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Aanderaa Current Meter Records from the New South Wales Continental Shelf, 1978-1980

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AANDERAA CURRENT METER RECORDS FROM THE NEW SOUTH WALES CONTINENTAL SHELF, 1978-1980

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Abstract

This report presents data from 10 Aanderaa RCM-4 current meter records from the New South Wales continental shelf during the period March 1978 to March 1980. The presentation is of time-series plots (hourly values as well as low-pass filtered values), progressive vector diagrams and current roses. The major features of each record are briefly described in terms of the 'mean' flow at each site over the recording period and the dominant period of the fluctuations.

INTRODUCTION

Between March 1978 and March 1980, 14 Aanderaa RCM-4 current meters were deployed at various sites on the New South Wales continental shelf (Table 1 and Fig.1). This report contains a graphical summary of the data from 10 of the instruments which gave reliable recordings. Details of the moorings are not described: usually a conventional CSIRO U-mooring with a surface marker buoy was used (Boland *et al.* 1975), but in deeper water near the shelfbreak subsurface buoys and acoustic releases were used. As this report is intended mainly as a record of the data available, only a brief interpretation of the major features of the results is given.

DATA PROCESSING

The Aanderaa RCM-4 current meter can record the current speed and direction, temperature, conductivity, and pressure, although in our case conductivity was not measured — for details of the instruments, see the Aanderaa operating manual (Aanderaa Instruments 1978).

Recording is on magnetic tape at preselected intervals (10 and 15 minute intervals were used in the records discussed here), and the various stages of the data processing as carried out on the CSIRO Marine Laboratories' in-house PDP11/20 computer may be summarised as follows:

1. The magnetic tape is read and the data put onto a *'raw data'* file — this can be listed if desired, as a first indication of the data quality.

2. The calibration constants are introduced to convert the raw data to a *'calibrated data'* file in physical units (e.g. °C, m/s, etc.). The manufacturer's constants are used for all parameters except current direction, in which it has been found that a polynomial relationship is better than the manufacturer's linear calibration, the errors in the latter case being substantial in some instruments (Forbes and Church 1980).

3. The calibrated data file is then edited to delete the pre-deployment and post-recovery sections (i.e. while the instrument was out of the water) and to correct any obviously erroneous records. This *'edited data'* file now contains (presumably) good data at the original sampling intervals (10 or 15 minutes here).

4. The edited data is then filtered using a Lanczos-squared taper filter spanning 4 hours (the half-power point is 0.18 cycles per hour) and reduced to an *'hourly data'* file.

5. If desired, the hourly data can be low-pass filtered using Munk's 'tide-killer' filter (Hamon 1977) to eliminate diurnal and higher frequencies; this is a symmetrical filter with a half-power point at 0.31 cycles per day and spans 2 days. The resulting *'residual data'* file also contains hourly values, but is of course 2 days shorter than the unsmoothed hourly file due to the filtering process.

6. Spectral plots are not included as most of the records are too short to adequately resolve the energetic few-day variability.

7. The edited data and hourly data files for each record are on disc on the local PDP11/20 computer at Cronulla as well as on the CYBER system.

DATA PRESENTATION

Each data set is referred to by the instrument/tape number (e.g. 580/11 is tape 11 from meter no. 580), and the results are given in standard format:

1. General description of the experiment and a brief interpretation of the data.

2. Time-series plot of temperatures and current vectors (in the form of a 'stick diagram') for both the hourly and residual data sets. The time-axis is in days, and the temperature and current vector scales are as indicated.

3. Progressive vector diagram (PVD), showing the total displacement in the north-south and east-west directions over the recording period, in kilometres. The direction of the local isobath at the mooring site is indicated, for comparison with the currents. The X's indicate days since the first record.

4. Current rose, grouping the data into sixteen $22\frac{1}{2}°$ direction sectors, with speed rings at 20 cm/s intervals to 1 m/s. In the central circle are given the total number of hourly records (in brackets) and the frequency of currents less than 1 cm/s (the threshold speed of the Savonius rotor is about 1.5 cm/s). All frequencies in the rose are in parts per thousand, i.e. 106 means 10.6%.

SUMMARY AND CONCLUSIONS

The results of 10 Aanderaa current meter deployments off the NSW coast from March 1978 to March 1980 are presented.

1. Strong southerly currents (exceeding 50 cm/s, or 1 knot) were recorded off Crowdy Head, Cape Hawke and Jervis Bay.

2. Although the dominant current fluctuations had periods of a few days, on occasion strong southerly currents (more than 1 knot) persisted for two weeks or more.

3. Some current reversals may have been associated with eddies propagating along the coast.

4. There is evidence of Ekman veering in the bottom boundary layer, notably onshore veering in strong southerly flow.

5. The temperature records show what is believed to be upwelling on occasion.

6. Unsmoothed temperature traces frequently reflect intense internal wave activity.

ACKNOWLEDGEMENTS

The data processing routines were written by David Crooks, John Church and Andrew Forbes. We are grateful to John Wood and Graham Wells for help with the moorings, and to the crew of 'Sprightly' for deployment and recovery. Graham Wells plotted the mooring positions, and the diagrams were labelled and reproduced by N. Charlesworth and C. Purday.

REFERENCES

Aanderaa Instruments (1978). Operating manual for recording current meter Model 4. Aanderaa Instruments, Bergen.

Boland, F.M., Cresswell, G.R., and Wood, J. (1975). The CSIRO continental shelf mooring system for current meters. Aust. CSIRO Div. Fish. Oceanogr. Rep. No. 62.

Forbes, A.M.G., and Church, J.A. (1980). The effects of compass calibration on Aanderaa current meter records. Aust. CSIRO Div. Fish. Oceanogr. Rep. No. 121.

Hamon, B.V. (1977). The spectrum of sea level at Sydney. Aust. CSIRO Div. Fish. Oceanogr. Rep. No. 80.

Table 1. New South Wales Aanderaa Records 1978-1980

Meter/ Tape #	Period in Water	Period of Data*	Position °S	°E	Meter/Water Depth (m)	Data+ Z T V D	Comments	
580/11	31/3 - 17/4/78	(19)31/3 - (07)17/4/78	32°01'	153°01'	65/130	✓ ✓ ✓ ✓	17 miles SE	Crowdy Head
1731/01	1/4 - 18/4/78	(16) 1/4 - (06)18/4/78	30°17'	153°26'	65/130	✓ ✓ ?	15 miles E	Coffs Harbour
1732/02	31/3 - 19/4/78	- - -	32°48'	152°21'	65/130		8 miles ESE	Port Stephens
572/11	21/7 - 2/8/78	(12)21/7 - (02) 2/8/78	32°12'	152°55'	80†/120	✓ ✓	18 miles E	Cape Hawke
1731/02	21/7 - 2/8/78	(12)21/7 - (10) 2/8/78	32°12'	152°55'	40/120	✓ ✓ ✓ ✓	18 miles E	Cape Hawke
1732/03	21/7 - 1/8/78	(09)21/7 - (13) 1/8/78	32°13'	152°38'	30/ 60	✓ ✓ ✓ ✓	3 miles E	Cape Hawke
572/13	30/3 - 15/5/79	(13)30/3 - (14)15/5/79	32°12'	153°00'	195/200	✓ ✓ ✓ ✓	22 miles E	Cape Hawke
1732/04	30/3 - 15/5/79	(13)30/3 - (14)15/5/79	32°12'	153°00'	140/200	✓ ✓ ✓ ✓	22 miles E	Cape Hawke
1731/09	30/3 - 16/5/79	(09)30/3 - (07)16/5/79	32°13'	152°45'	83/105	✓ ✓ ✓ ✓	10 miles E	Cape Hawke
1733/09	30/3 - 16/5/79	(09)30/3 - (00)16/5/79	32°13'	152°45'	100/105	✓ ✓ ✓ ✓	10 miles E	Cape Hawke
1247/-	30/3	(Not recovered)	32°13'	152°37'	42/ 50		3 miles E	Cape Hawke
1731/11	15/10-12/12/79	(11)15/10-(04)18/11/79	34°05'	151°15'	50/100	✓ ✓ ✓ ✓	5 miles ESE	Cronulla
1733/06	15/10-12/12/79	(11)15/10-(14)15/11/79	34°05'	151°15'	93/100	✓ ✓ ✓ ✓	5 miles ESE	Cronulla
1731/12	30/1- 26/3/80	(10)30/1- (16)14/3/80	35°08'	150°52'	55/150	✓ ✓ ✓ ✓	4 miles ESE	Point Perpendicular

Notes: * Period of data is to the nearest hour (in brackets)

+ Z = Depth; T = Temperature; V = Speed; D = Direction

† 572/11 Sank to the seabed on the 22/7/78

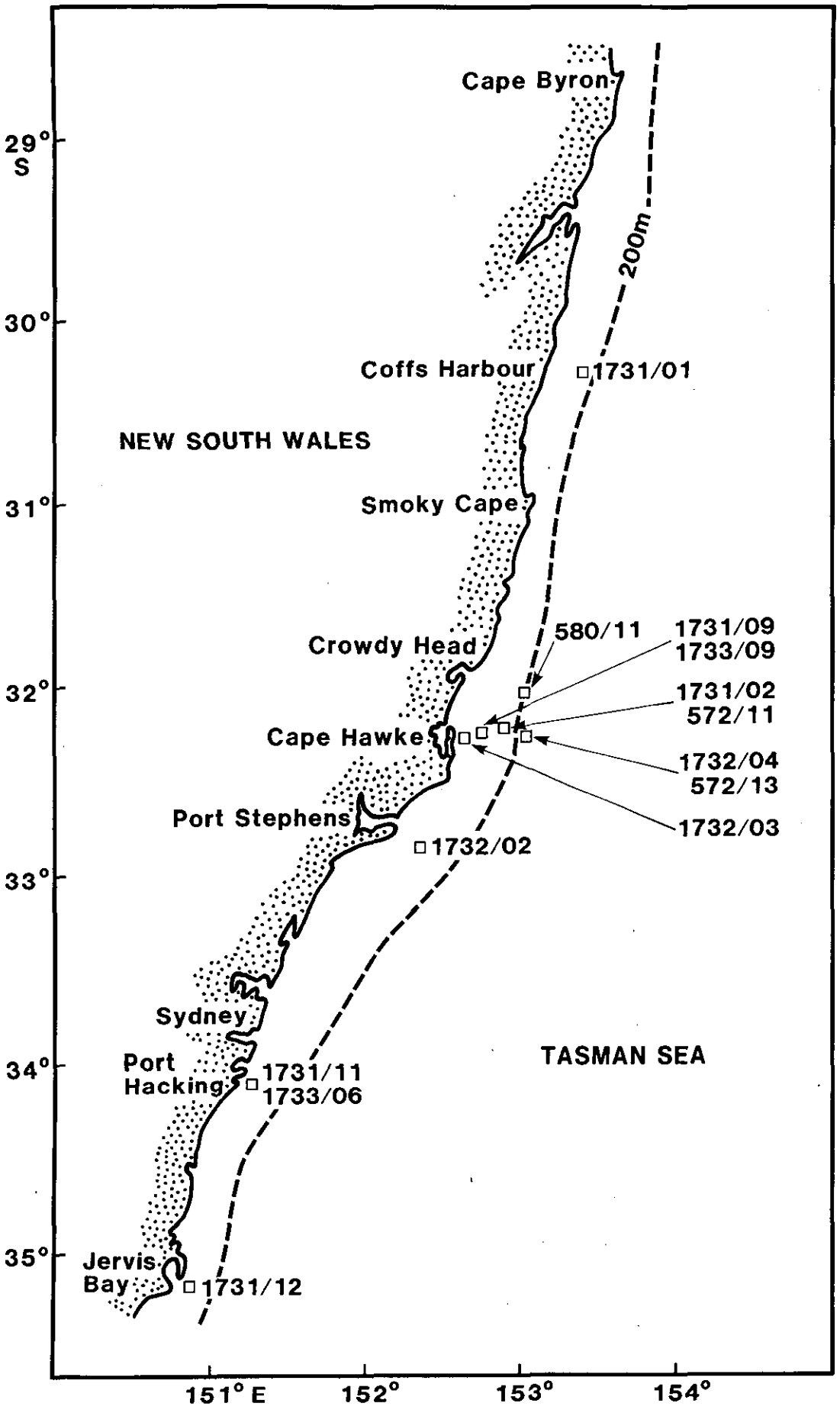
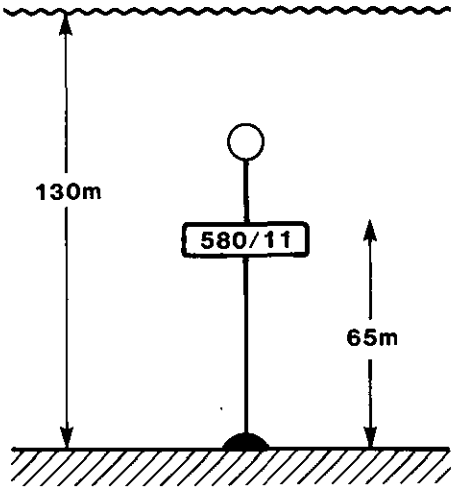


Fig. 1. Location chart showing positions of the current meters listed in this report.

TAPE NUMBERS 580/11, 1731/01, 1732/02

These three instruments were moored along the outer shelf off Coffs Harbour (1731), Crowdy Head (580), and Port Stephens (1732), all at mid-depth in about 130 m water. In conjunction with R.V. 'Sprightly' cruises SP5/78, SP6/78 and SP7/78, they were deployed to examine the relationship between currents on the continental shelf and dynamic height patterns in deeper water. All three moorings were of the CSIRO U-type, and all three were recovered without difficulty.



DATA

Instrument 1731 failed to record current speed, and 1732 did not operate at all, so no data for these two meters are presented here. 580 yielded good data.

The most striking feature of the current vectors from 580/11 is the consistent southerly/southeasterly flow at a mean speed of about 52 cm/s (over a knot) and directed offshore relative to the coast and bottom topography. Godfrey *et al.* (1980) show that the East Australian Current was 'separating' from the coast at Crowdy Head during this period, as evidenced by 580/11 as well as ship-drift observations on 'Sprightly'. The low-passed current vectors show an interesting $2\frac{1}{2}$ day oscillation for the first half of the record, while the smoothed temperature trace reveals a remarkably regular $3\frac{3}{4}$ day cycle, not obviously linked with the current fluctuations; one of the temperature changes was a sudden cooling of almost 4°C in a few hours on the 10th, and an equally dramatic return (see the unfiltered temperature record).

