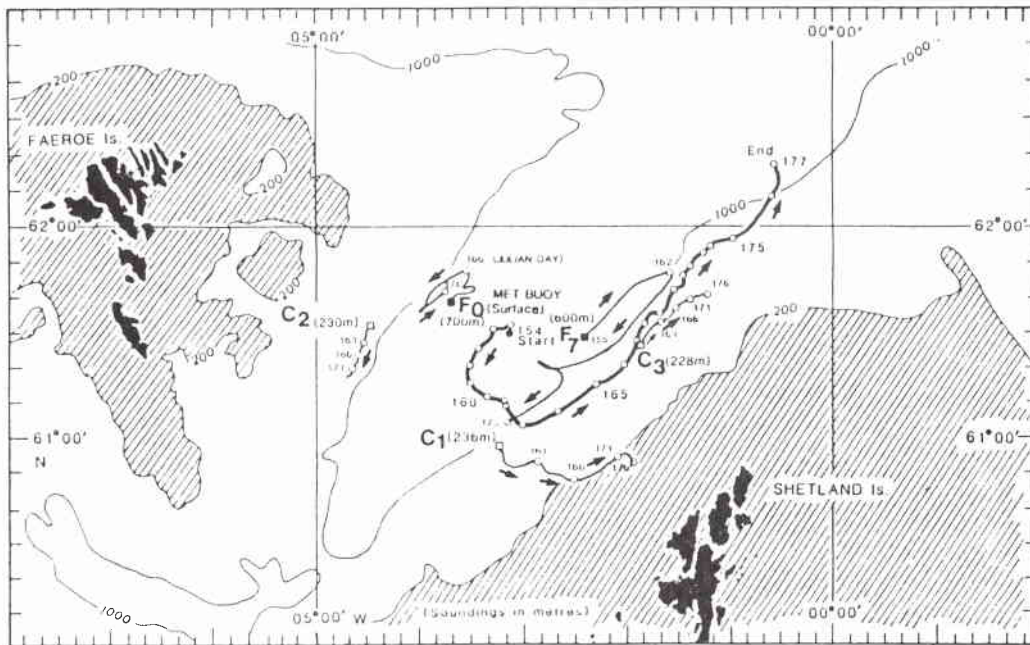
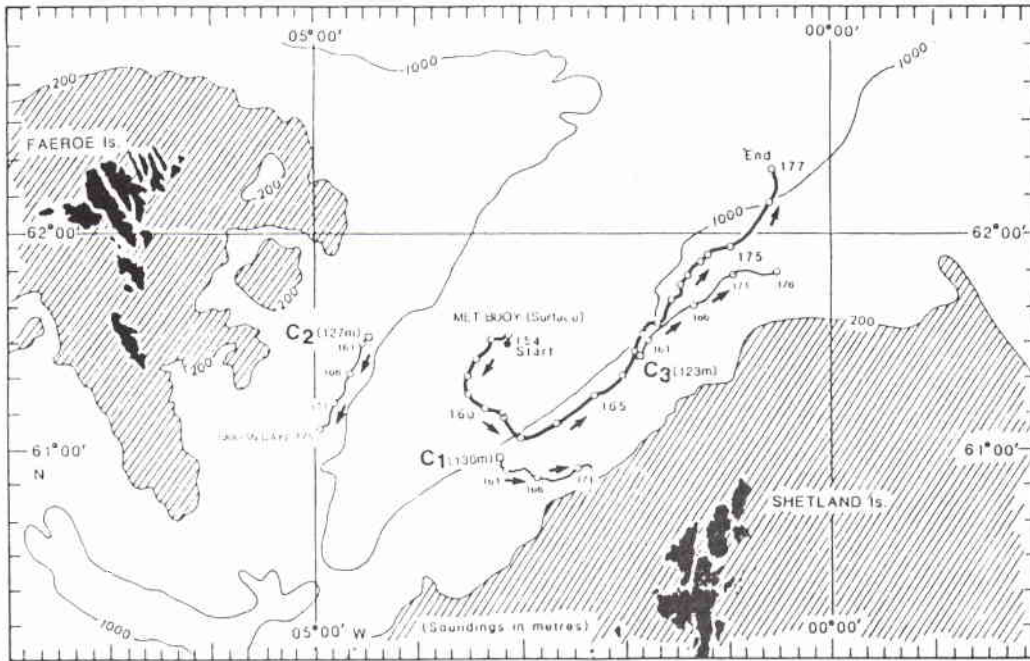


Figure 2 Scaled progressive vector diagrams for the SAACLANTCEN currentmeter moorings and trajectory for the met. buoy. (The upper panel shows the shallower records and the lower panel the deeper ones.)

SACLANTCEN SM-231

4.1. STATISTICS

The statistics of the currentmeter records are included in the current roses of Figs. 3-9, as the mean speed V , its standard deviation (st. dev.), resultant direction Θ , the maximum speed V_{\max} and the minimum speed V_{\min} .

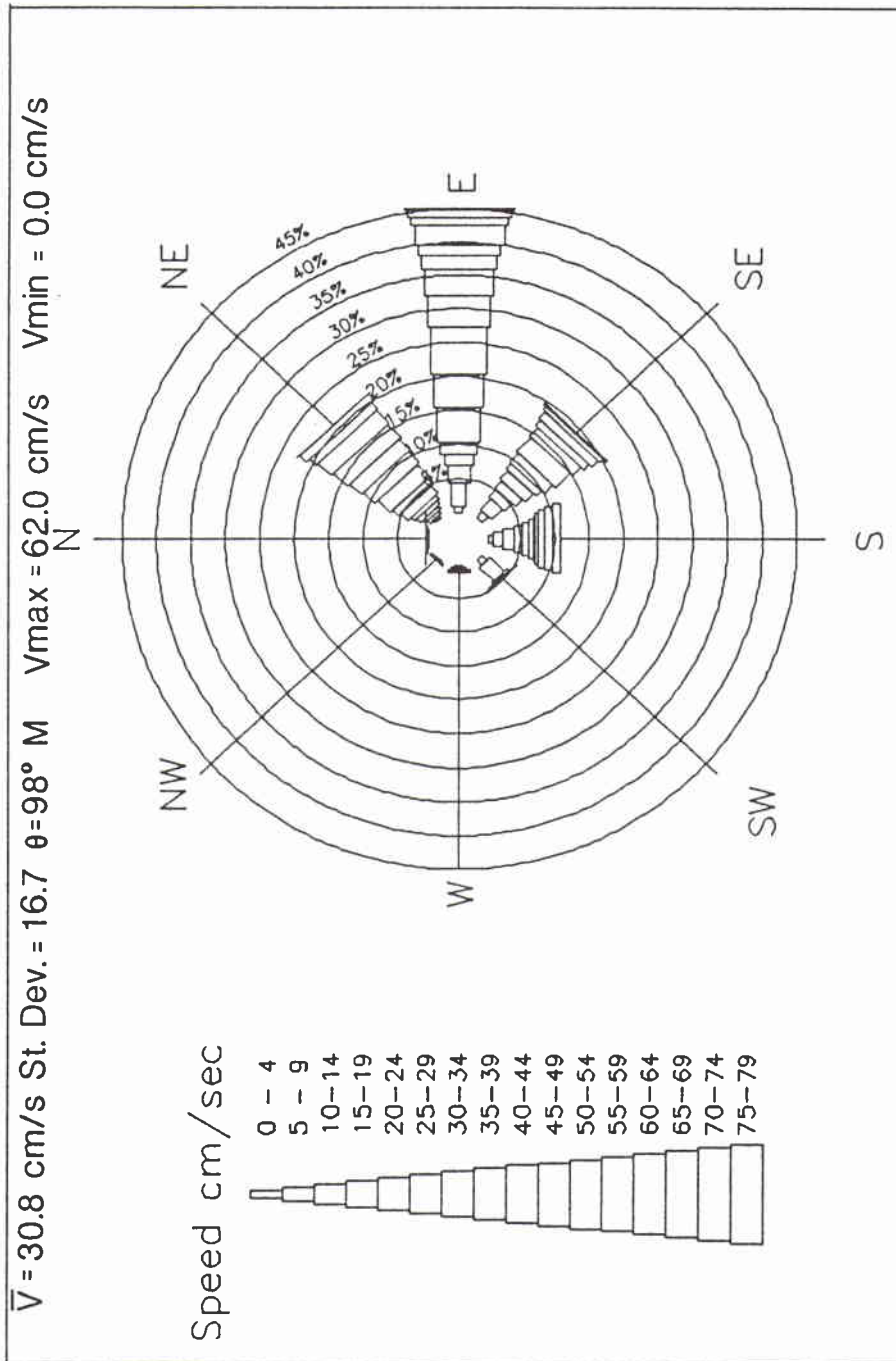


Figure 3 *Compass rose for SACLANTCEN currentmeter mooring C₁ at 110 m depth. (All directions are referred to magnetic north.)*

SACLANTCEN SM-231

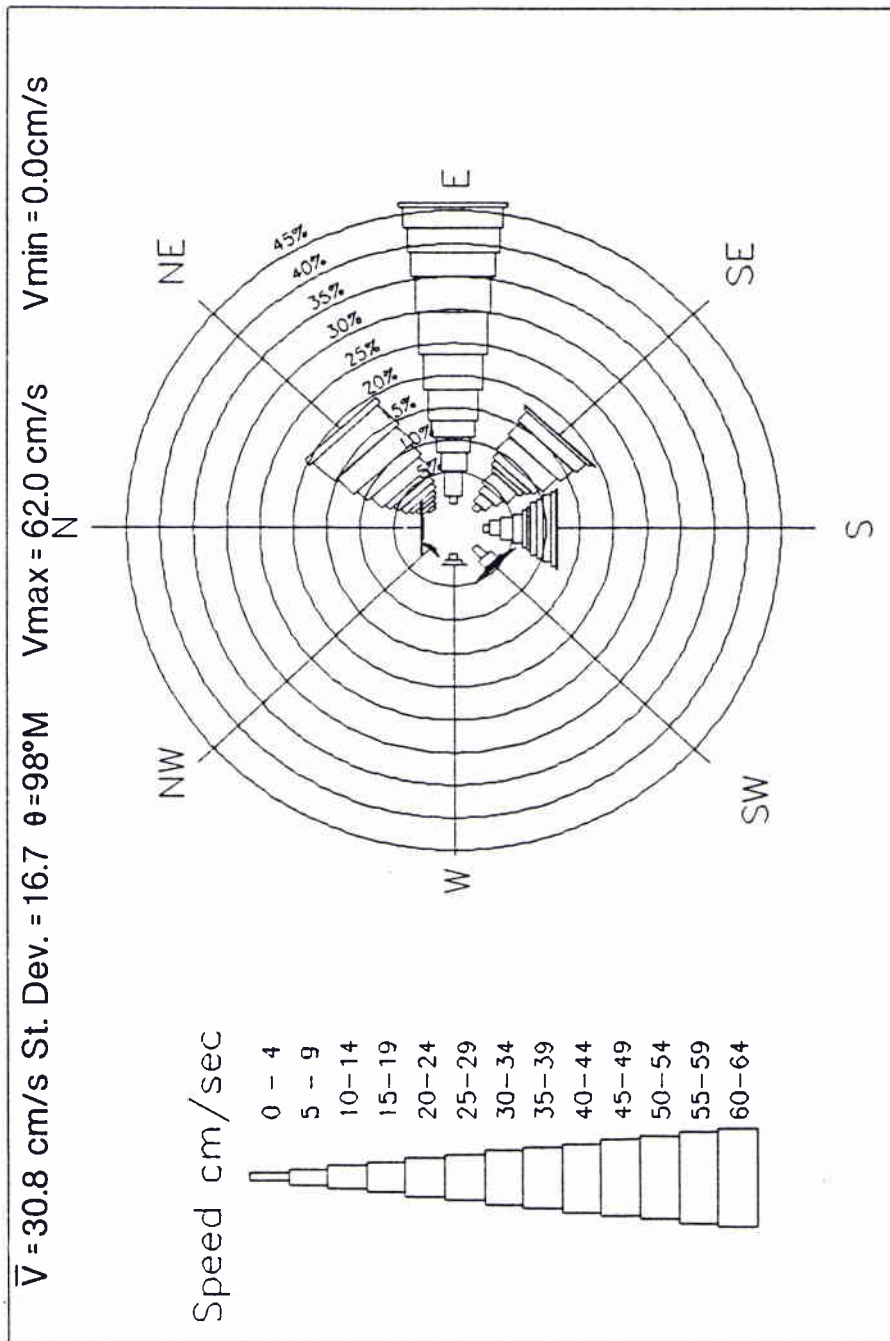


Figure 4 Compass rose for SACLANTCEN currentmeter mooring C_1 at 131 m depth. (All directions are referred to magnetic north.)