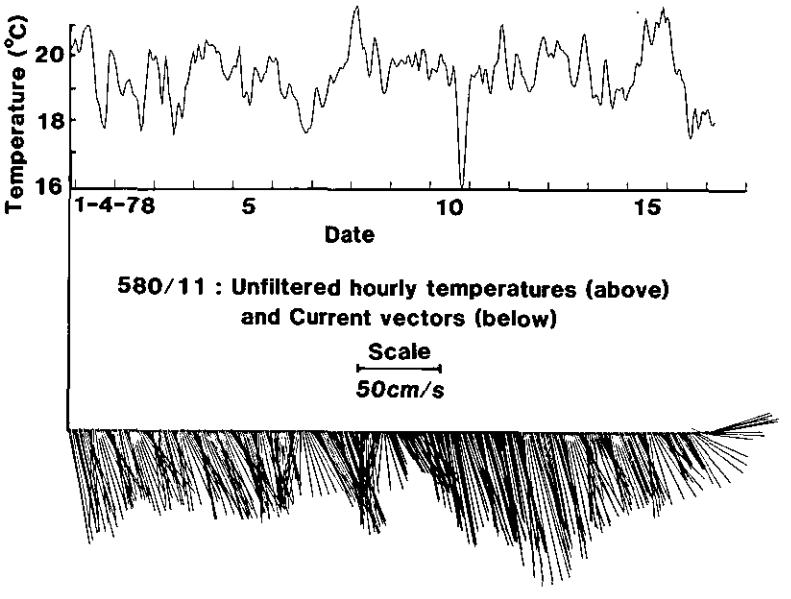
At higher frequencies, there is evidence of inertial activity (about 22 hours) in both the temperature and current data.

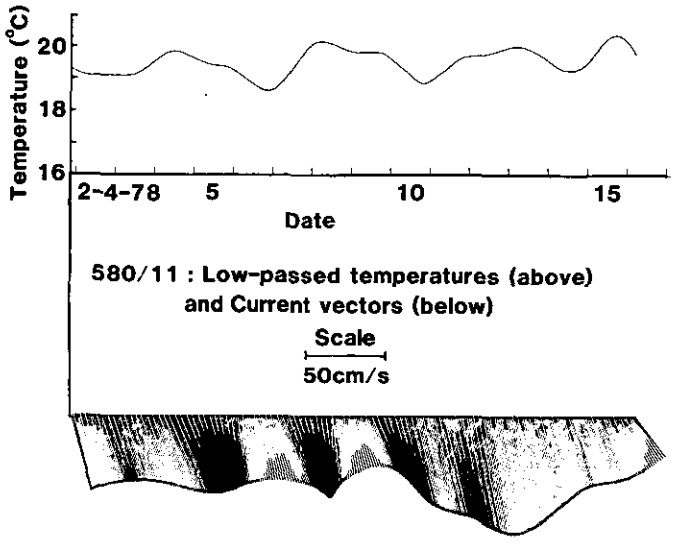
PERSONNEL INVOLVED

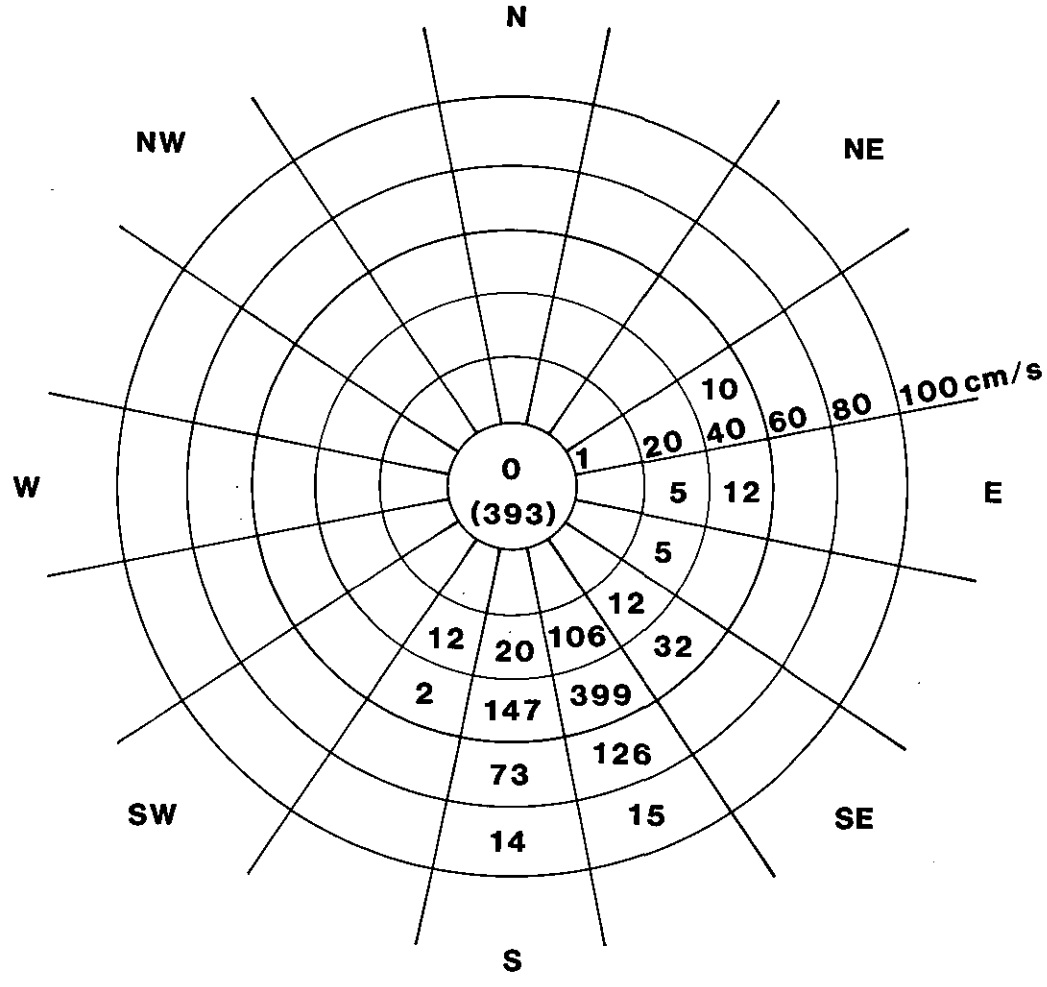
Experiment leader: Stuart Godfrey.
Cruise leaders: Alan Pearce (SP5/78); Terry Golding (SP6/78, SP7/78).

PUBLICATION

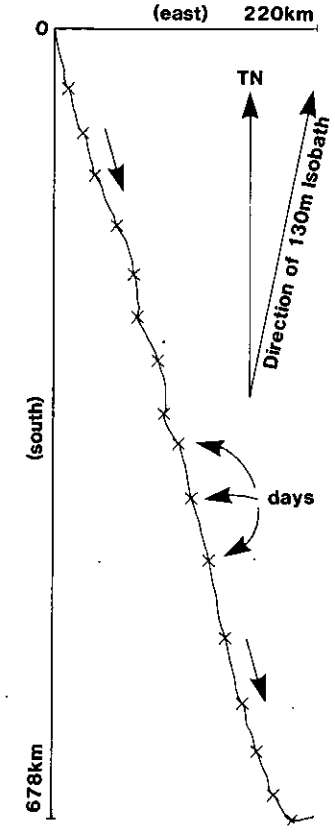
Godfrey, J.S., Cresswell, G.R., Golding, T.J., Pearce, A.F., and Boyd, R. (1980). The separation of the East Australian Current. *J. Phys. Oceanogr.* 10, 430-440.


Temperature (°C)
20
18
16
1-4-78
5
10
15
Date
580/11 : Unfiltered hourly temperatures (above)
and Current vectors (below)
Scale
50cm/s


Temperature (°C)
20
18
16
2-4-78
5
10
15
Date
580/11 : Low-passed temperatures (above)
and Current vectors (below)
Scale
50cm/s



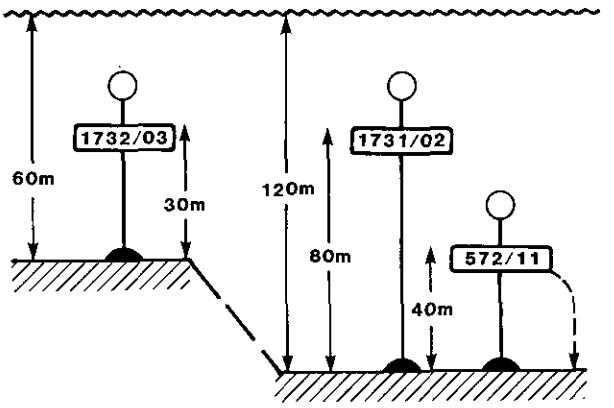
580/11 : Current rose
(Instrument/Water depths 65/130m)



580/11 : Progressive vector diagram

TAPE NUMBERS 572/11, 1731/02, 1732/03

As part of a study of short-term (daily) variability in the currents near Cape Hawke, three current meters were deployed on the shelf in July 1978, during R.V. 'Sprightly' cruise SP10/78. The moorings were the conventional U-pattern, and all were recovered safely (although the anchor for 1731/02 broke free when the eye-bolt sheared during recovery, and the subsurface float for 572/11 leaked so it sank to the seabed during the second day).



DATA

Good results were obtained from 1731/02 and 1732/03; 572/11 seemed to operate normally but the current data are meaningless as the instrument was lying on its side on the seabed, and so are not presented here.

At the outer mooring (1731/02), the currents were weak southerly to south-westerly at the start of the period, with a minor reversal on the third day, a more substantial reversal two days later, and then a complete anti-clockwise rotation over the following few days, as if an eddy-like feature was moving along the outer shelf (see the PVD). With the passage of this event, the temperature fell by over 1°C. Note that the unfiltered vectors and the PVD show a further northerly countercurrent at the end of the period.

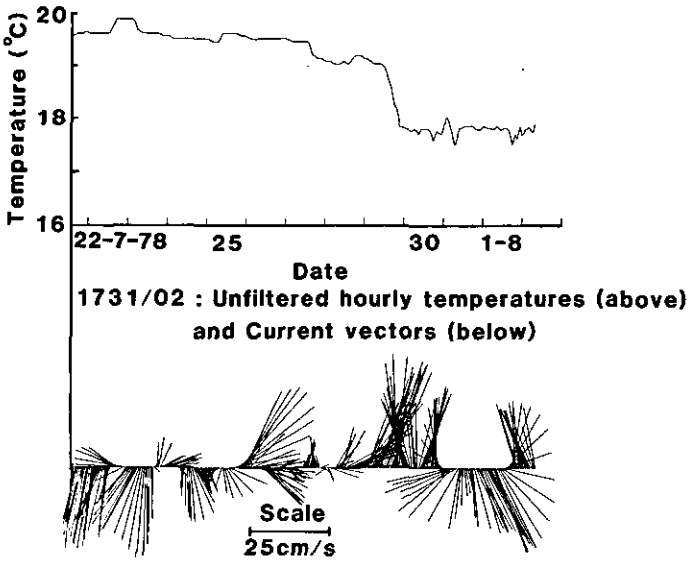
Along the inner shelf (1732/03), the flow was dominantly to the south (with two minor reversals) for the whole 11 day period, even while the countercurrent along the outer shelf was strong. A map of the temperature structure beyond the shelf by 'Sprightly' showed that the East Australian Current was swinging away eastwards more than 100 n miles offshore at this time (Pearce 1980) and that the structure on the shelf was very weak; this would explain the confused flow situation on the shelf in the lee of the strong offshore stream. It is possible that the northeasterly flow at the outer shelf (see the PVD for 1731/02) and the associated cooling on the 26th to 30th were part of an entrainment into the East Australian Current.

PERSONNEL INVOLVED

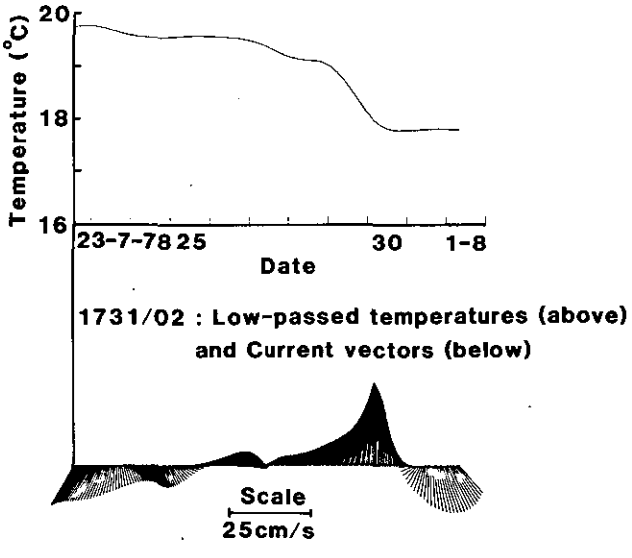
Alan Pearce (SP10/78).

PUBLICATION

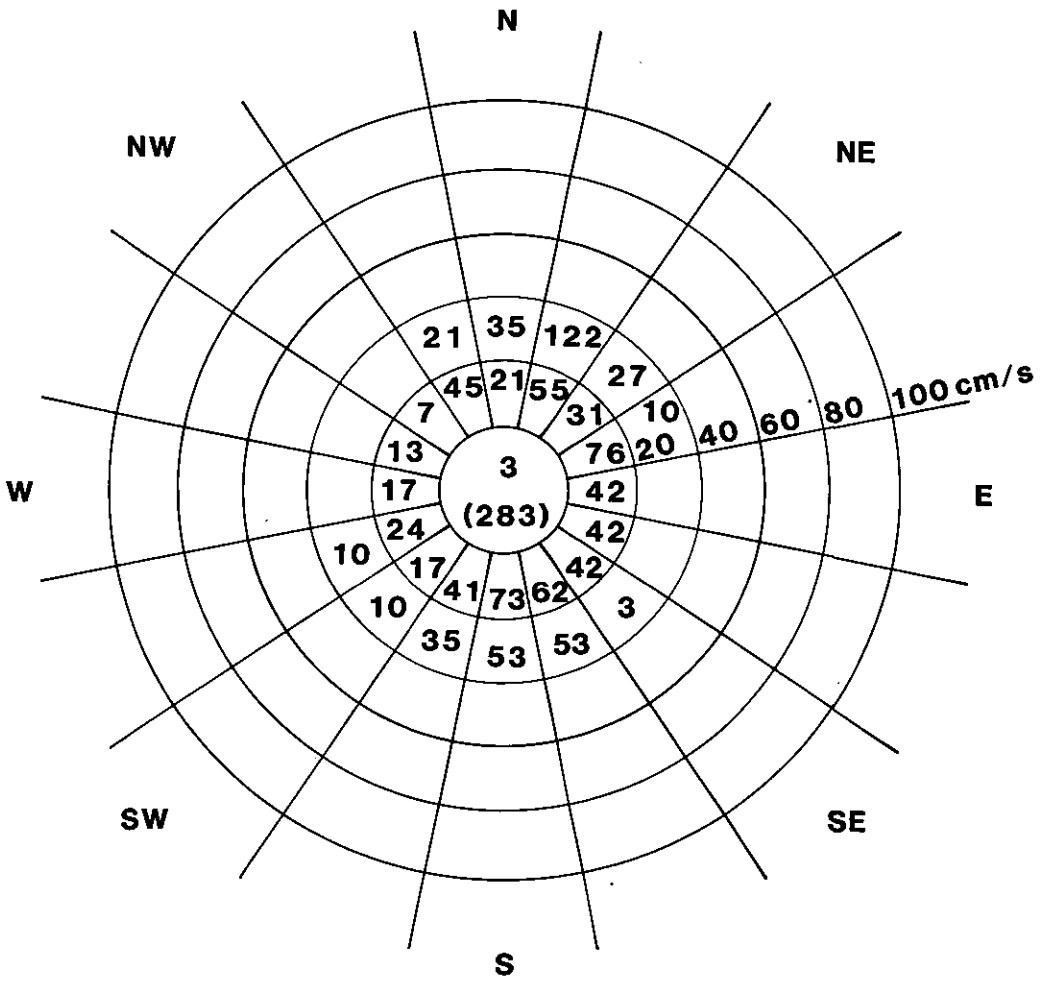
Pearce, A.F. (1980). Variability of currents off Cape Hawke, New South Wales, 1978-1979. Aust. CSIRO Div. Fish. Oceanogr. Rep. No. 128.



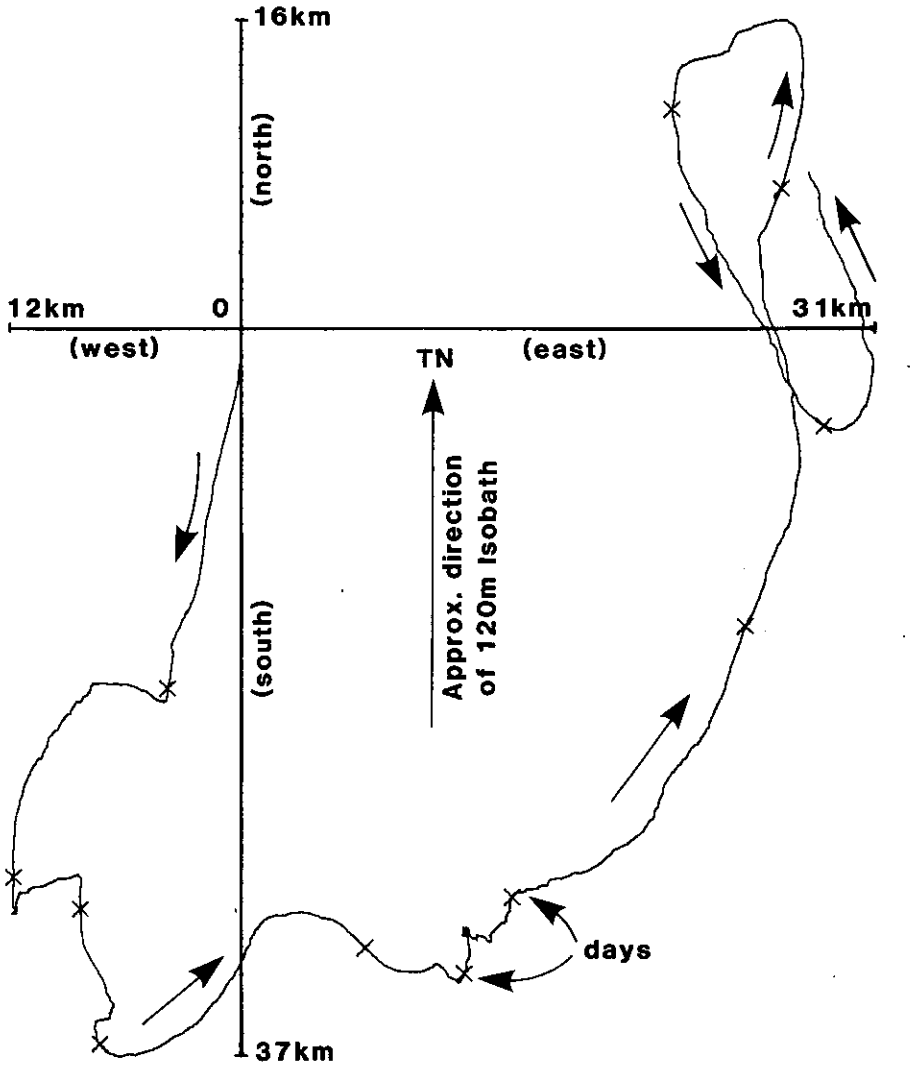
1731/02 : Unfiltered hourly temperatures (above) and Current vectors (below)



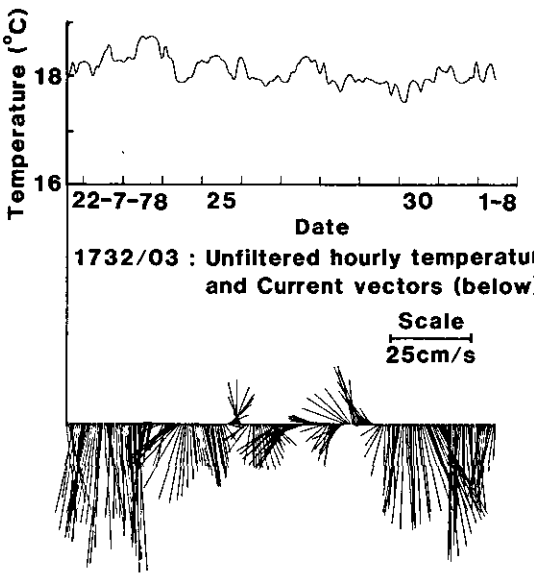
1731/02 : Low-passed temperatures (above) and Current vectors (below)



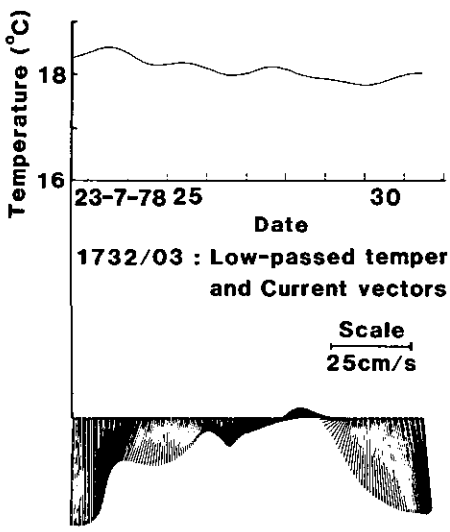
1731/02 : Current rose
(Instrument/Water depths 40/120m)



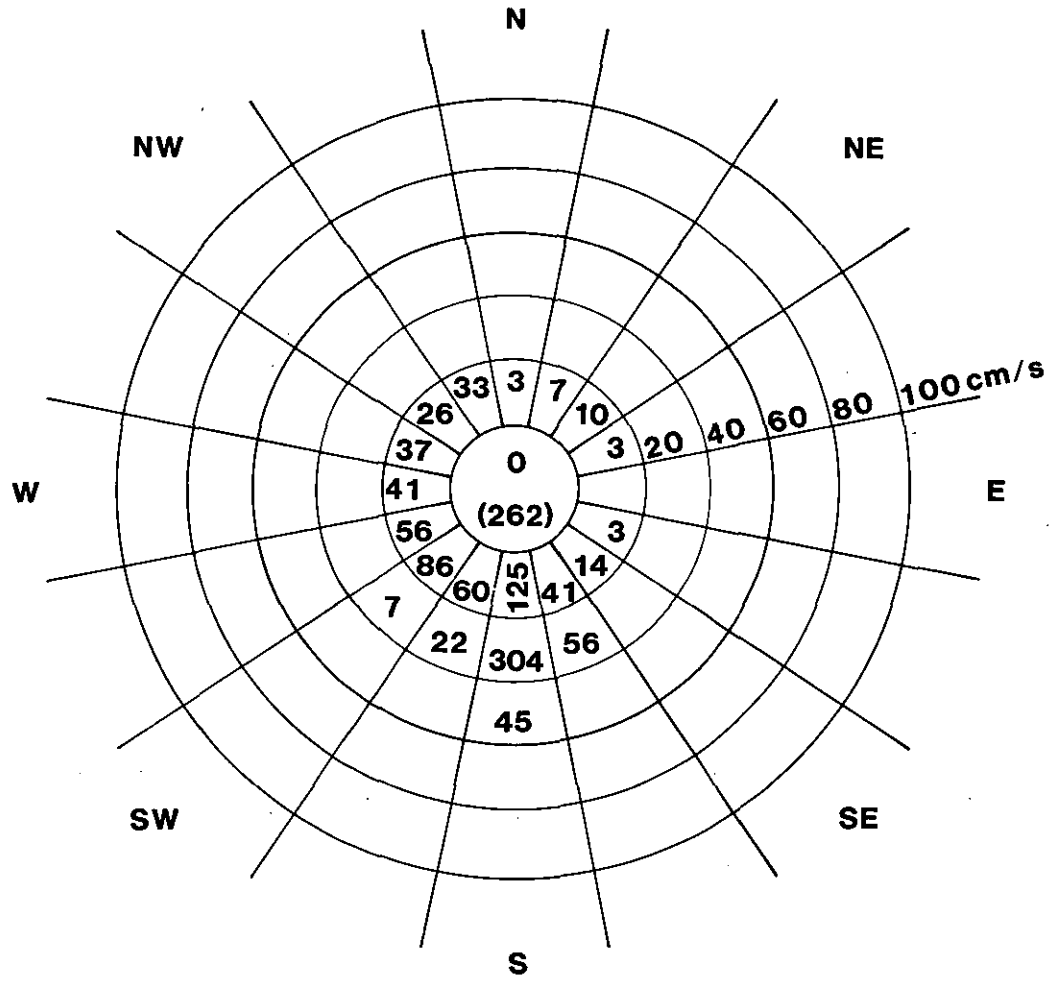
1731/02 : Progressive vector diagram



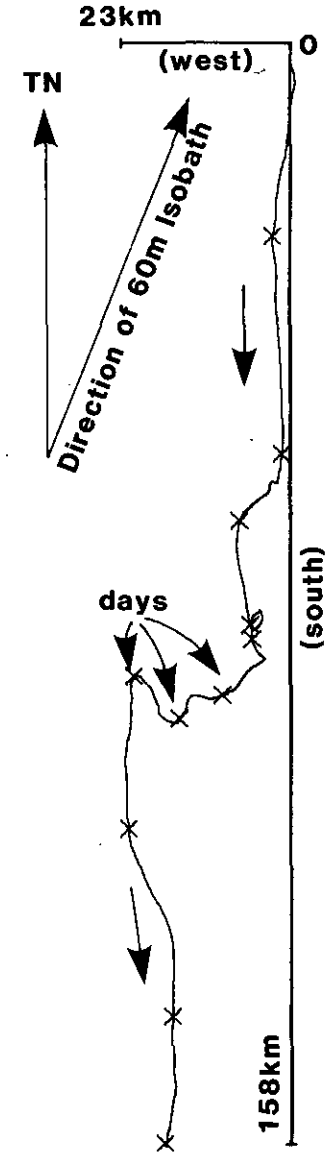
1732/03 : Unfiltered hourly temperatures (above) and Current vectors (below)



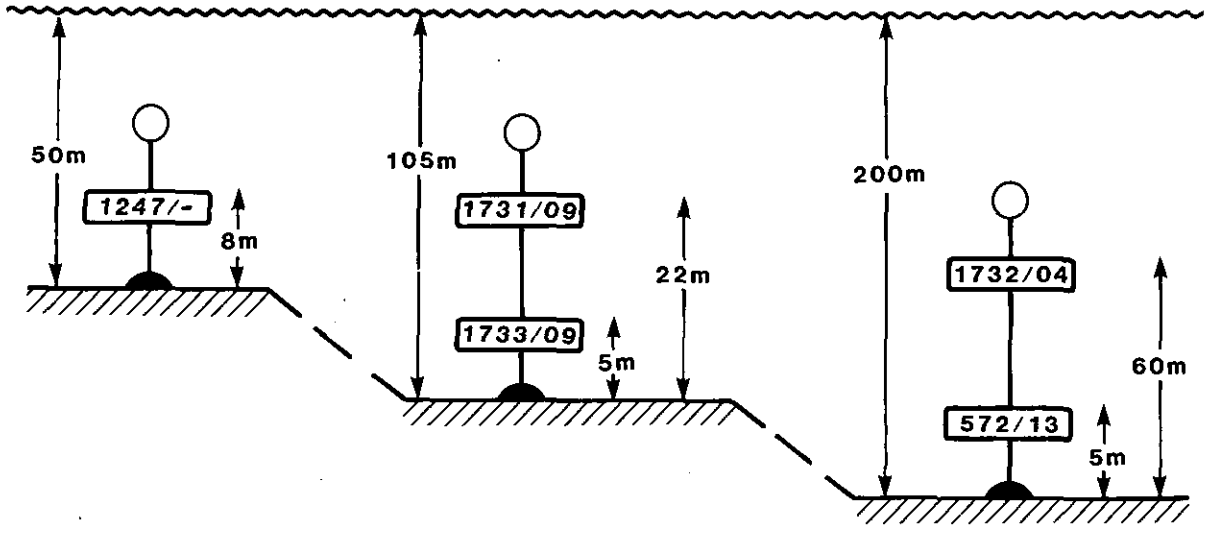
1732/03 : Low-passed temperatures (above) and Current vectors (below)



1732/03 : Current rose
(Instrument/Water depths 30/60m)



1732/03 : Progressive
vector diagram



TAPE NUMBERS 572/13, 1247/-, 1731/09, 1732/04, 1733/09

Continuing the study of daily variability and the relationship between on-shelf and off-shelf circulations off Cape Hawke, five Aanderaas were moored for a period of about 6 weeks. They were deployed at the start of criuse SP4/79 and recovered towards the end of SP6/79. U-moorings were used at the 50 m and 105 m sites, and an acoustic release at the outermost site. At recovery, no trace of 1247 was found in spite of repeated searches.

DATA

The records from the four meters which were recovered, were good. At the lower meter on the midshelf mooring, there was a pronounced onshore current component (see the PVD for 1733/09); the direction calibration of that instrument has been checked, so the onshore flow must be real, associated with a local topographic irregularity near the mooring and/or with Ekman veering in the bottom boundary layer. At the other three current meters, the flow paralleled the bathymetry for both southerly and northerly currents (see the PVD's).