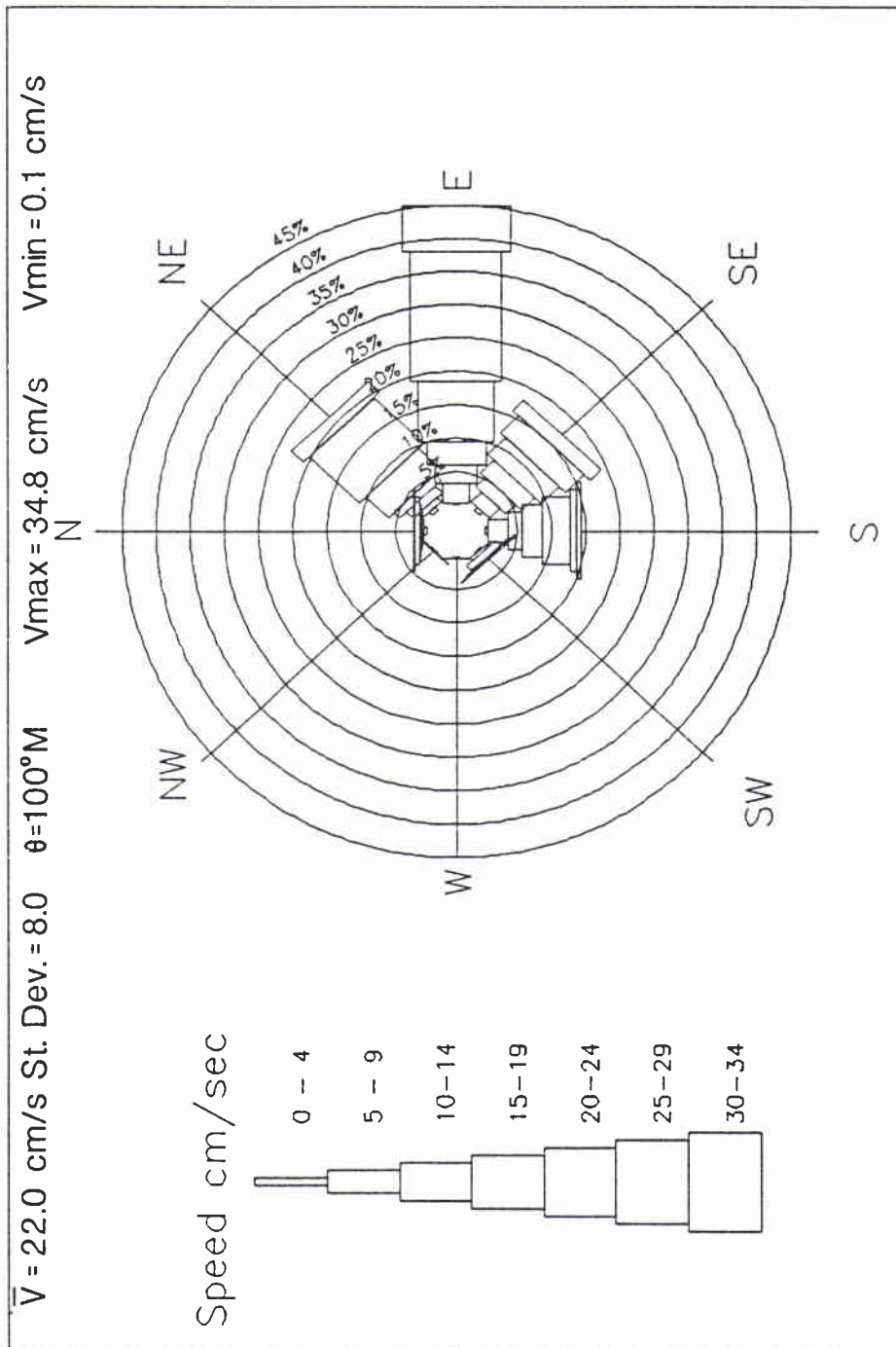


Figure 5 Compass rose for SACLANTCEN currentmeter mooring C_1 at 236 m depth. (All directions are referred to magnetic north.)

SACLANTCEN SM-231

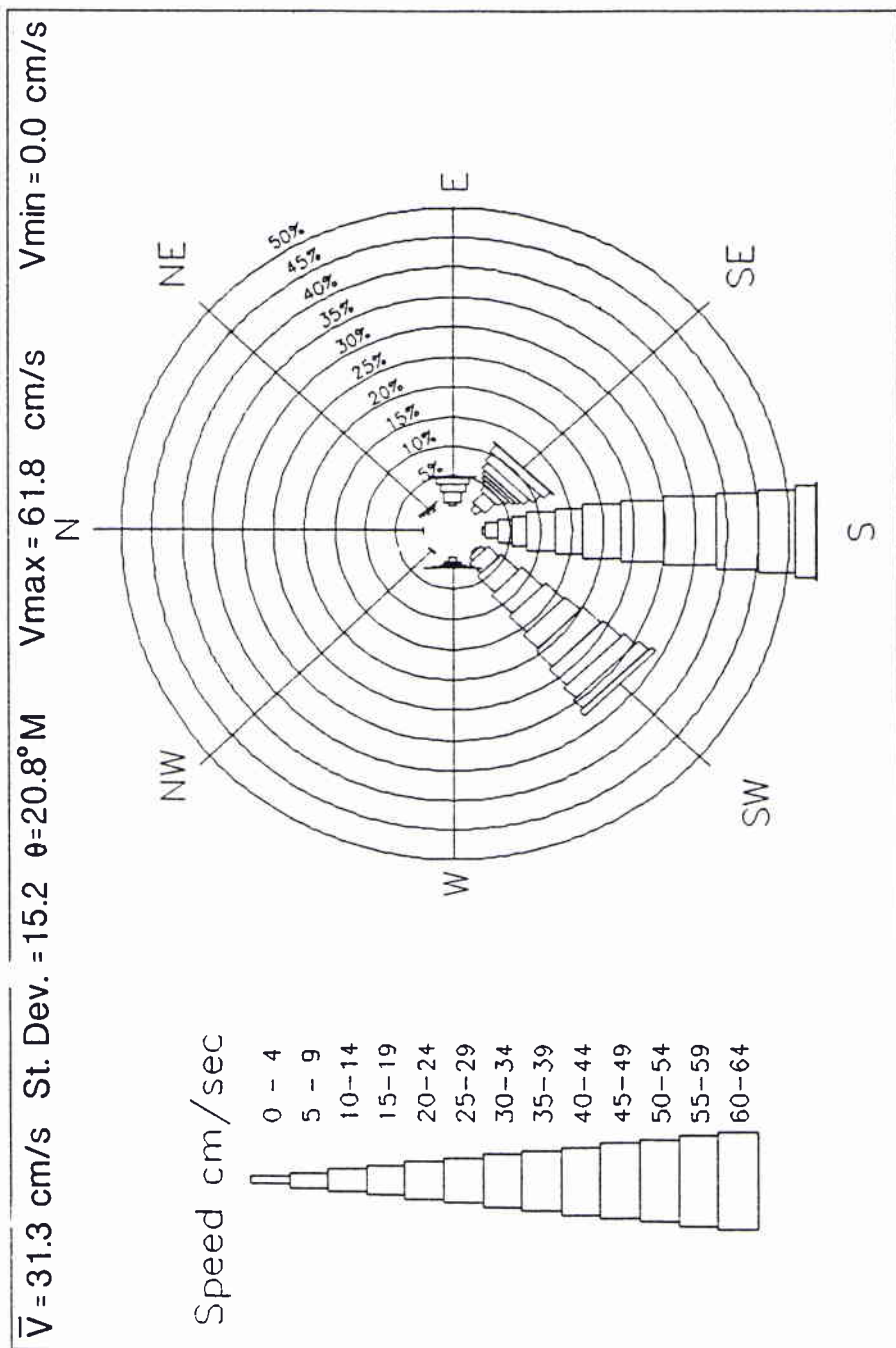


Figure 6 Compass rose for SACLANTCEN currentmeter mooring C₂ at 127 m depth. (All directions are referred to magnetic north.)