A notable feature of the four records is the strong (visual) coherence in the smoothed current vectors (this can be seen more easily in Pearce (1980) where four stick diagrams are presented together). The current at mid-depth is stronger than that near the seabed, as would be expected, with vertical shears of the order of 0.01/s, or 1 cm/s per metre depth. The horizontal shear between the upper current meters was of the order of 10^{-5}/s or 1 cm/s per kilometre, which is approaching typical values in the cyclonic shear zone of western boundary currents. The strong southerly current over the shelf break during the first two weeks of record was in fact the East Australian Current; as described by Pearce (1980), ship drift and geomagnetic electrokinetograph (GEK) vectors measured by 'Sprightly' were 1 to 2 m/s (2 to 4 knots) and Aanderaa 1732/04 recorded speeds of 1 to 1.5 m/s during this period. Low values of the Richardson number during this period have been interpreted by Boland and Pearce (1981) as a result of entrainment of coastal water into the EAC. From about the 16th April, the EAC seemed to meander away from the coast, leaving a weaker oscillating current system on the shelf, with north/south direction changes every few days evident at all four instruments. At the very end of the period, the currents at the shelf break switched to northerly well in advance of the mid-shelf currents, indicating that some of the current variability on the shelf originates beyond the shelf.

Dramatic changes in the thermal structure on the shelf were observed on XBT sections from 'Sprightly' during cruise SP4/79, indicating an active upwelling event being forced partly by conventional wind-driven Ekman upwelling, and reinforced by frictional onshore veering in the bottom boundary layer due to the strong flow (Pearce 1980, Pearce and Boland 1981). This upwelling is reflected in the 2° to 4° drop in temperature recorded on all four meters in the first few days of operation.

PERSONNEL INVOLVED

Fred Boland (SP4/79 and SP6/79);
Alan Pearce (SP4/79).

PUBLICATIONS

Boland, F.M., and Pearce, A.F. (1981). Direct current measurements near an East Australian Current Front. Meeting of Australian Physical Oceanographers, Cronulla, 2-5 March 1981.

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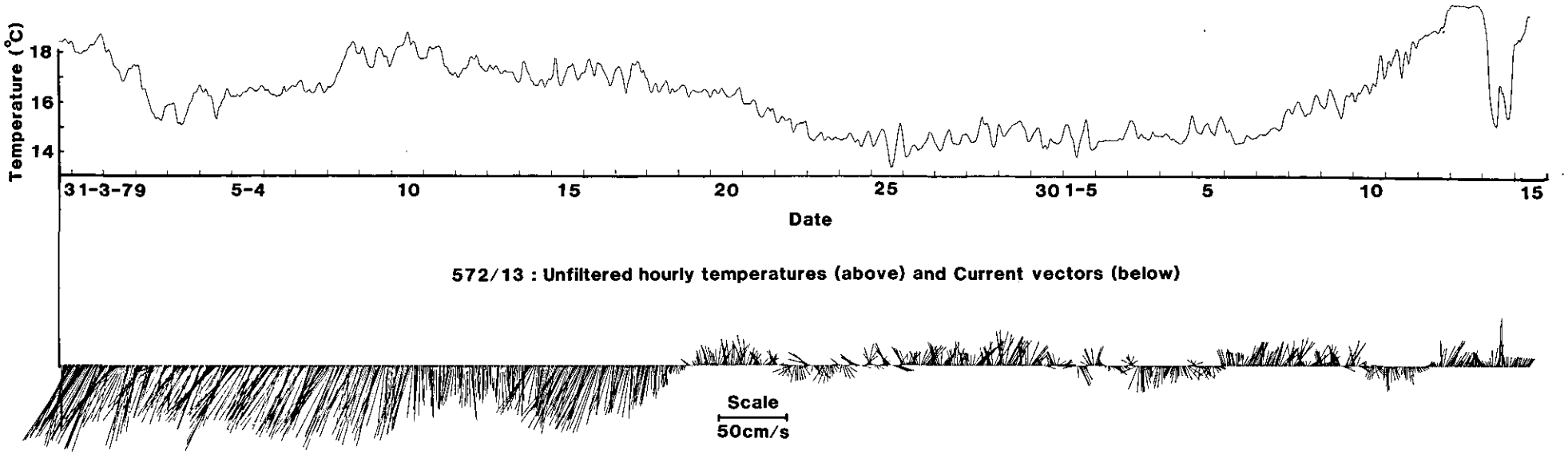
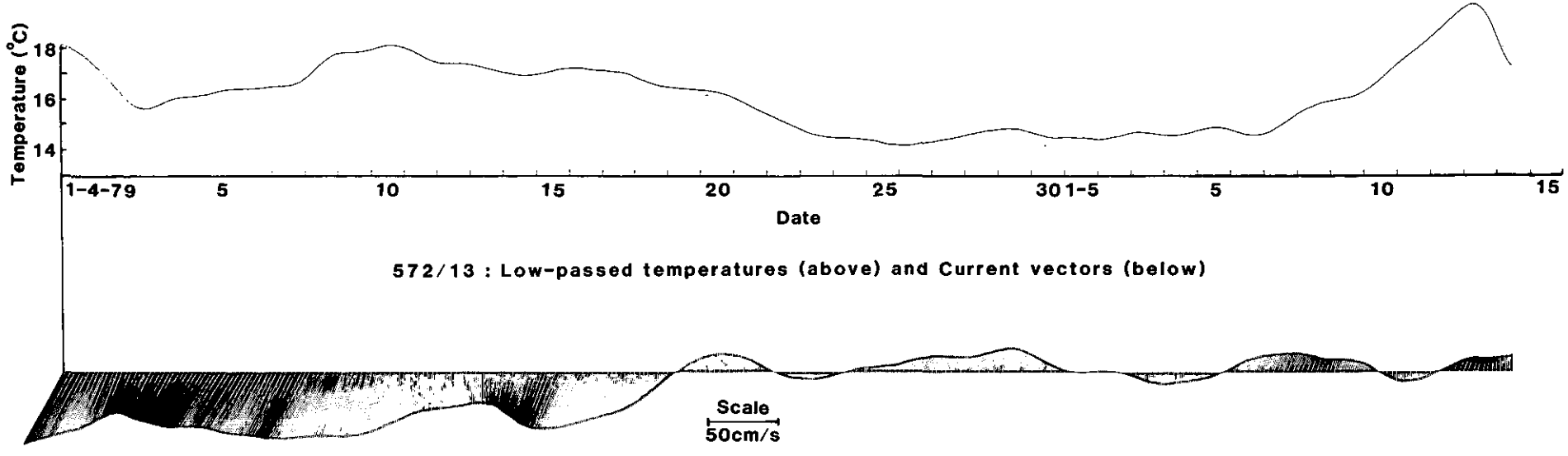
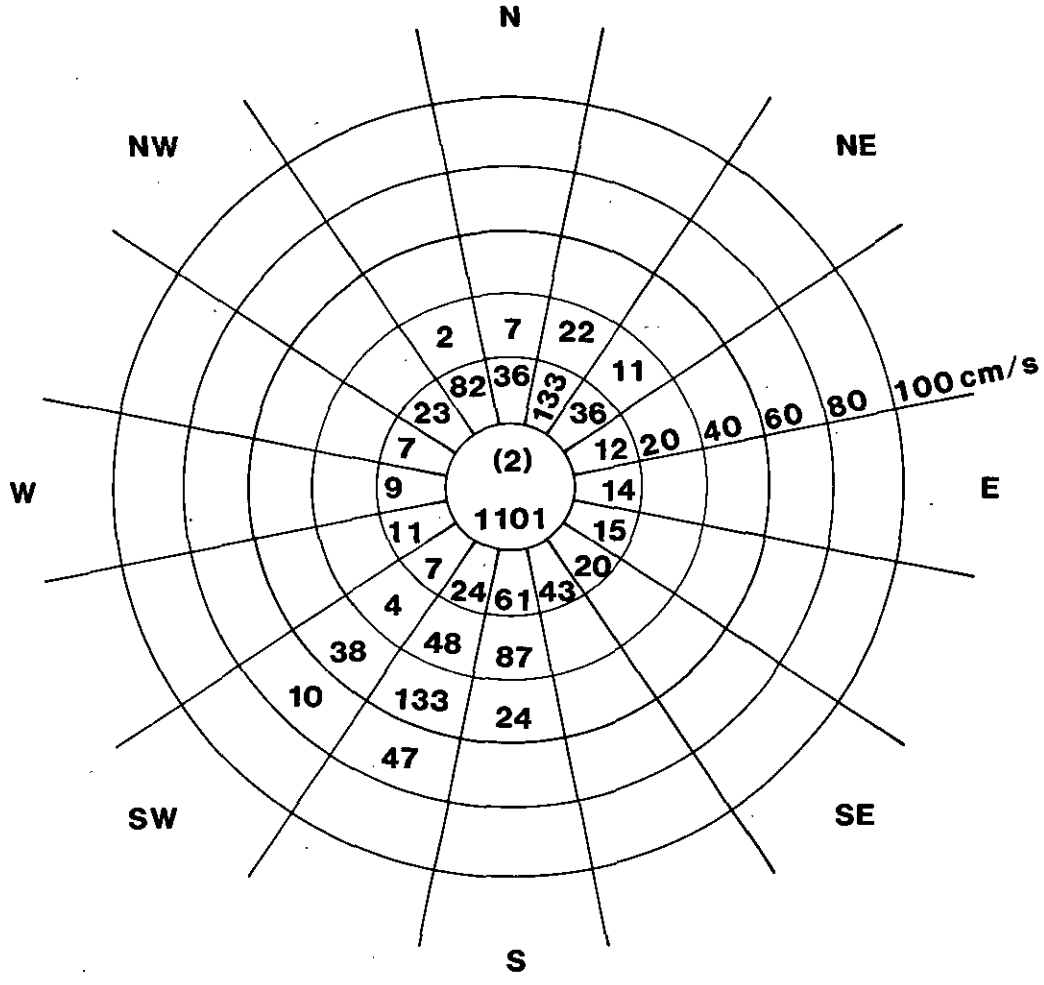
Pearce, A.F., and Boland, F.M. (1981). Localised upwelling on the NSW shelf. Meeting of Australian Physical Oceanographers, Cronulla, 2-5 March 1981.



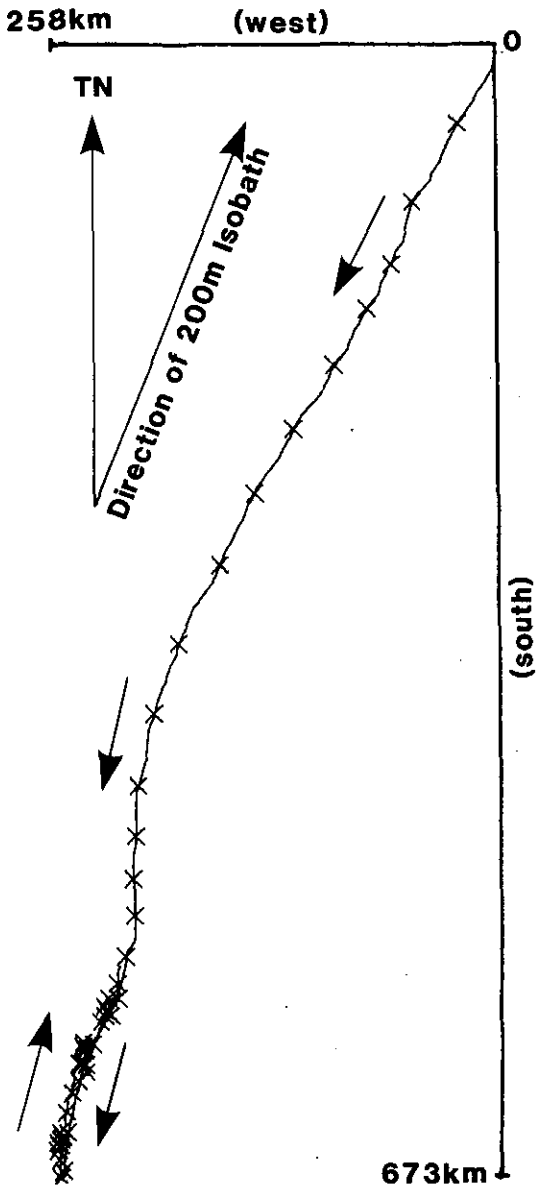
572/13 : Unfiltered hourly temperatures (above) and Current vectors (below)



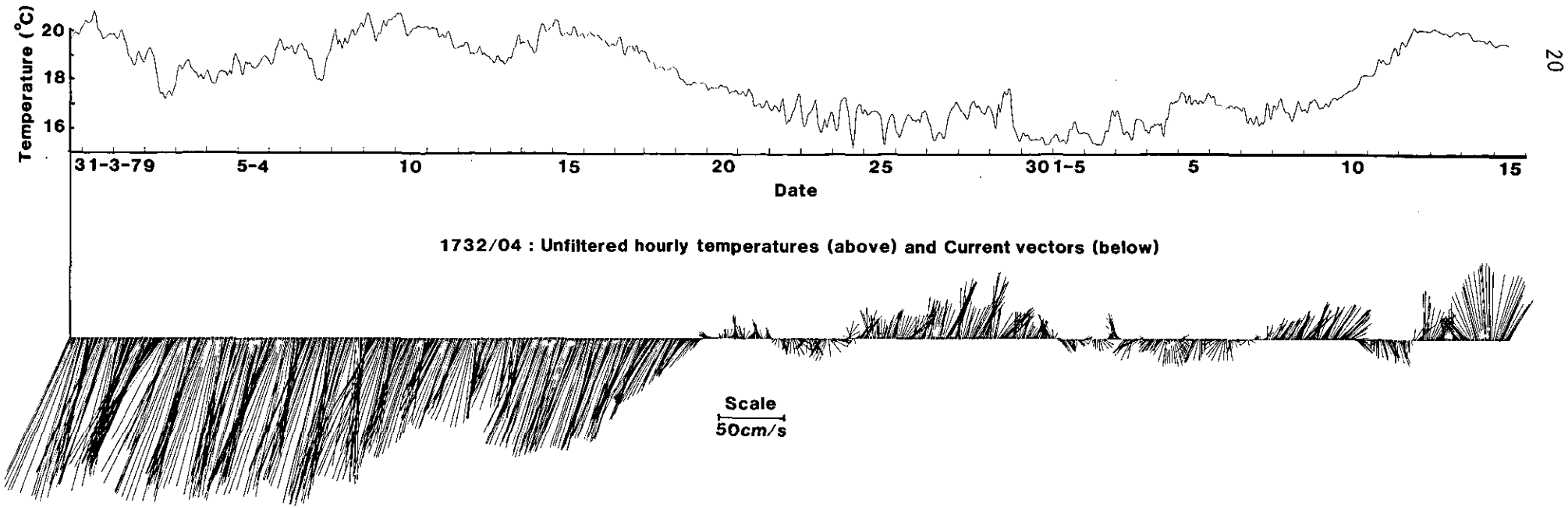
572/13 : Low-passed temperatures (above) and Current vectors (below)