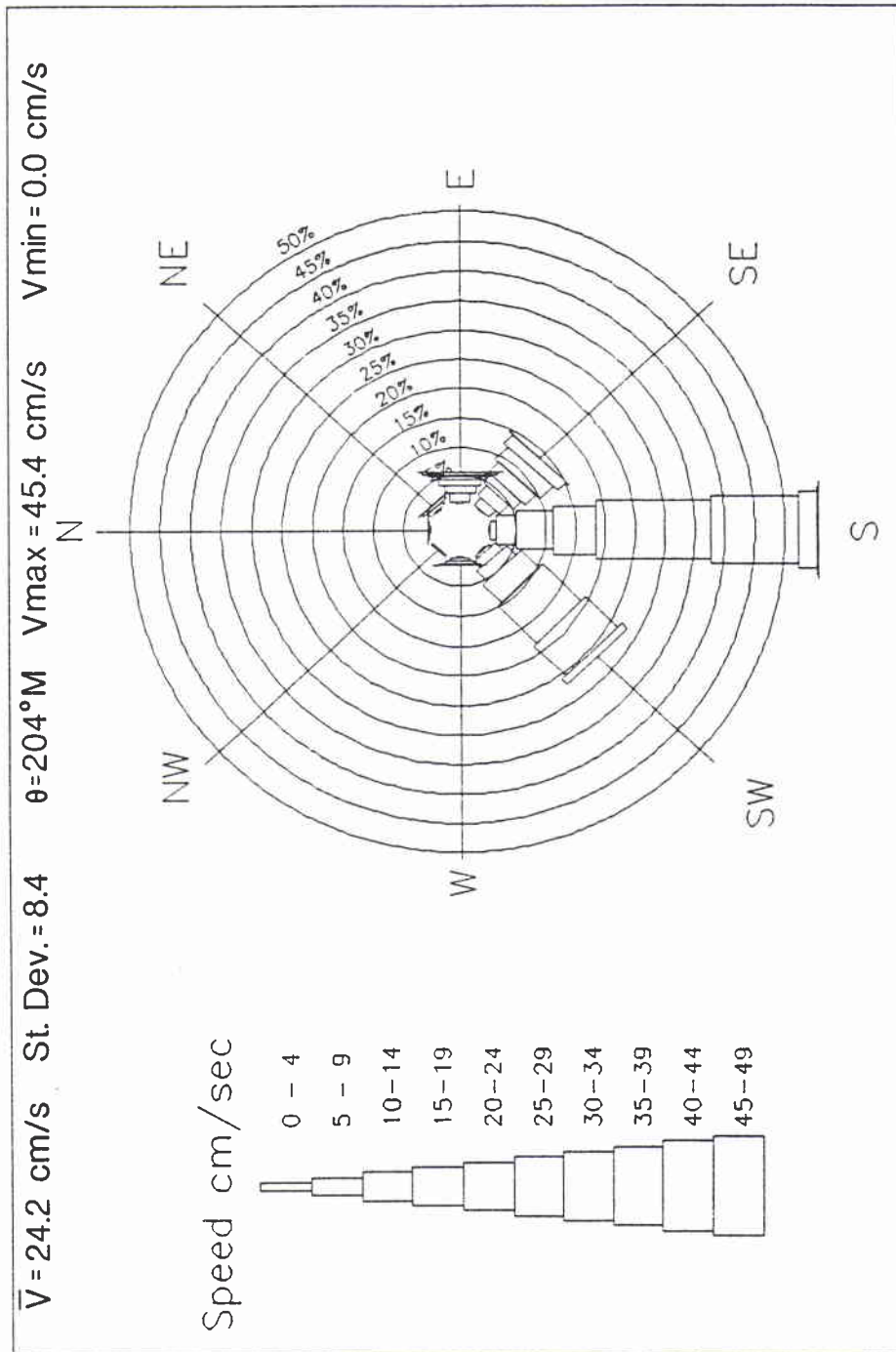


Figure 7 Compass rose for SACLANTCEN currentmeter mooring C_2 at 230 m depth. (All directions are referred to magnetic north.)

SACLANTCEN SM-231

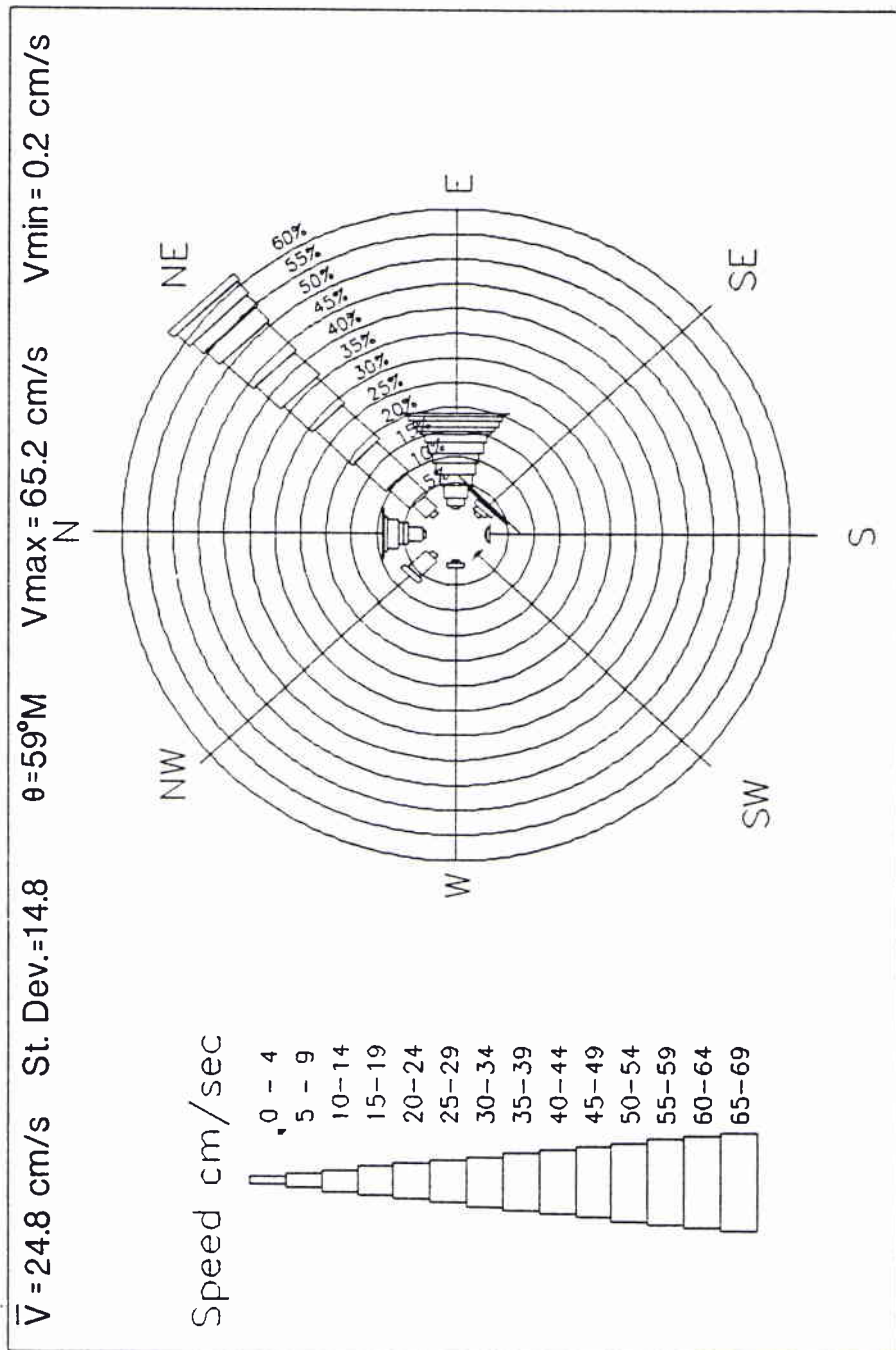


Figure 8 Compass rose for SACLANTCEN currentmeter mooring C₃ at 123 m depth. (All directions are referred to magnetic north.)

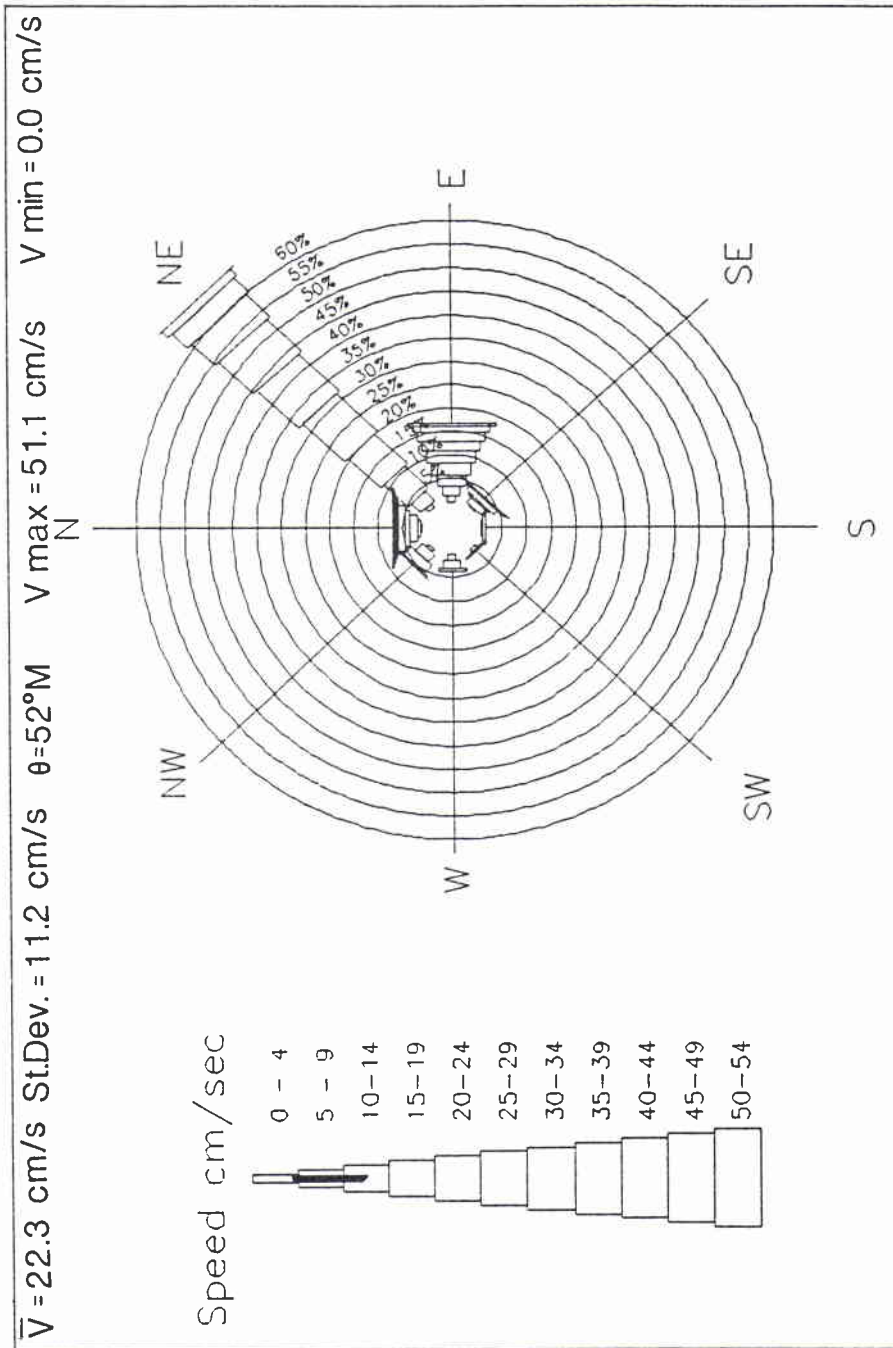


Figure 9 Compass rose for SACLANTCEN currentmeter mooring C_3 at 228 m depth. (All directions are referred to magnetic north.)

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4.2. TIME-SERIES PLOTS

For the currentmeters, these are given as the complete raw data series of speed and direction in Figs. 10–16. The exact start and end times are given in Table 1, where the reader may find the conversion from the Julian day of the plots to the calendar day equivalent.

For the float movements, a time-series of the north and east components was constructed from the filtered time-series (Figs. 17 and 18). The pressure and temperature time-series (Float 18 only) are given in Figs. 19 and 20.

For the met. buoy, a time-series of the wind vector (as a stick diagram), the air temperature, and the water temperature is given in Fig. 21. Only data from every 6 h are plotted and only from those thermistors that functioned (see Table 4). Note, the trajectory of the met. buoy can be found in Fig. 2.

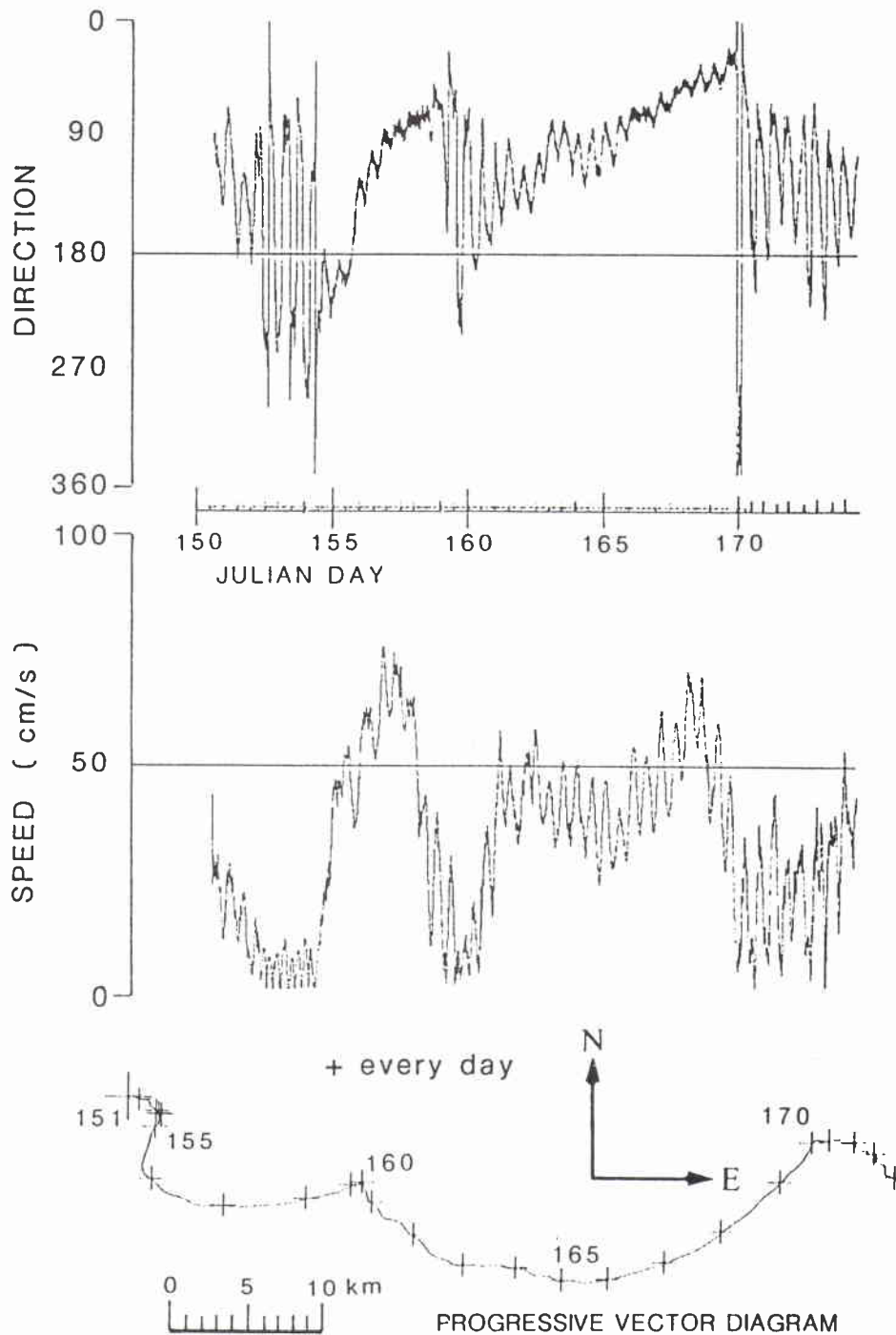


Figure 10 Time-series plots of the current direction and speed for SACLANTCEN currentmeter mooring C_1 at 110 m depth. The corresponding progressive vector diagram is given in Subsect. 4.3.

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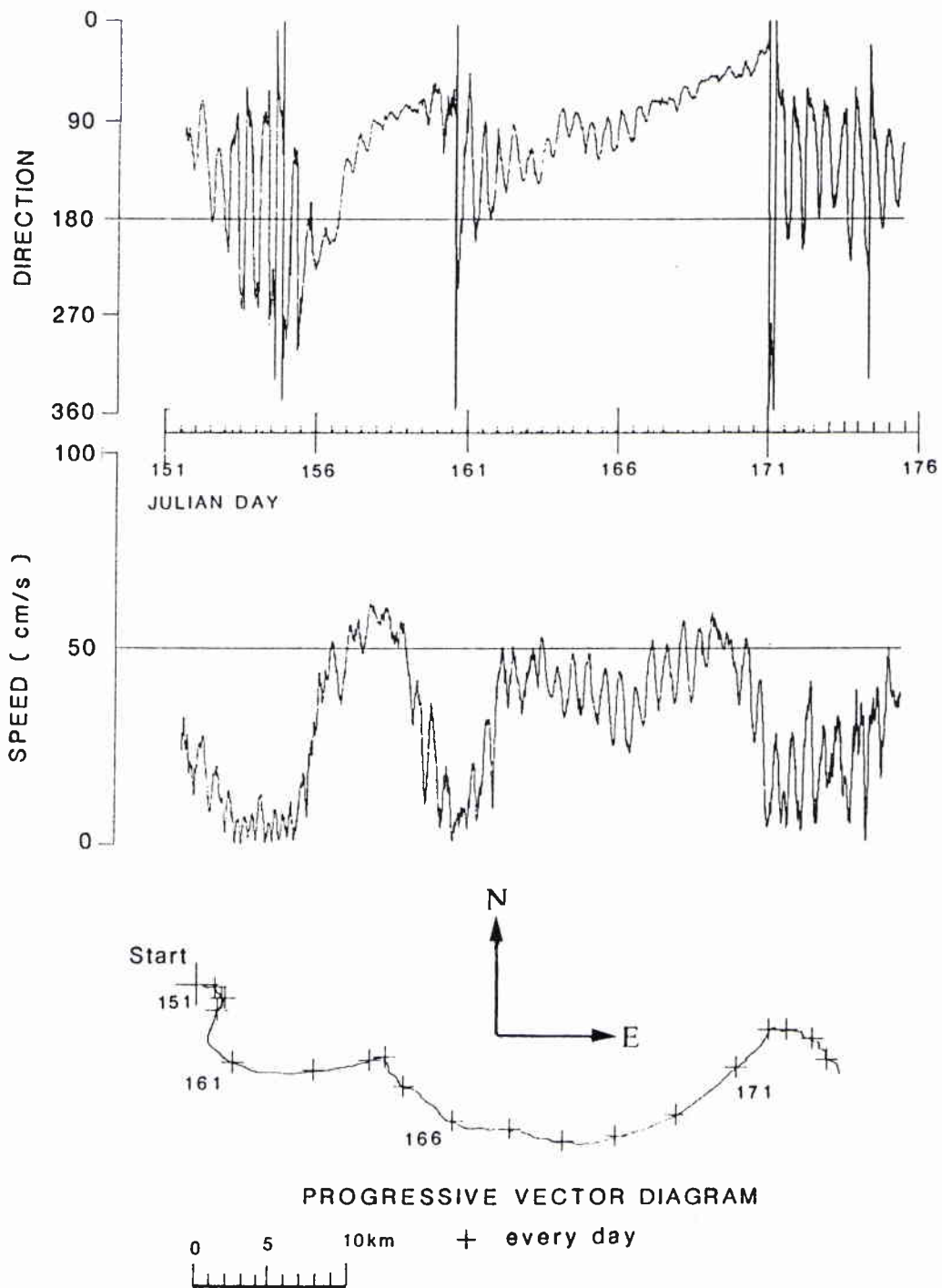


Figure 11 Time-series plots of the current direction and speed for SAC-LANTCEN currentmeter mooring C₁ at 131 m depth. The corresponding progressive vector diagram is given in Subject. 4.3.

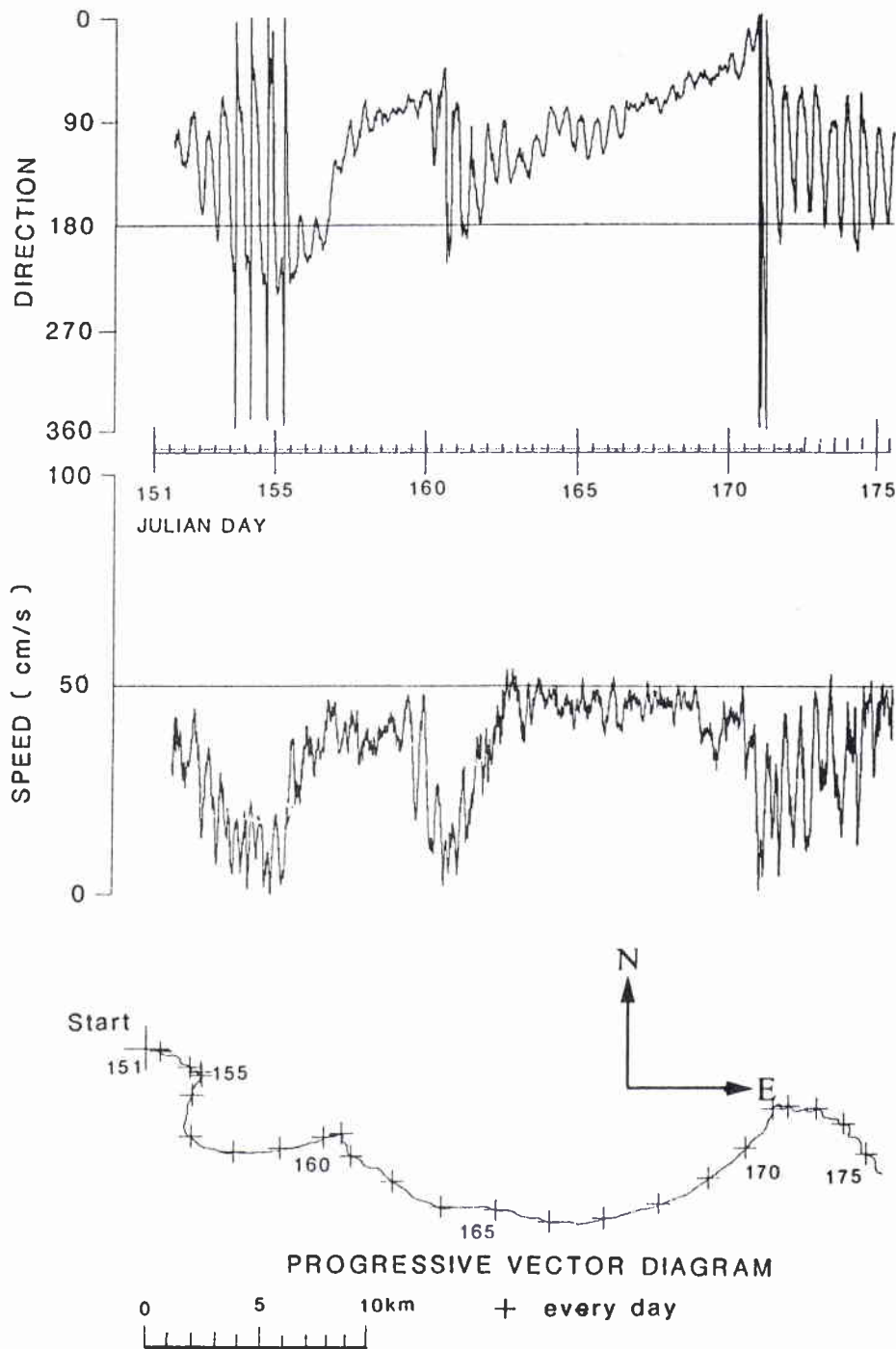


Figure 12 Time-series plots of the current direction and speed for SAC-LANTCEN currentmeter mooring C_1 at 236 m depth. The corresponding progressive vector diagram is given in Subsect. 4.3.