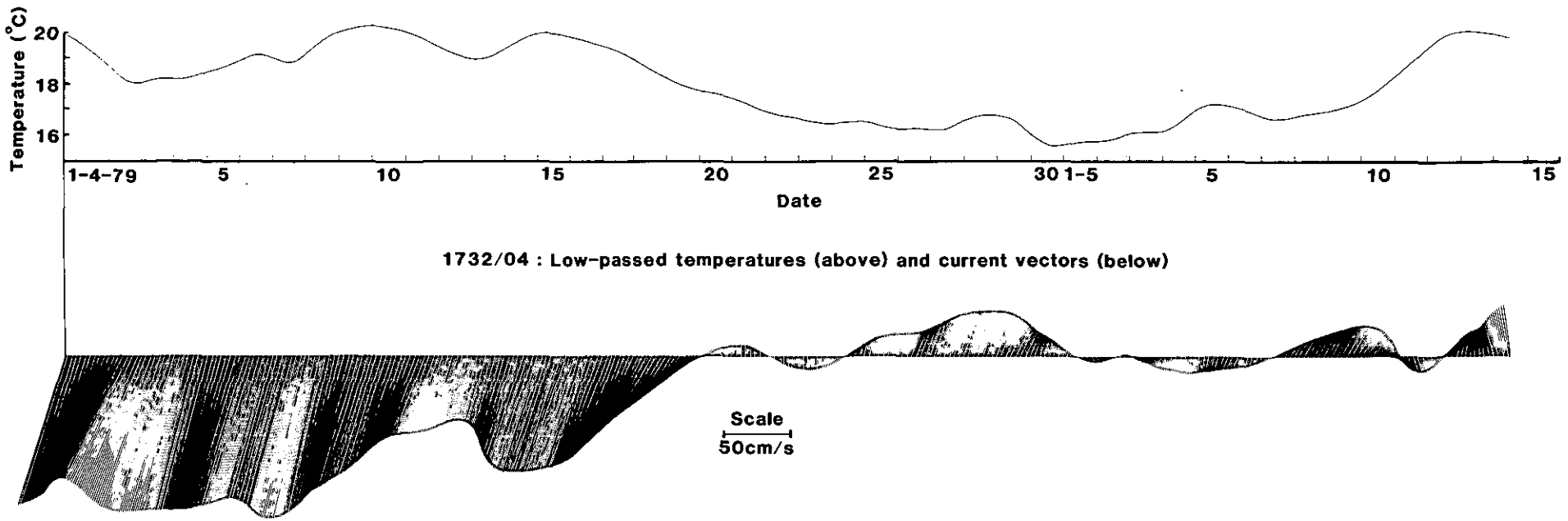


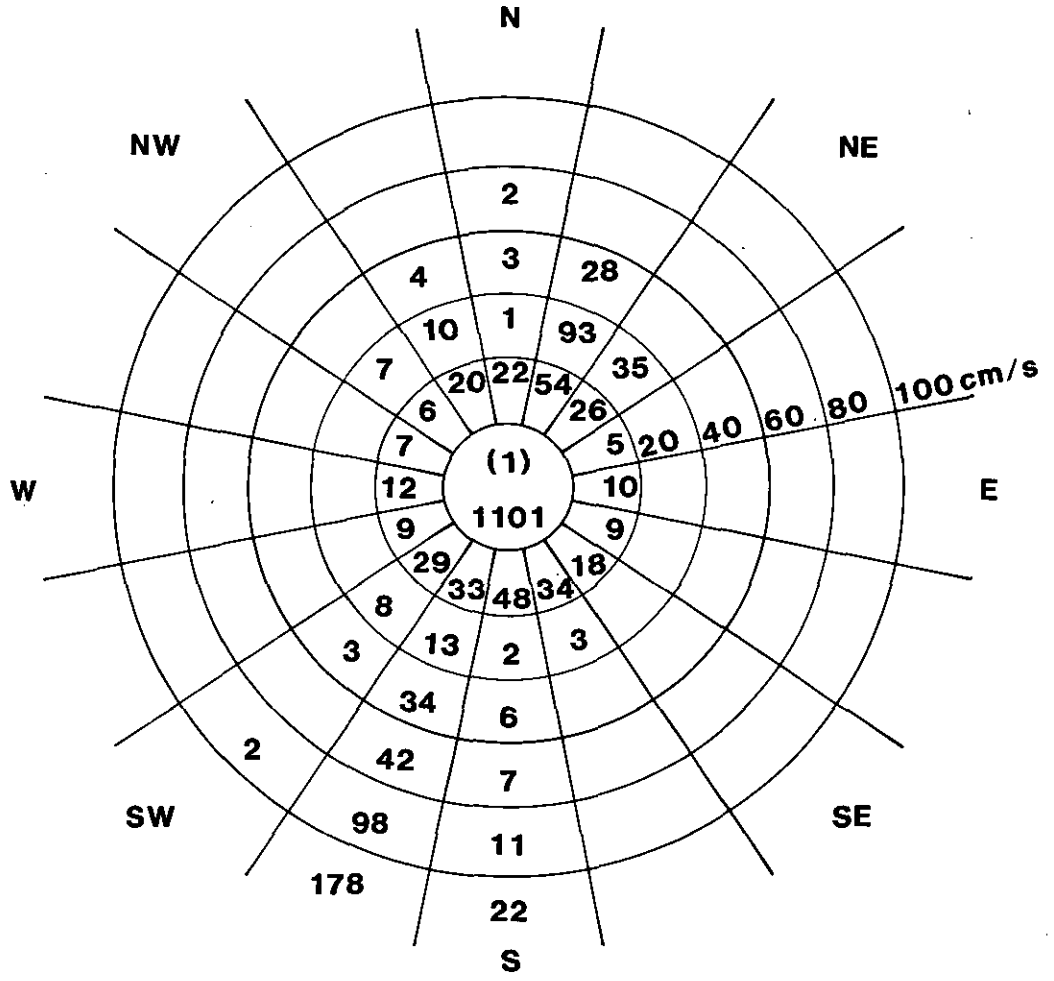
572/13 : Current rose
(Instrument/Water depths 195/200m)



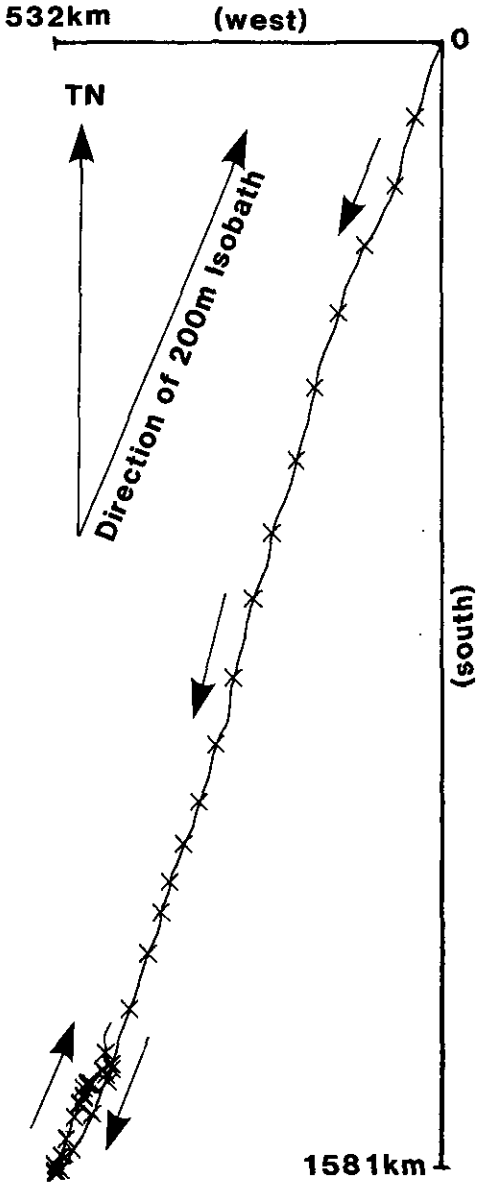
572/13 : Progressive vector diagram


Temperature (°C)
20
18
16
31-3-79
5-4
10
15
20
25
30 1-5
5
10
15
Date
1732/04 : Unfiltered hourly temperatures (above) and Current vectors (below)
Scale
50cm/s

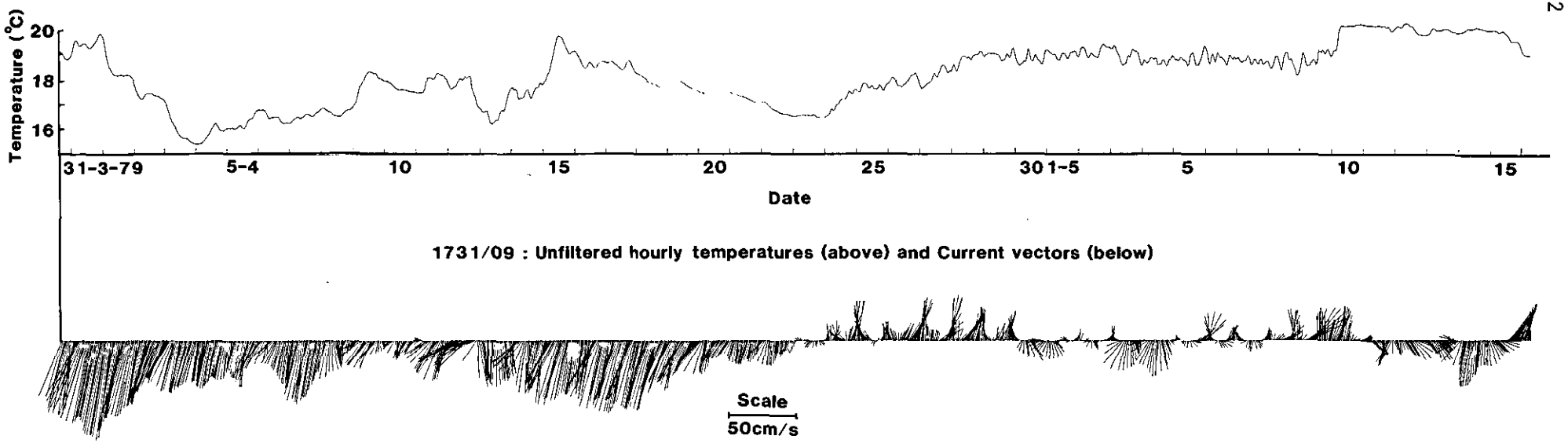

Temperature (°C)
20
18
16
1-4-79
5
10
15
20
25
30 1-5
5
10
15
Date
1732/04 : Low-passed temperatures (above) and current vectors (below)
Scale
50cm/s



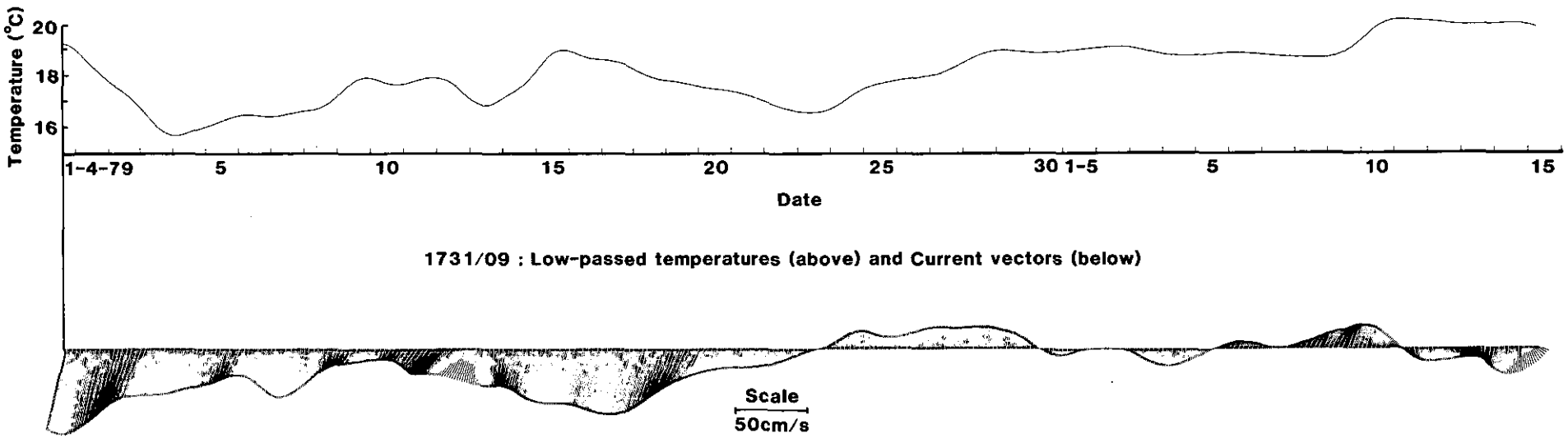
1732/04 : Current rose
(Instrument/Water depths 140/200m)