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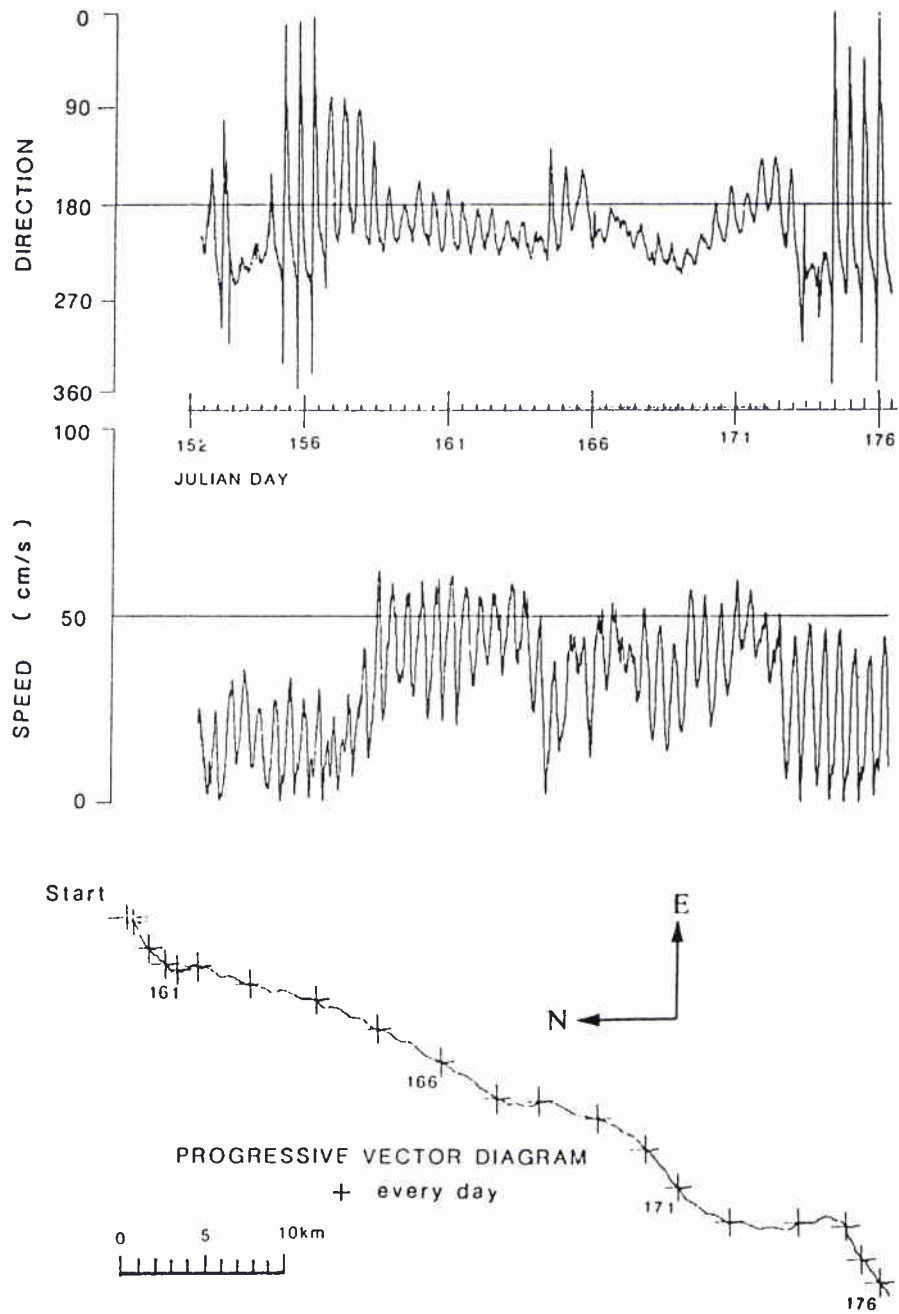


Figure 13 Time-series plots of the current direction and speed for SACLANTCEN currentmeter mooring C₂ at 127 m depth. The corresponding progressive vector diagram is given in Subsect. 4.3.

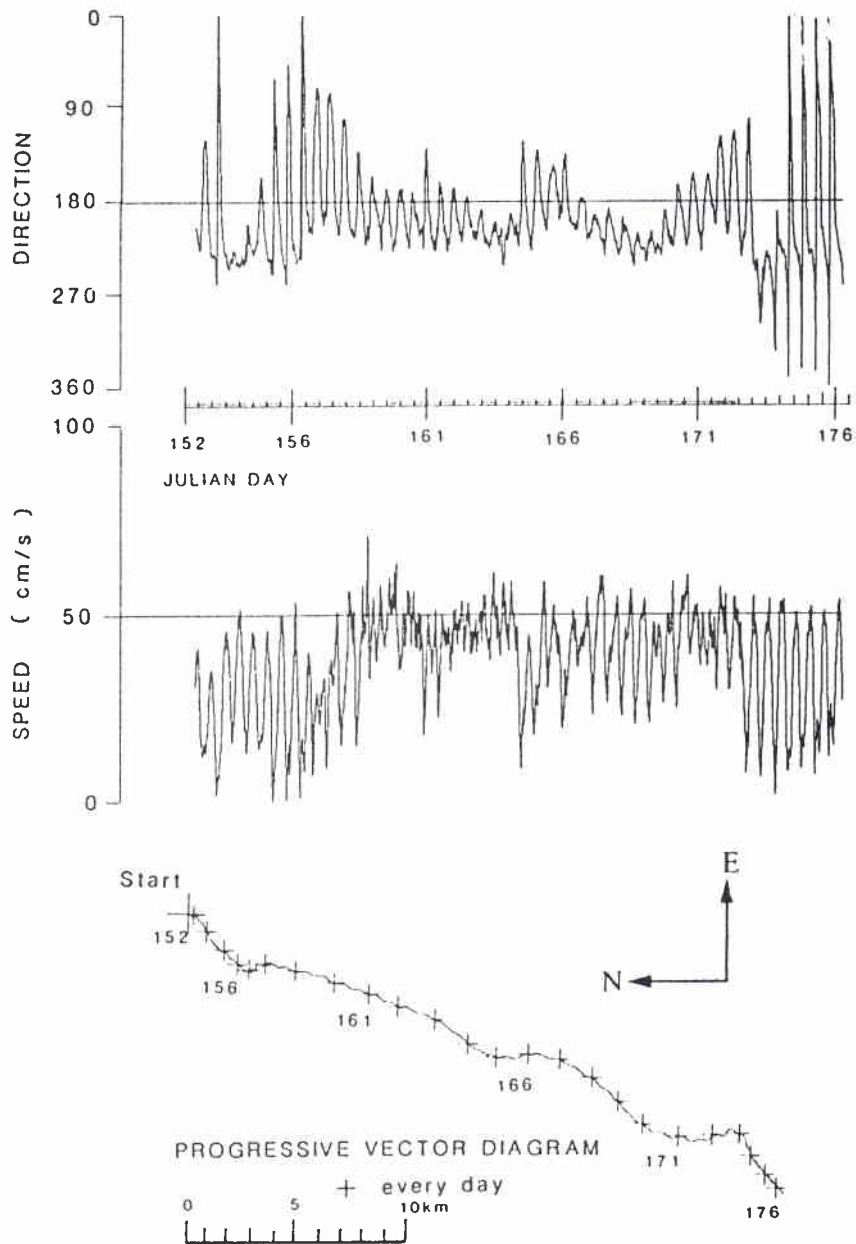


Figure 14 Time-series plots of the current direction and speed for SAC-LANTCEN currentmeter mooring C_2 at 233 m depth. The corresponding progressive vector diagram is given in Subsect. 4.3.

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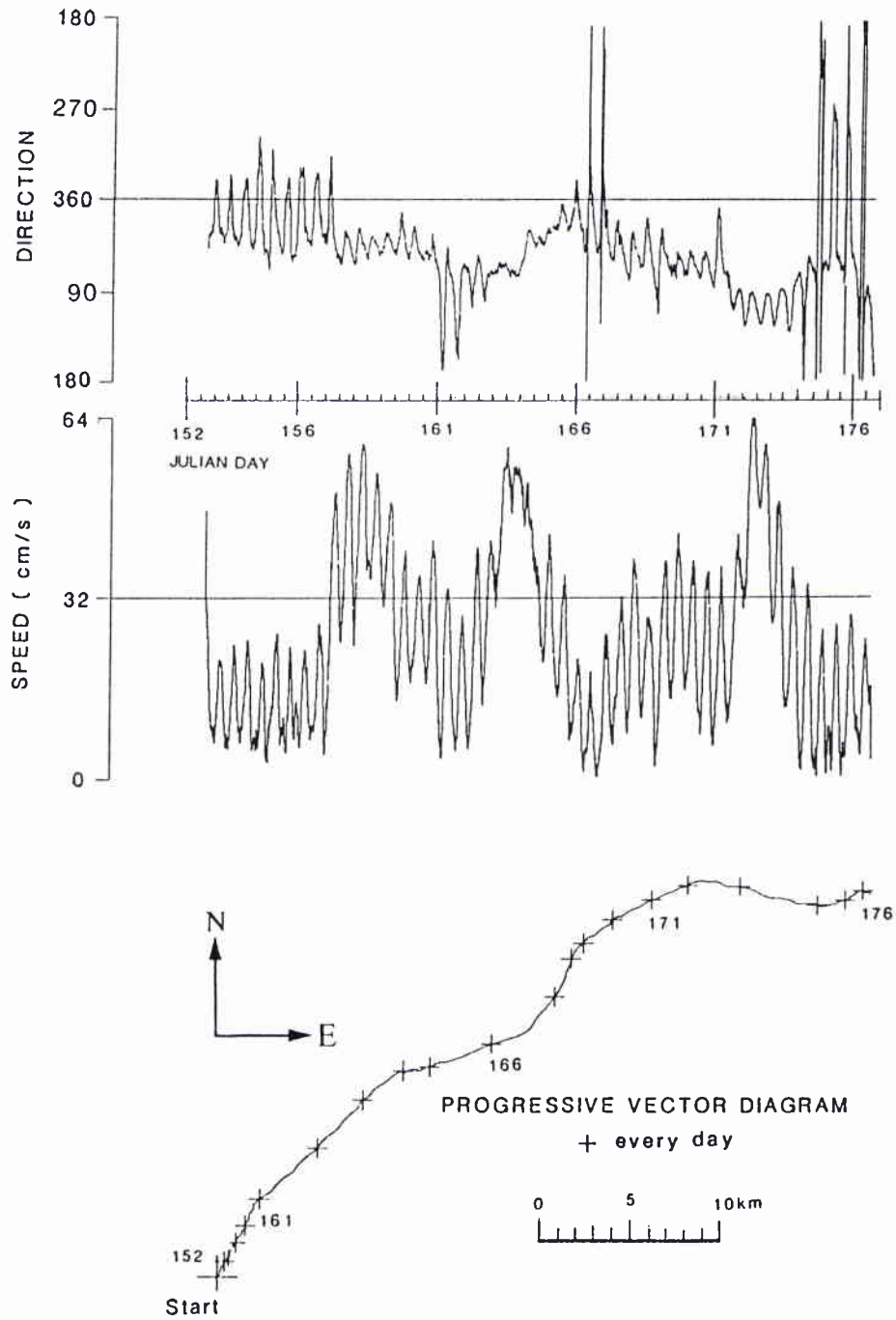


Figure 15 Time-series plots of the current direction and speed for SAC-LANTCEN currentmeter mooring C_3 at 123 m depth. The corresponding progressive vector diagram is given in Subsect. 4.3.