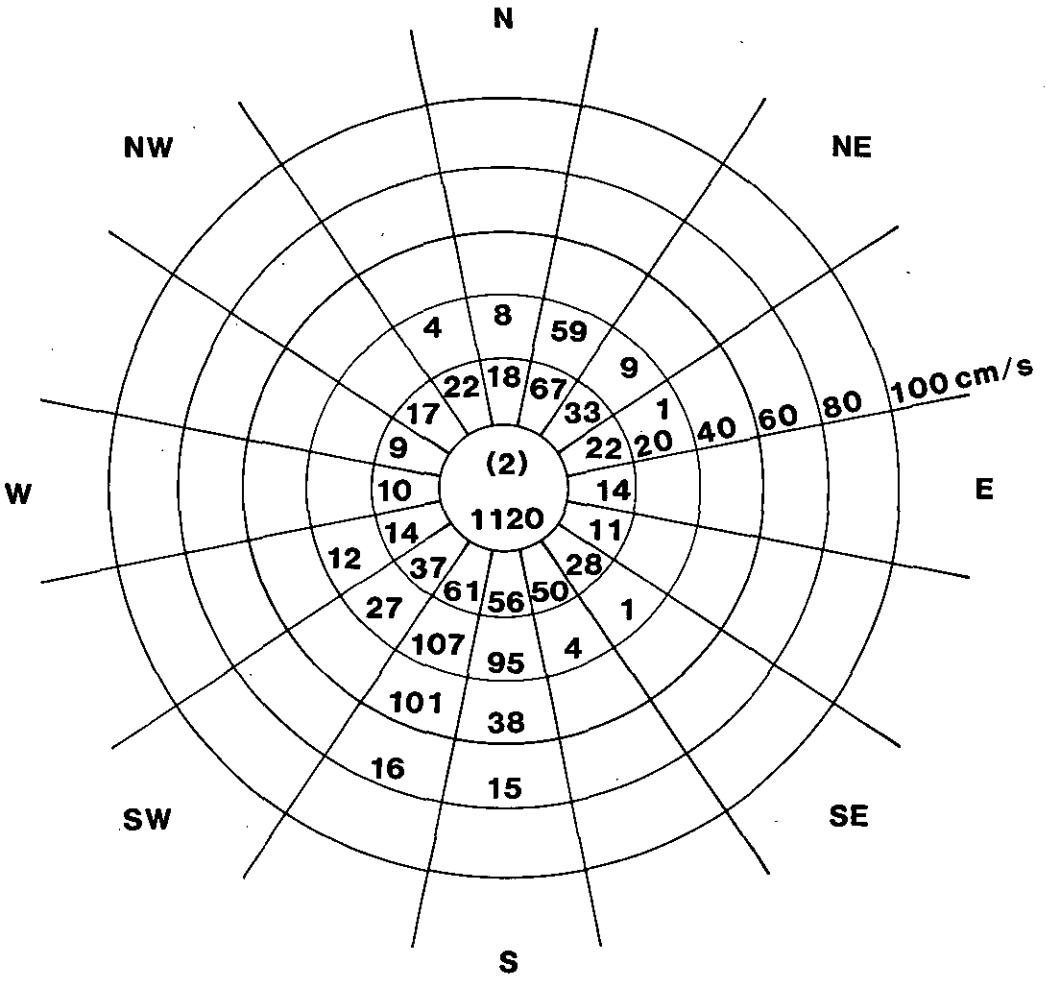
1732/04 : Progressive vector diagram



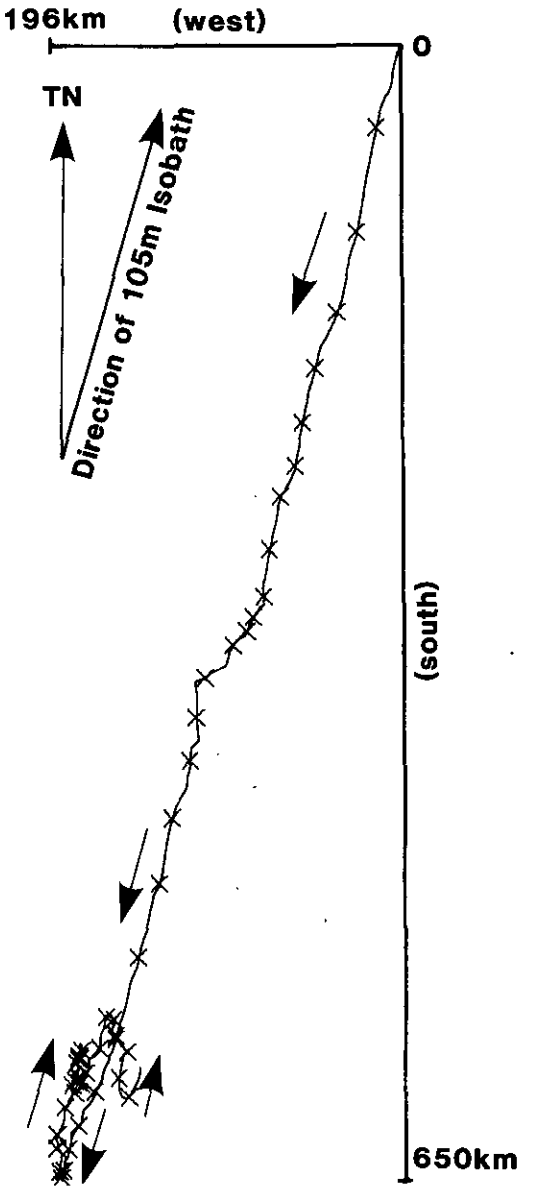
1731/09 : Unfiltered hourly temperatures (above) and Current vectors (below)



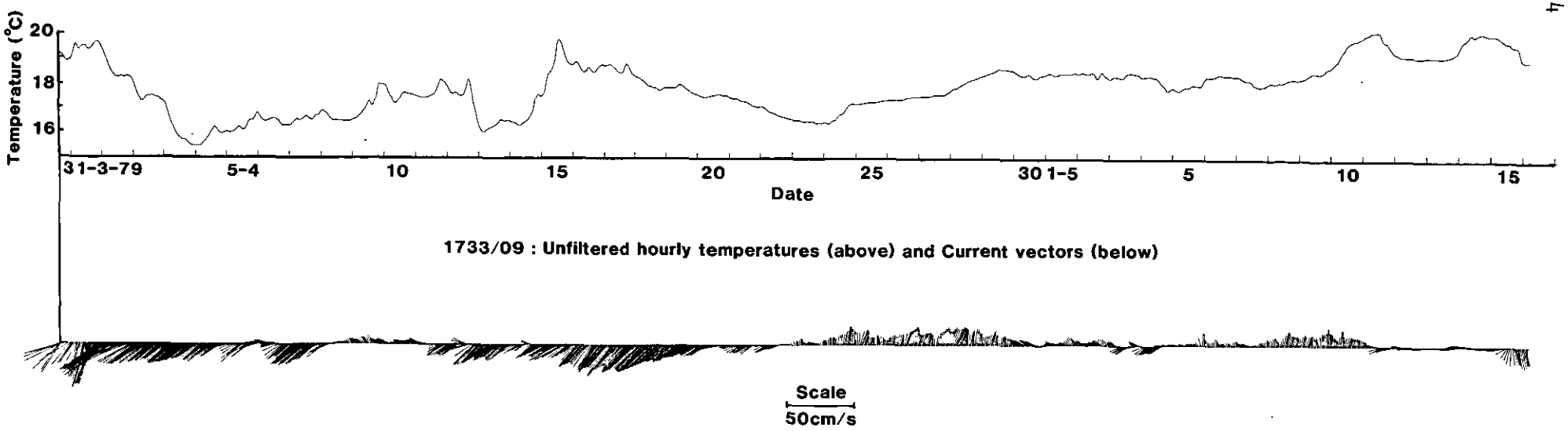
1731/09 : Low-passed temperatures (above) and Current vectors (below)



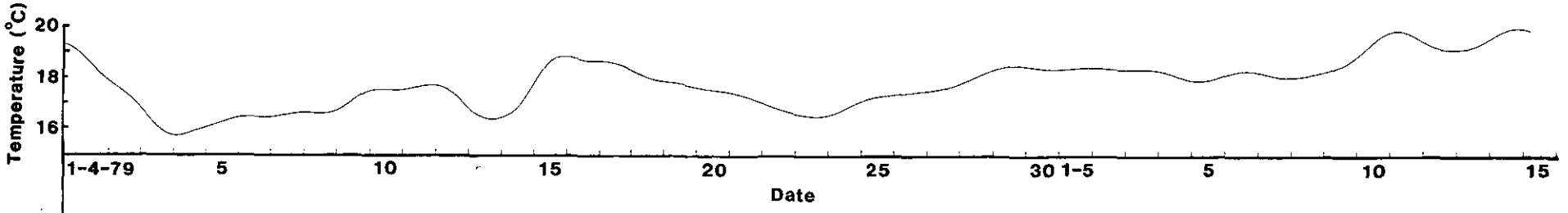
1731/09 : Current rose
(Instrument/Water depths 83/105m)



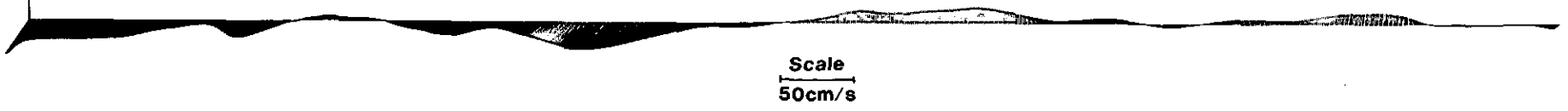
1731/09 : Progressive vector diagram

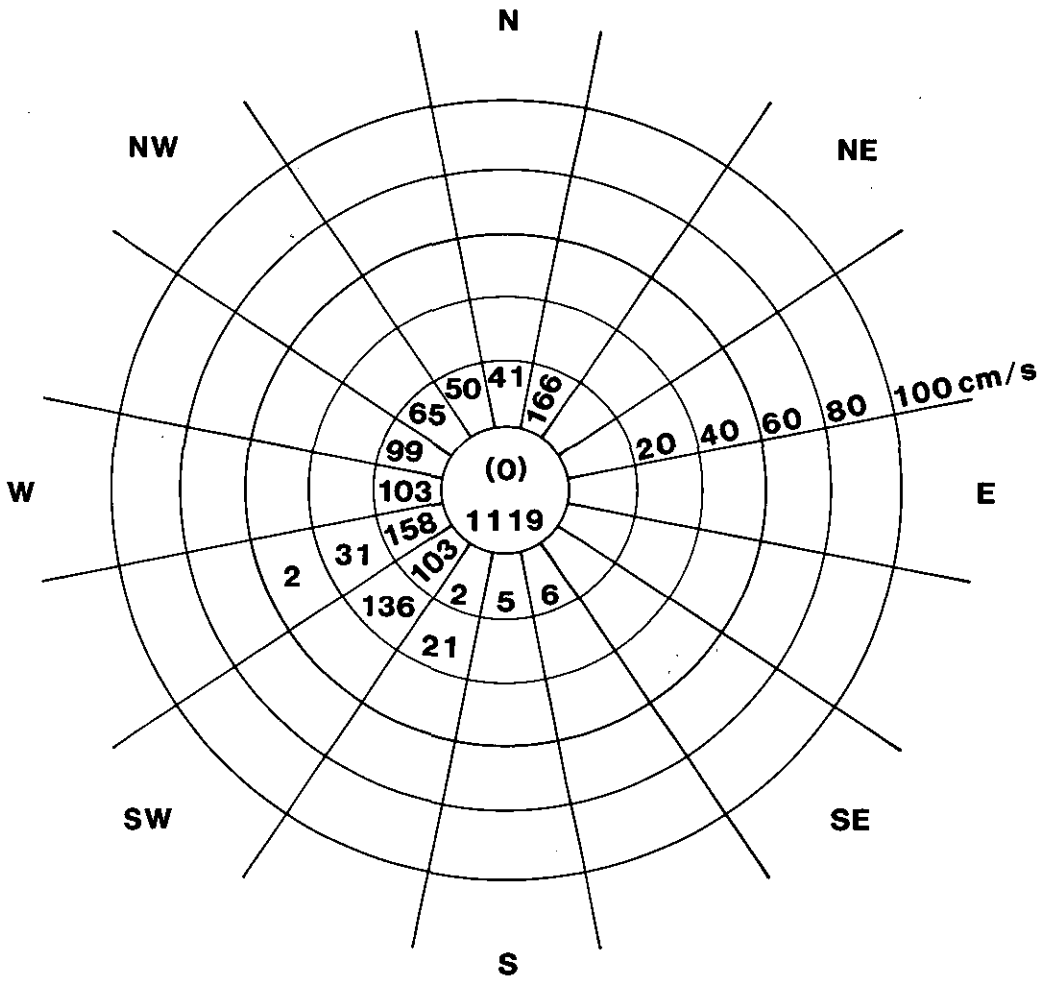


1733/09 : Unfiltered hourly temperatures (above) and Current vectors (below)

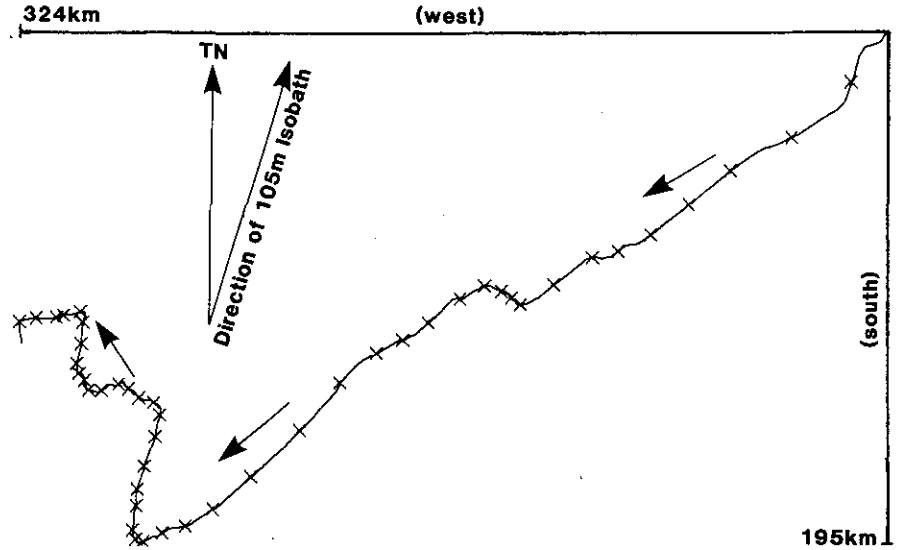


1733/09 : Low-passed temperatures (above) and Current vectors (below)





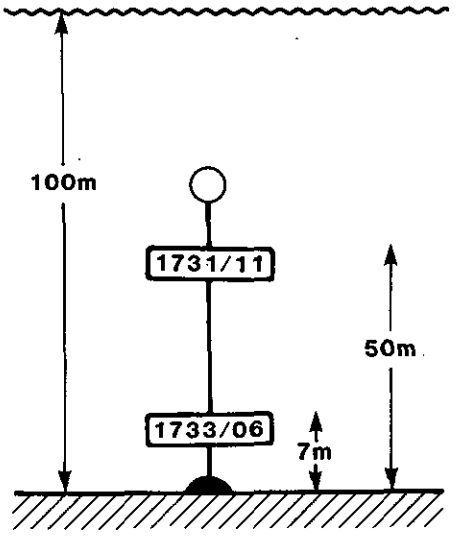
1733/09 : Current rose
(Instrument/Water depths 100/105m)



1733/09 : Progressive vector diagram

TAPE NUMBERS 1731/11, 1733/06

These two current meters were deployed at the Port Hacking "100 m station", where weekly hydrology sampling has been carried out for many years. When recovery was attempted, the acoustic release failed to respond and fruitless attempts were made by R.V. 'Karin' to drag for the mooring. Eventually the NSW State Fisheries vessel 'Kapala' trawled it up (and we gratefully acknowledge the assistance of the State Fisheries for this).



DATA

Good data were recorded on both tapes until they ran out.

For the first three weeks, there was strong vertical coherence in the flow and the few-day oscillations were largely barotropic. The vertical shear during this period was 1 to 3 x 10^{-3}/s. However towards the end of the recording period, the upper meter showed a very strong southerly pulse of current with a speed of about 25 cm/s (accompanied by an influx of appreciably warmer water), while near the seabed the currents remained weak until a *northerly* reversal occurred and no rise in temperature was recorded. (Caution, the record for 1731/11 is 2 days longer than for 1733/06).