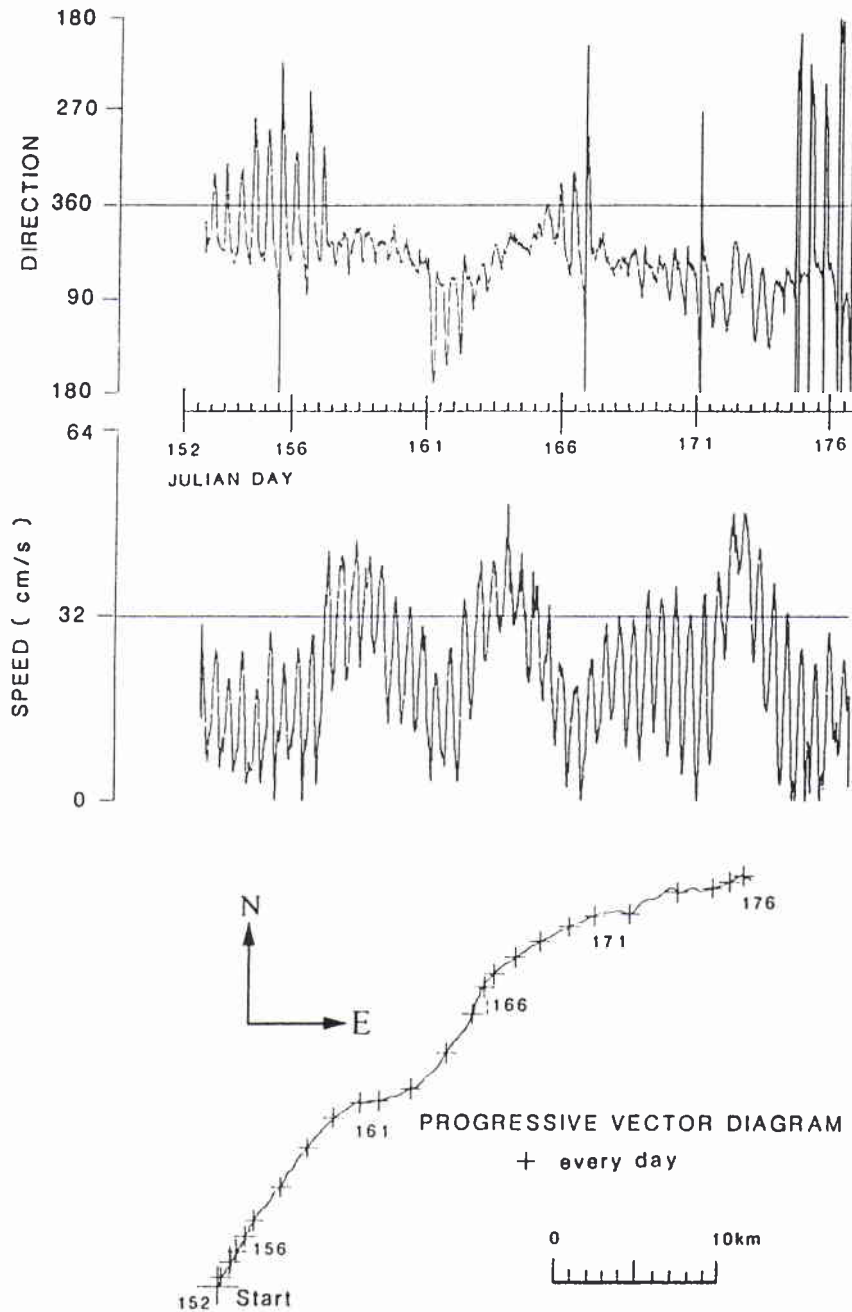


Figure 16 Time-series plots of the current direction and speed for SAC-LANTCEN currentmeter mooring C_3 at 228 m depth. The corresponding progressive vector diagram is given in Subsect. 4.3.

SACLANTCEN SM-231

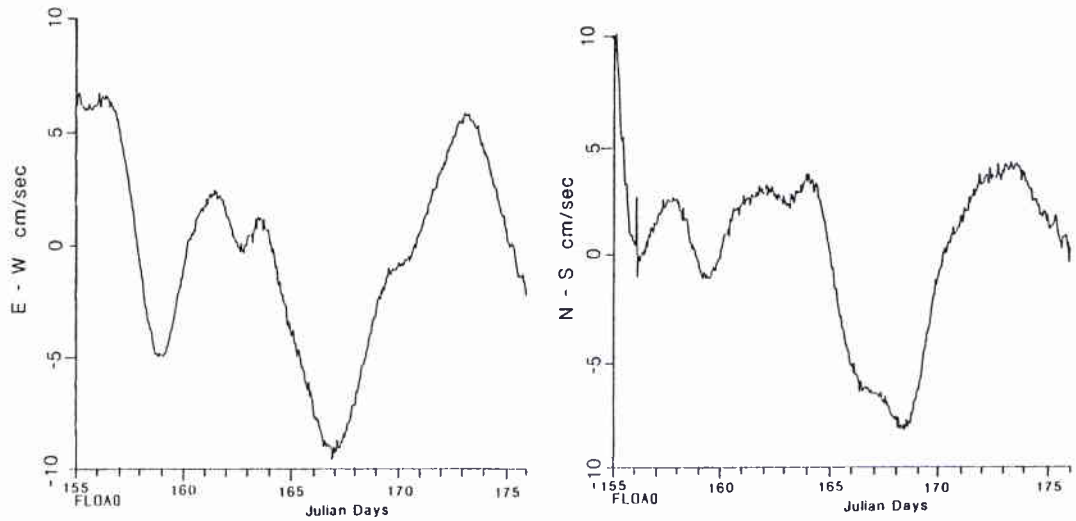


Figure 17 Time-series plots of the north-south and east-west velocity components for Float 0.

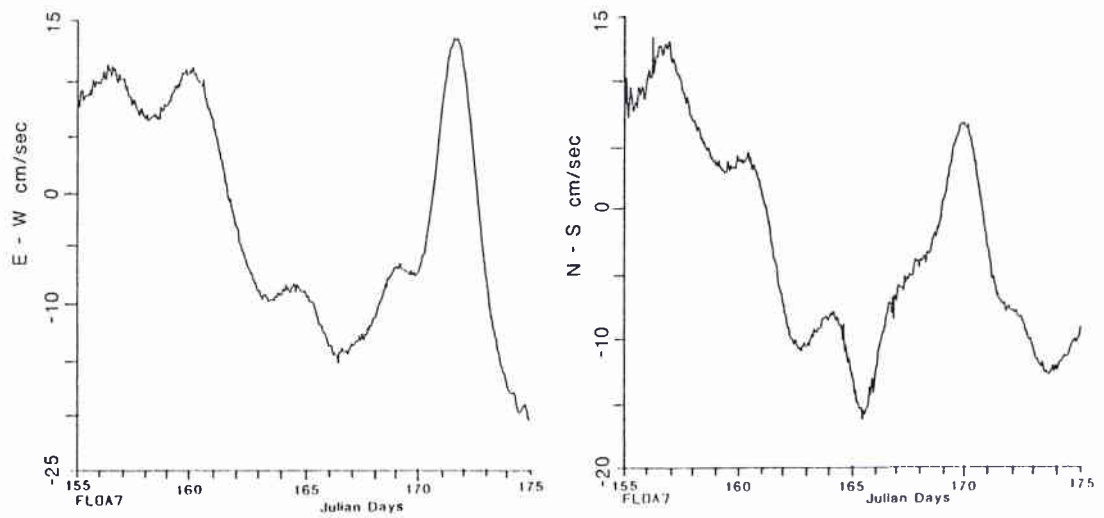


Figure 18 Time-series plots of the north-south and east-west velocity components for Float 7.

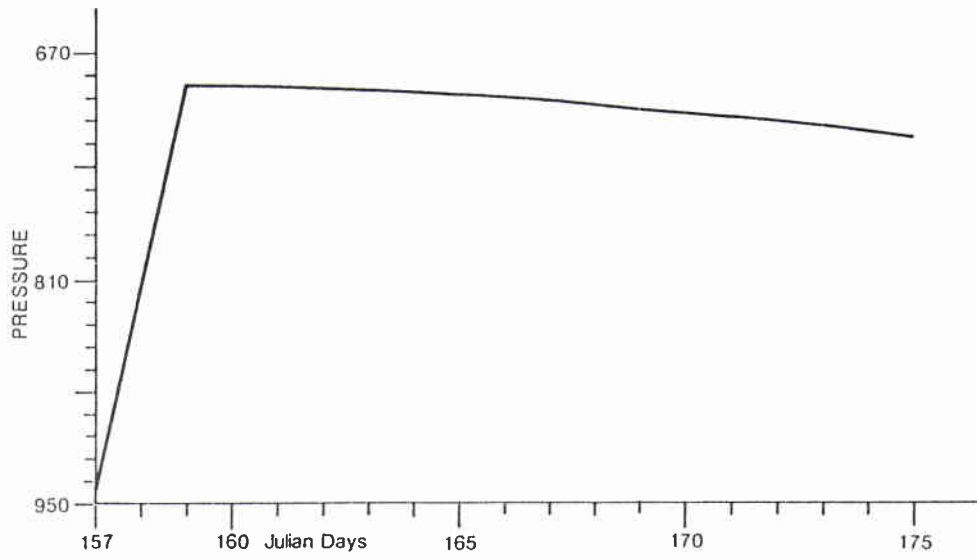


Figure 19 *Time-series plot of the pressure for Float 0.*

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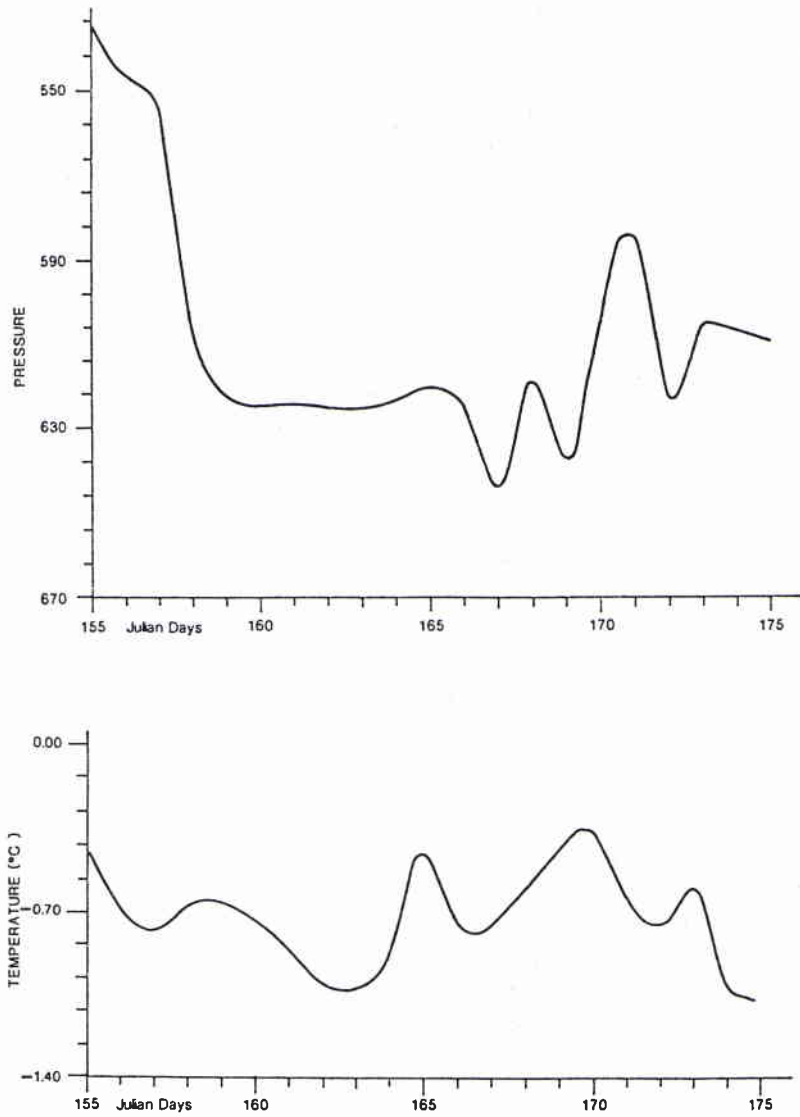