The PVD's are interesting, with a persistent cross-isobath component evident for the lower instrument, presumably associated with Ekman veering in the bottom boundary layer. At the upper meter the flow was more parallel to the bathymetry. The PVD for 1733/06 (particularly) also reveals numerous loops, indicative of intense eddy-like motions on a relatively small scale

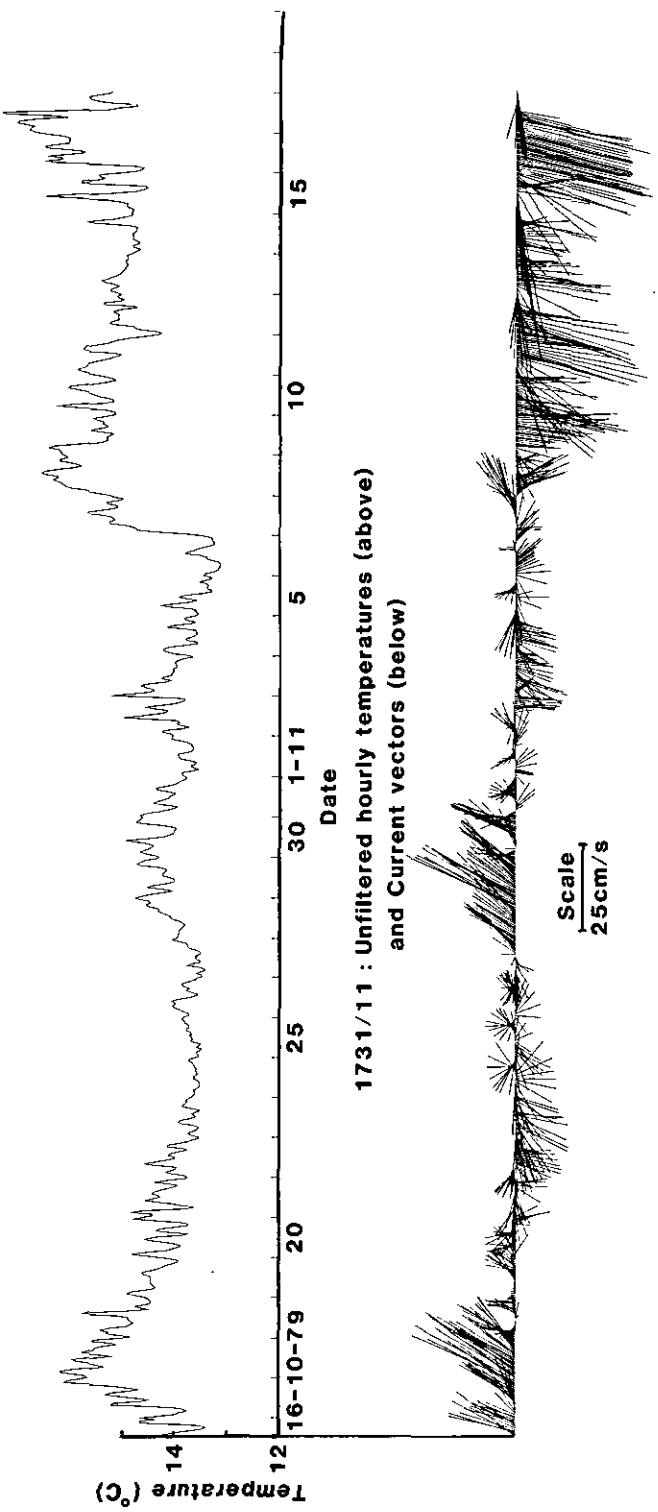
Strong internal wave activity is apparent in the unsmoothed temperature trace for the upper meter, and the weekly hydrology data (Pearce 1982) shows periods of marked thermal structure at this level.

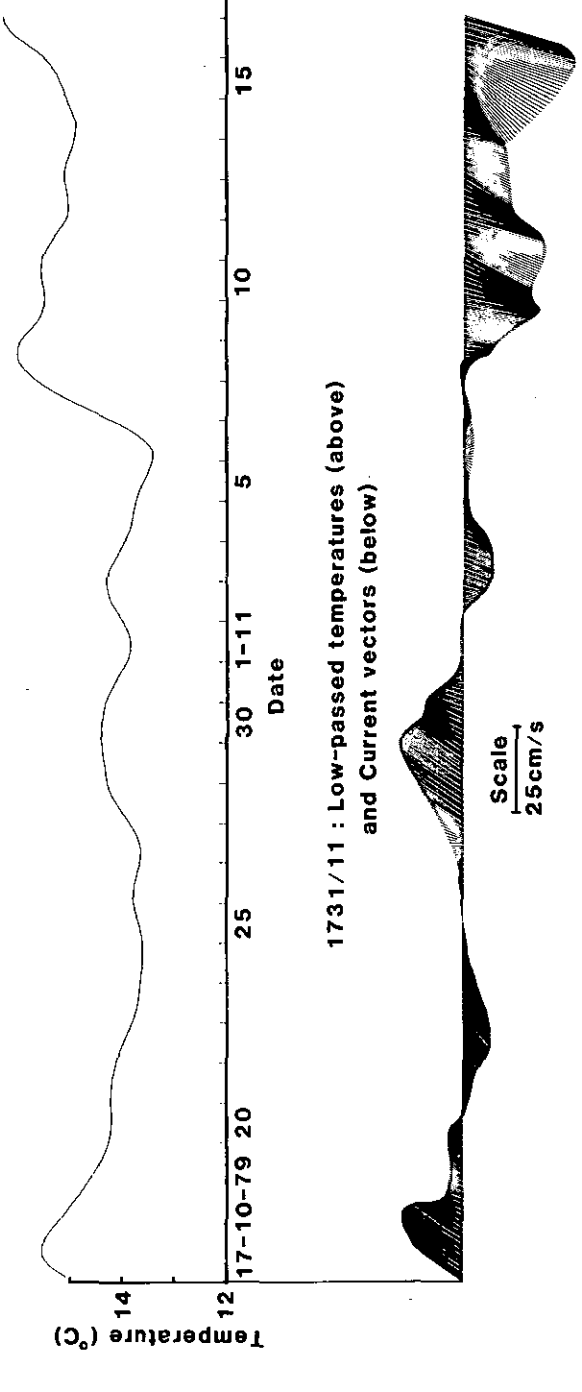
PERSONNEL INVOLVED

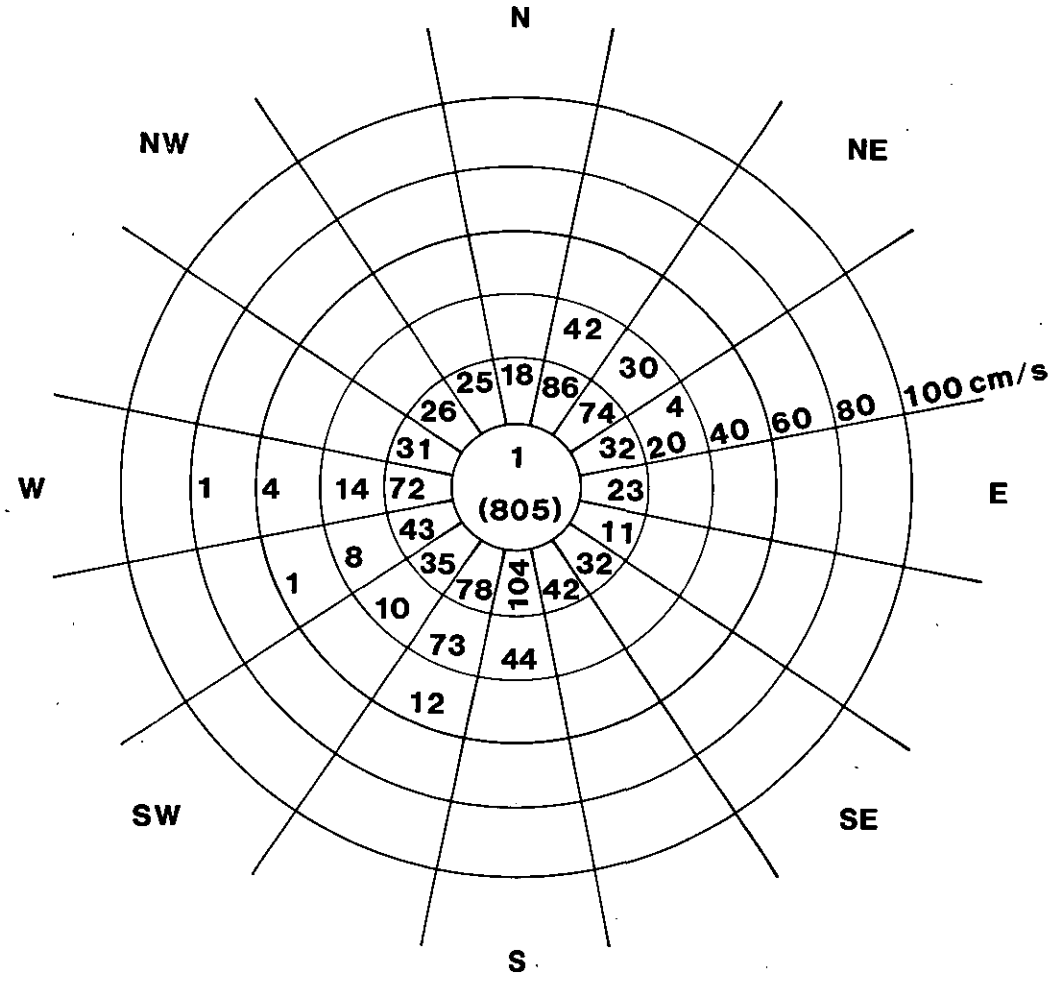
Rory Thompson, Fred Boland, Terry Golding, and Alan Pearce.

PUBLICATION

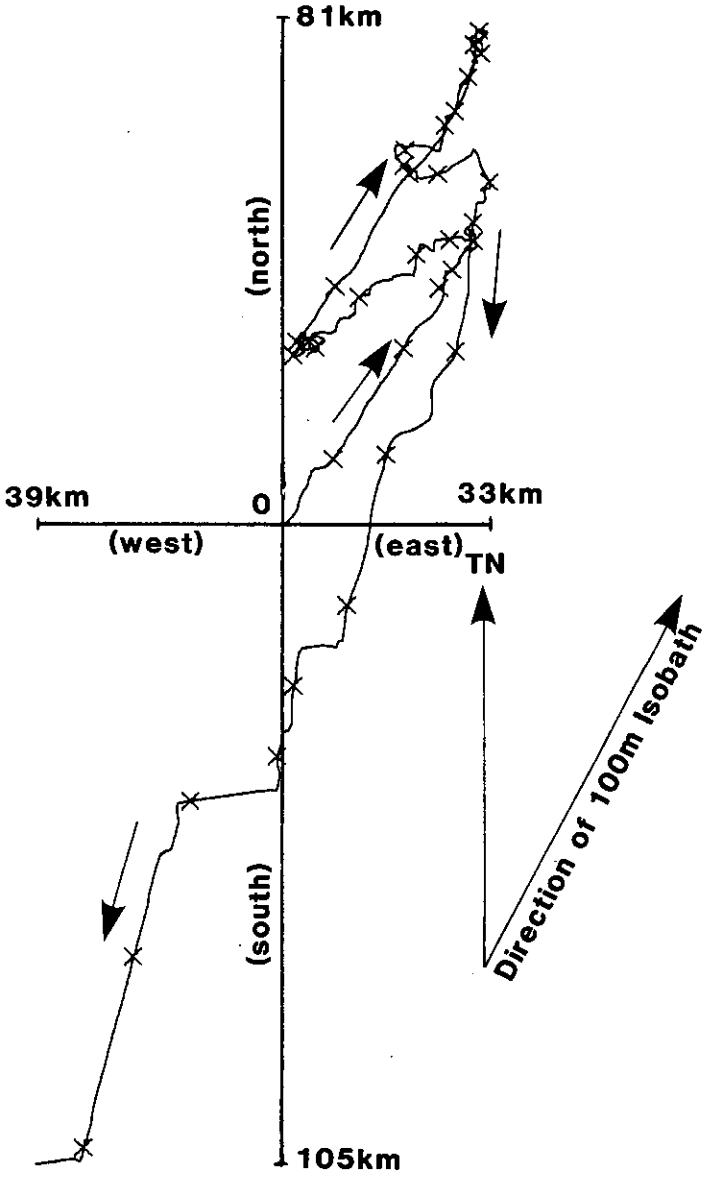
Pearce, A.F. (1982). Hydrological and current variability at the Port Hacking 100 m station during the 1979 spring season. (In preparation).


Temperature (°C)
14
12
16-10-79
20
25
30
1-11
5
10
15
Date
1731/11 : Unfiltered hourly temperatures (above)
and Current vectors (below)
Scale
25cm/s

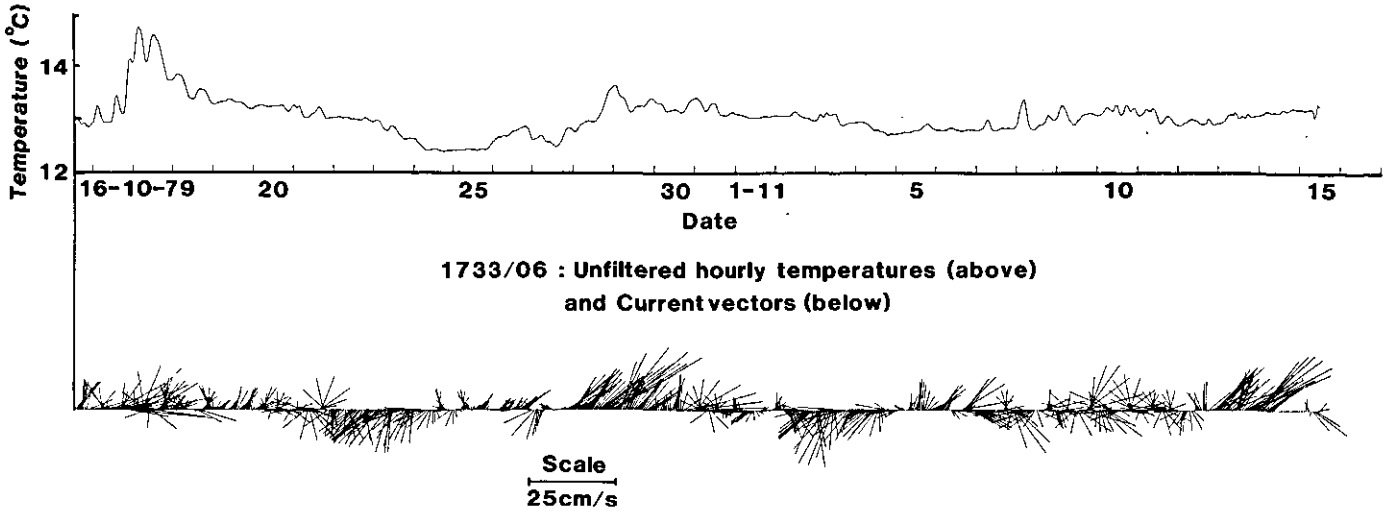

Temperature (°C)
14
12
17-10-79
20
25
30
1-11
5
10
15
Date
1731/11 : Low-passed temperatures (above)
and Current vectors (below)
Scale
25cm/s