Figure 20 *Time-series plots of the pressure and temperature for Float 7.*

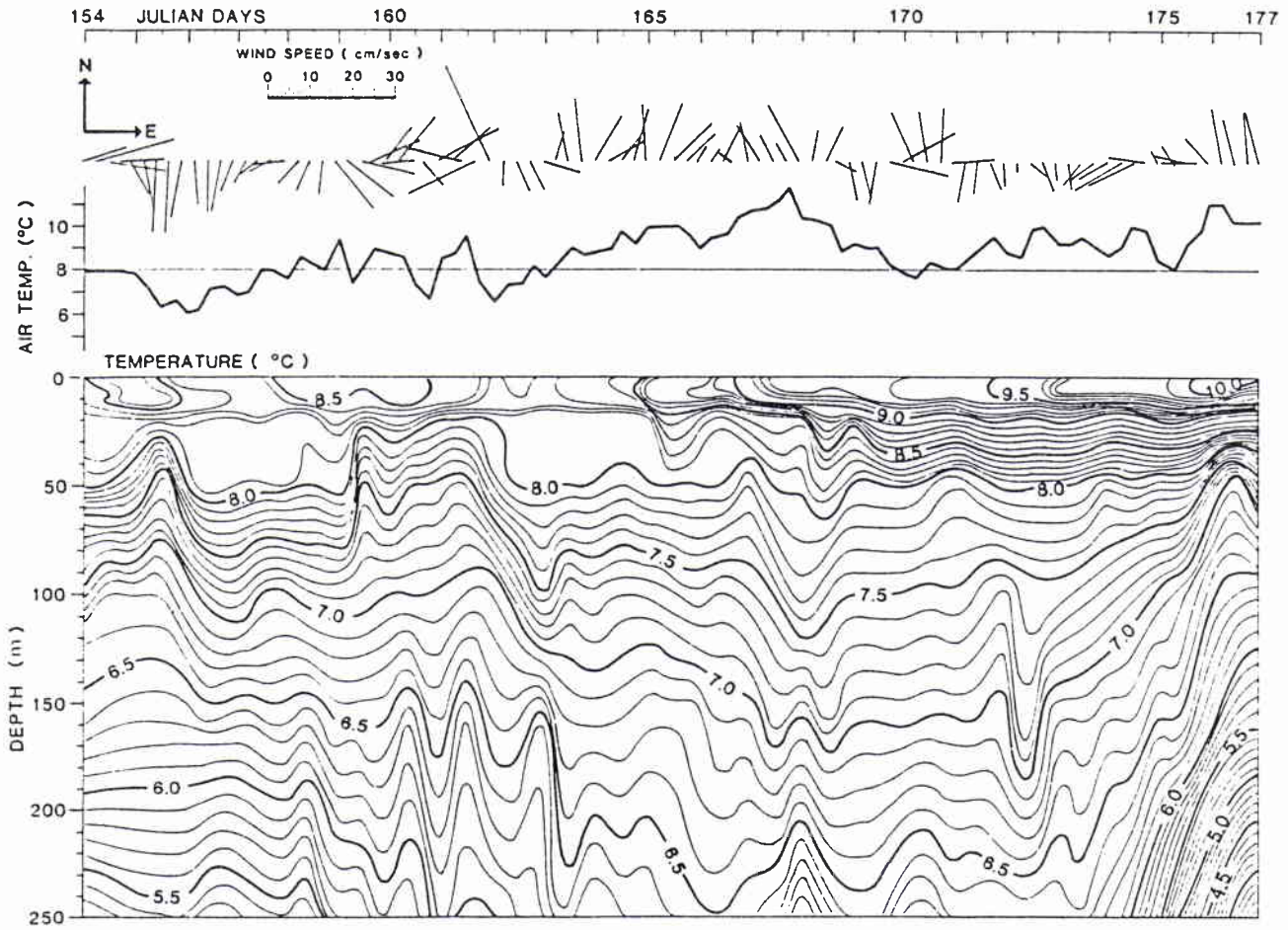
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Figure 21 Time-series plots of the met. buoy data every 6 h: (upper diagram) stick diagram of the wind vector, pointing towards the direction the wind was blowing; (middle) air temperature; (lower) water temperatures at various sensor depths.

4.3. PROGRESSIVE VECTOR DIAGRAMS

Progressive vector diagrams of the currentmeter data are included in the same figure as their respective time-series plot (Figs. 10–16). These were constructed from the accumulated north and east distances. Tick marks indicate the start of every day. For the floats (Figs. 22 and 23), these were constructed from the filtered east–west and north–south components. Tick marks indicate the start of every day.

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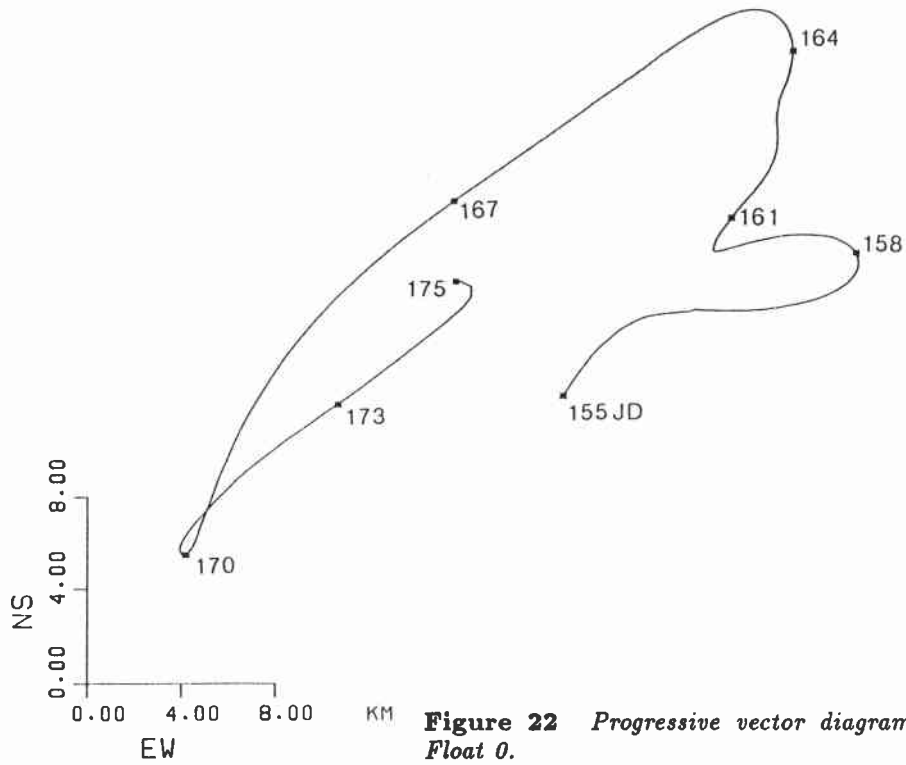


Figure 22 Progressive vector diagram for Float 0.

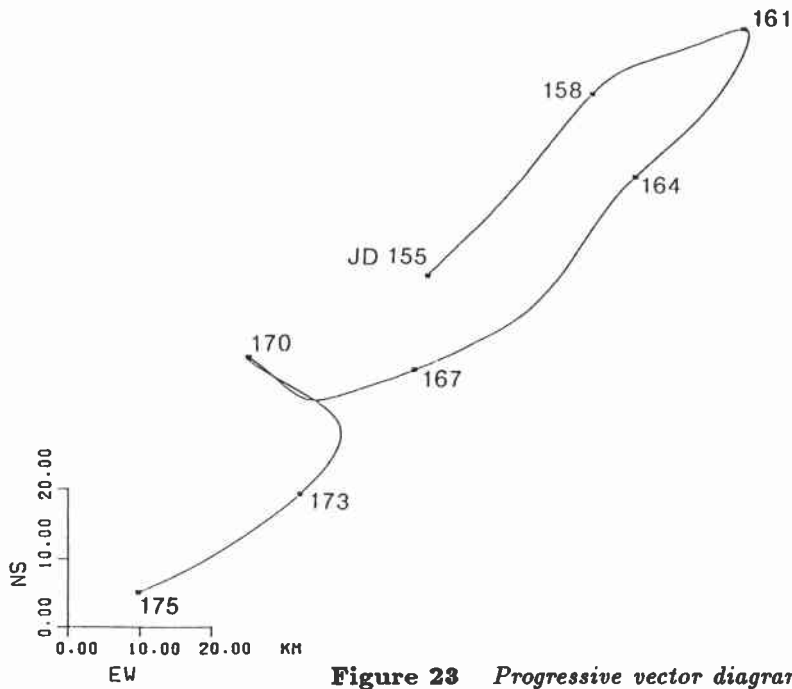


Figure 23 Progressive vector diagram for Float 7.

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4.4. STICK DIAGRAMS

The stick diagrams of Figs. 24–30 were produced from a 2-h sub-sampling of the the raw currentmeter data.

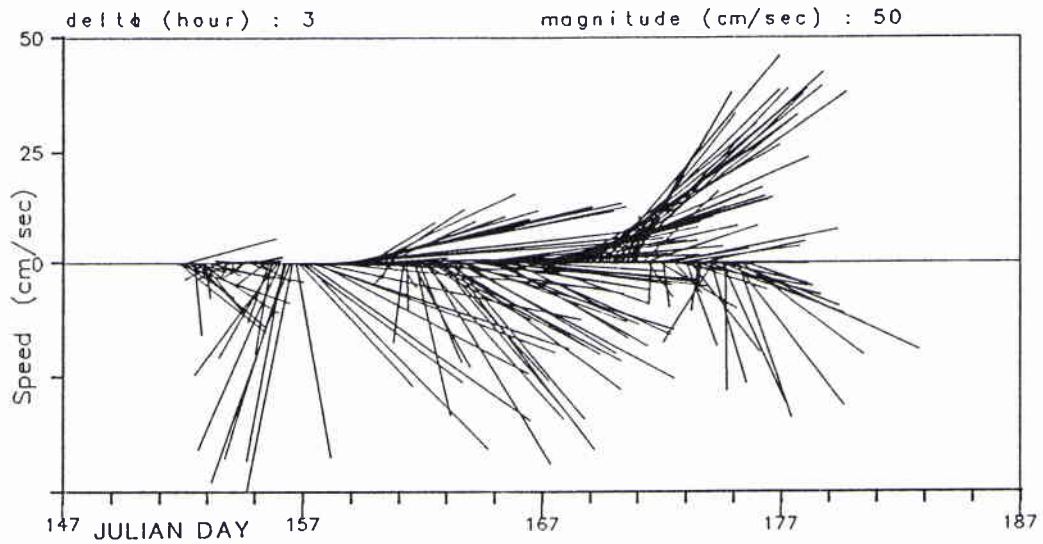


Figure 24 Stick diagrams for SACLANTCEN currentmeter mooring C₁ at 110 m depth, subsampled every 3 h.

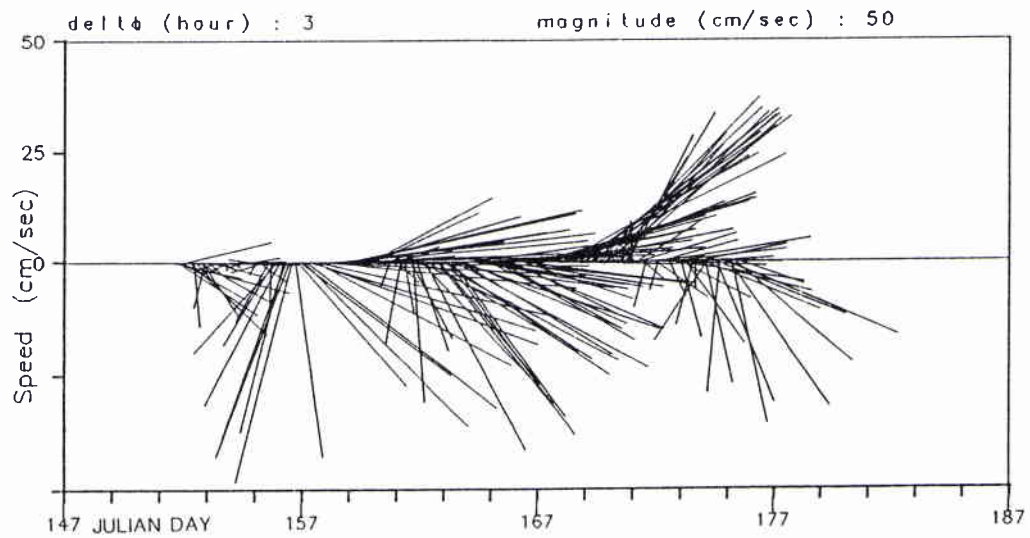


Figure 25 Stick diagrams for SACLANTCEN currentmeter mooring C₁ at 131 m depth, subsampled every 3 h.

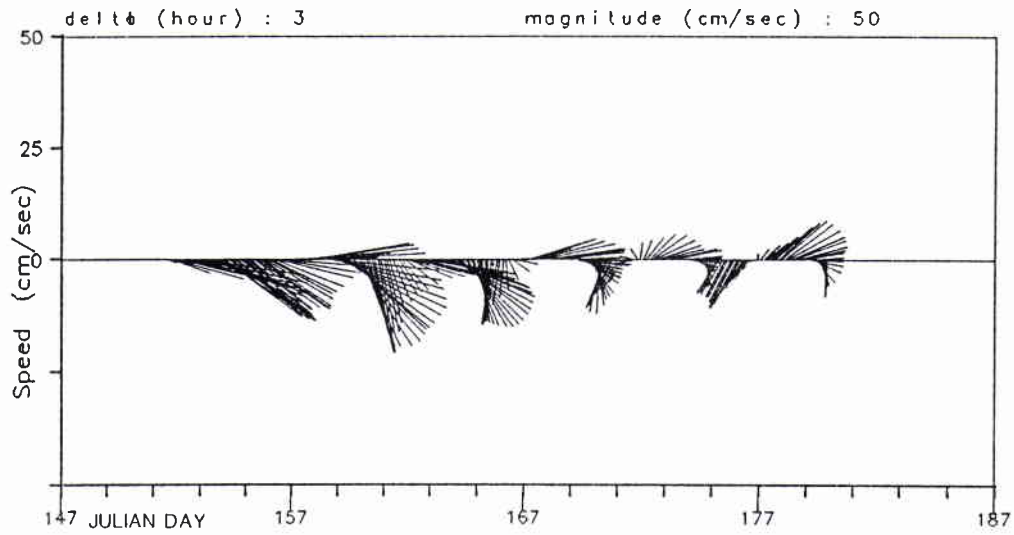


Figure 26 Stick diagrams for SACLANTCEN currentmeter mooring C₁ at 236 m depth, subsampled every 3 h.

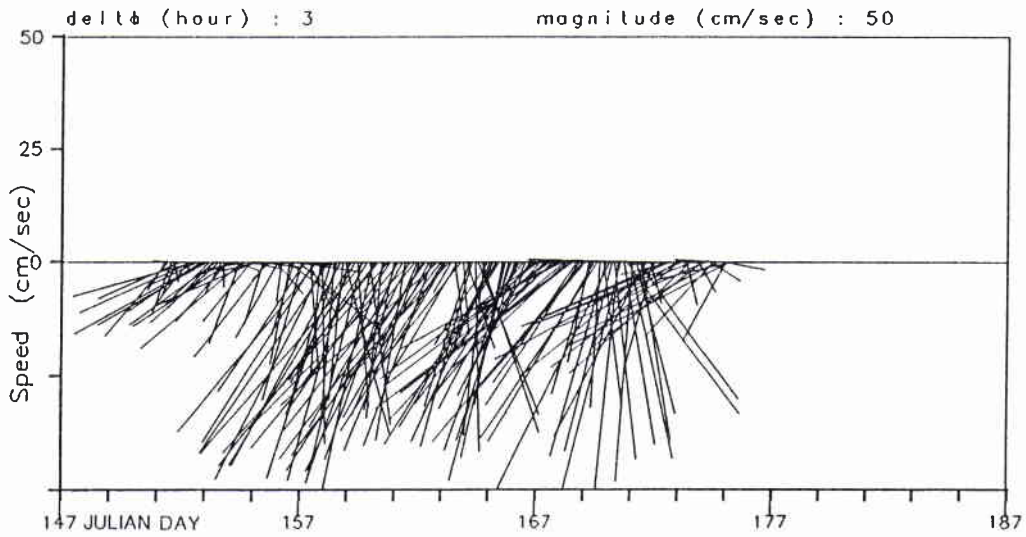


Figure 27 Stick diagrams for SACLANTCEN currentmeter mooring C₂ at 127 m depth, subsampled every 3 h.

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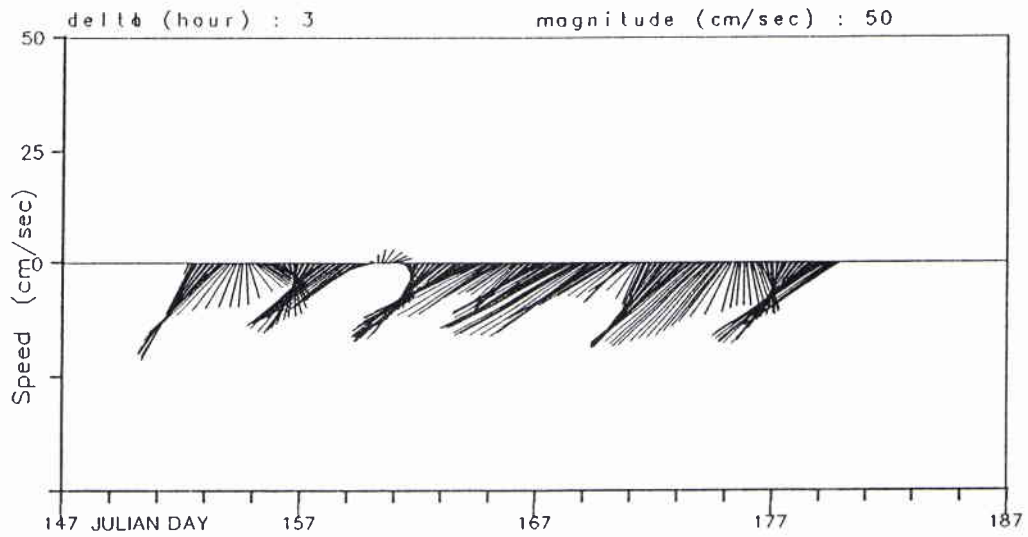


Figure 28 Stick diagrams for SACLANTCEN currentmeter mooring C₂ at 230 m depth, subsampled every 3 h.

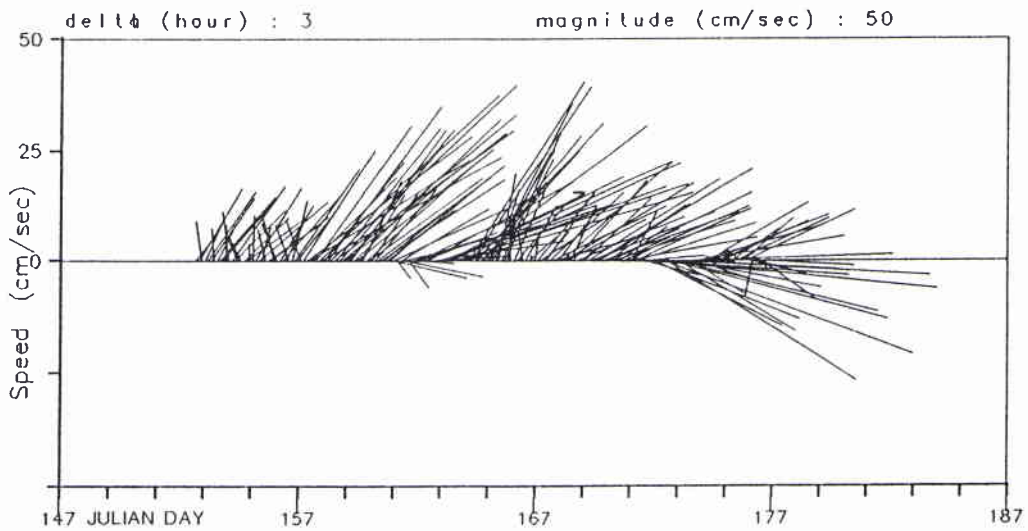


Figure 29 Stick diagrams for SACLANTCEN currentmeter mooring C₃ at 123 m depth, subsampled every 3 h.

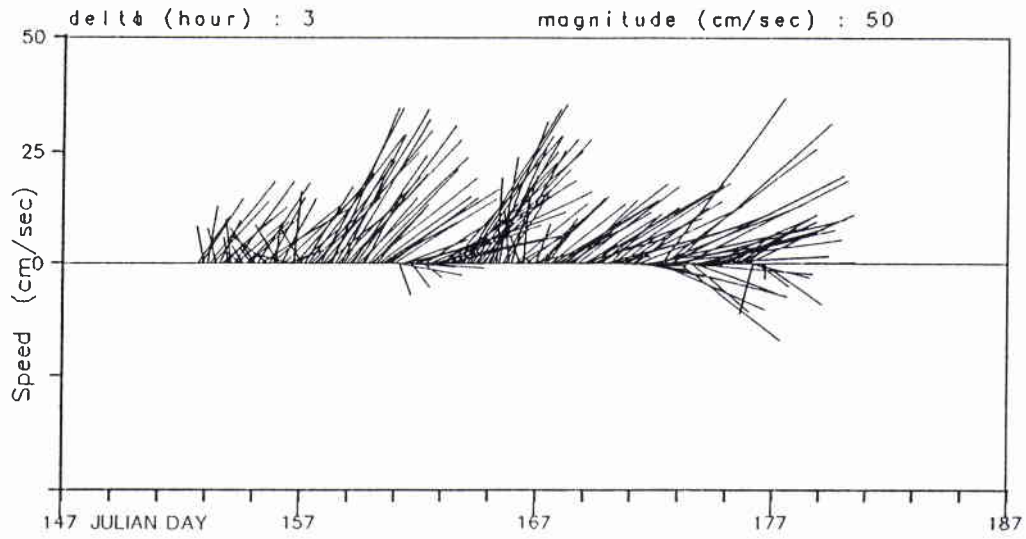


Figure 30 Stick diagrams for *SACLANTCEN* currentmeter mooring C_3 at 228 m depth, subsampled every 3 h.

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