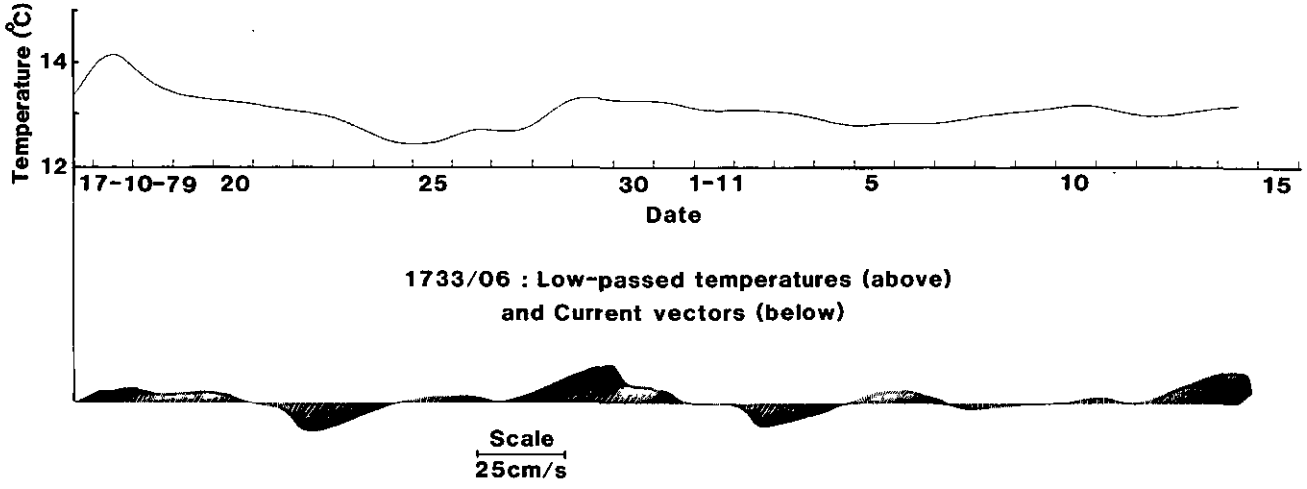


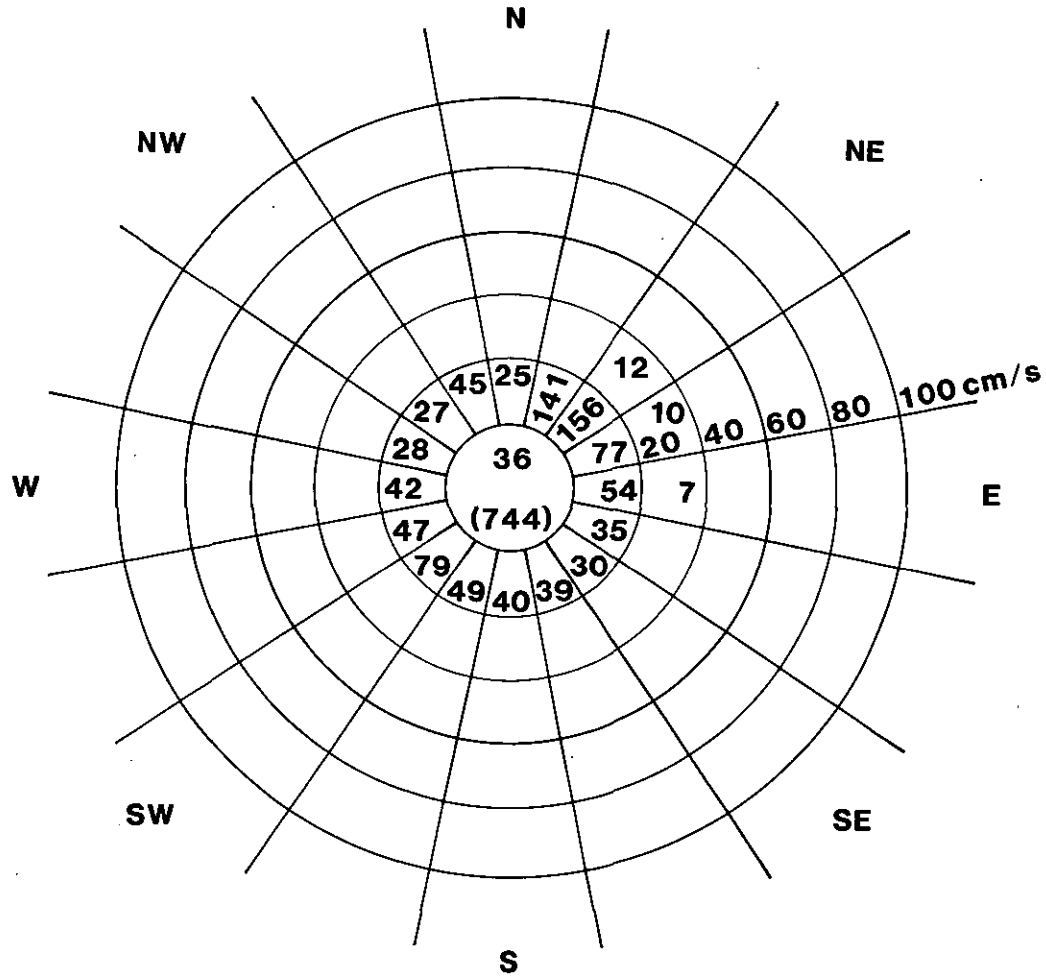
1731/11 : Current rose
(Instrument/Water depths 50/100m)



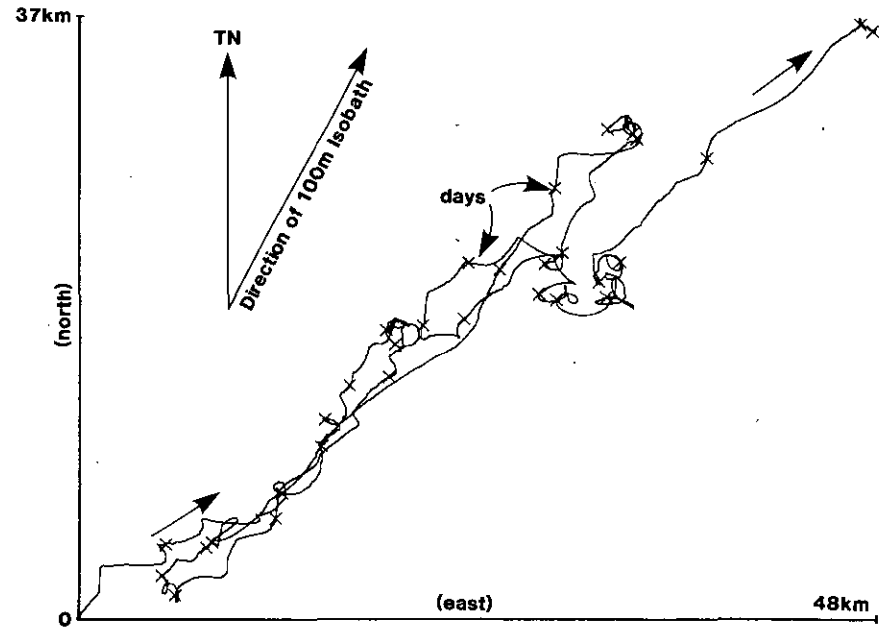
1731/11 : Progressive vector diagram


Temperature (°C)
14
12
16-10-79
20
25
30
1-11
5
10
15
Date
1733/06 : Unfiltered hourly temperatures (above)
and Current vectors (below)
Scale
25cm/s


Temperature (°C)
14
12
17-10-79
20
25
30
1-11
5
10
15
Date
1733/06 : Low-passed temperatures (above)
and Current vectors (below)
Scale
25cm/s



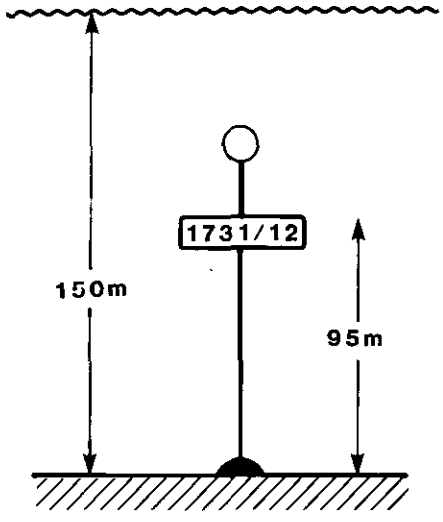
1733/06 : Current rose
(Instrument/Water depths 93/100m)



1733/06 : Progressive vector diagram

TAPE NUMBER 1731/12

In conjunction with the Royal Australian Navy Research Laboratory (RANRL) an Aanderaa was moored off Jervis Bay in February/March 1980 to measure the currents off the entrance to the Bay. An acoustic release mooring was deployed, but towards the end of the recording period the upper portion of the mooring (including the current meter) broke free; it was subsequently recovered, drifting freely some miles north of the mooring site, by a fisherman.



DATA

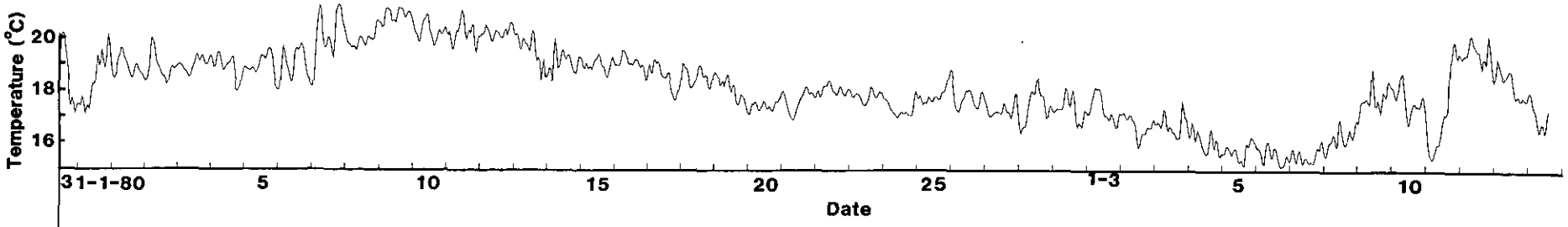
The recorded data were good until the tape ran out.

The current vectors and PVD indicate that the flow off Jervis Bay was strong (exceeding 50 cm/s, or 1 knot) and southerly for most of the period. Interestingly, "northerly" currents flowed parallel to the local bathymetry, while "southerly" currents were due south and hence had an offshore component relative to the seabed contours — this was presumably due to the shape of the Jervis Bay headland (Fig. 1). The flow was remarkably steady for lengthy periods (compared with the frequent current reversals recorded at most of the other sites in this report), and the rise in temperature associated with each of the periods of northerly flow suggests that this may have been cyclonic eddying and recirculation of warm East Australian Current water onto the shelf. The strong onshore flow (into the Bay?) for the 3-day period in the middle of the record is a puzzle.

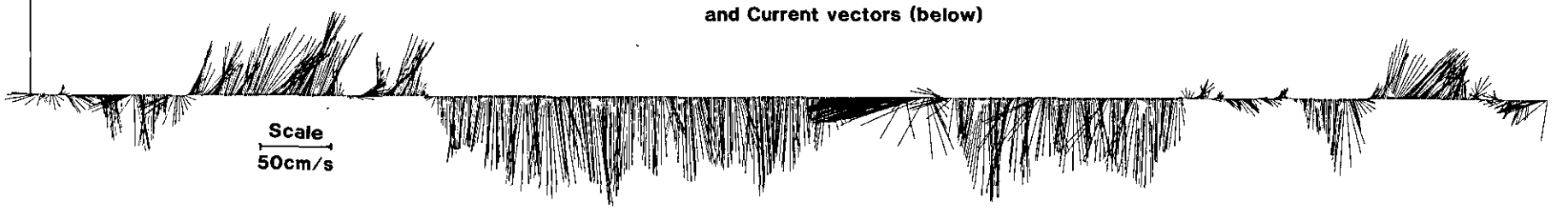
The unsmoothed temperature trace exhibits pronounced internal wave activity, and on the 11th March the temperature rose by 4°C in a few hours.

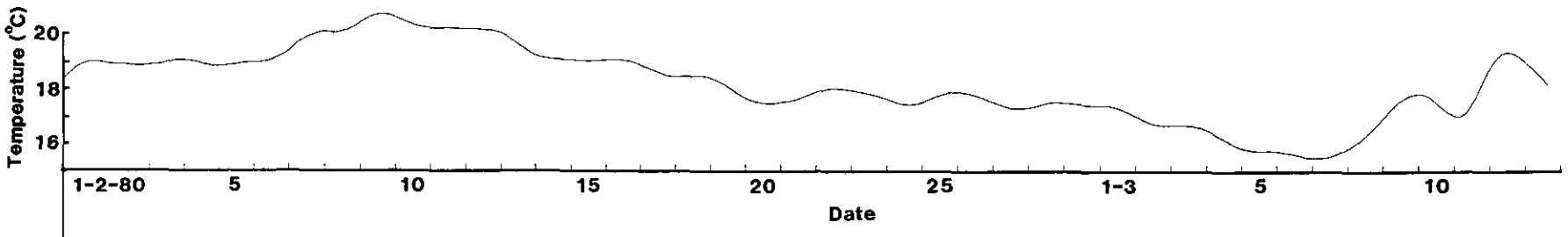
PERSONNEL INVOLVED

Jim Johnson (RANRL), Fred Boland and Alan Pearce.

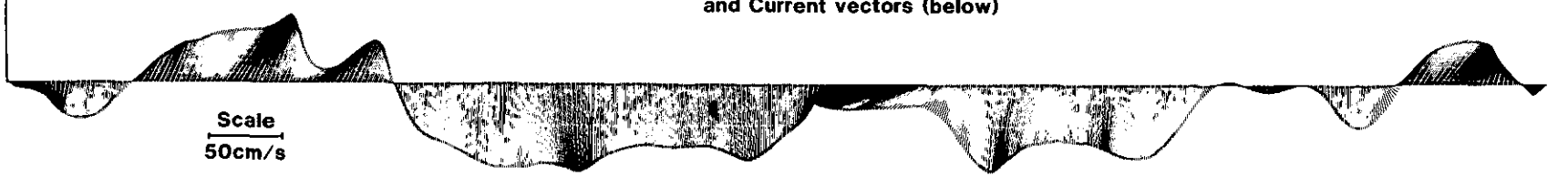


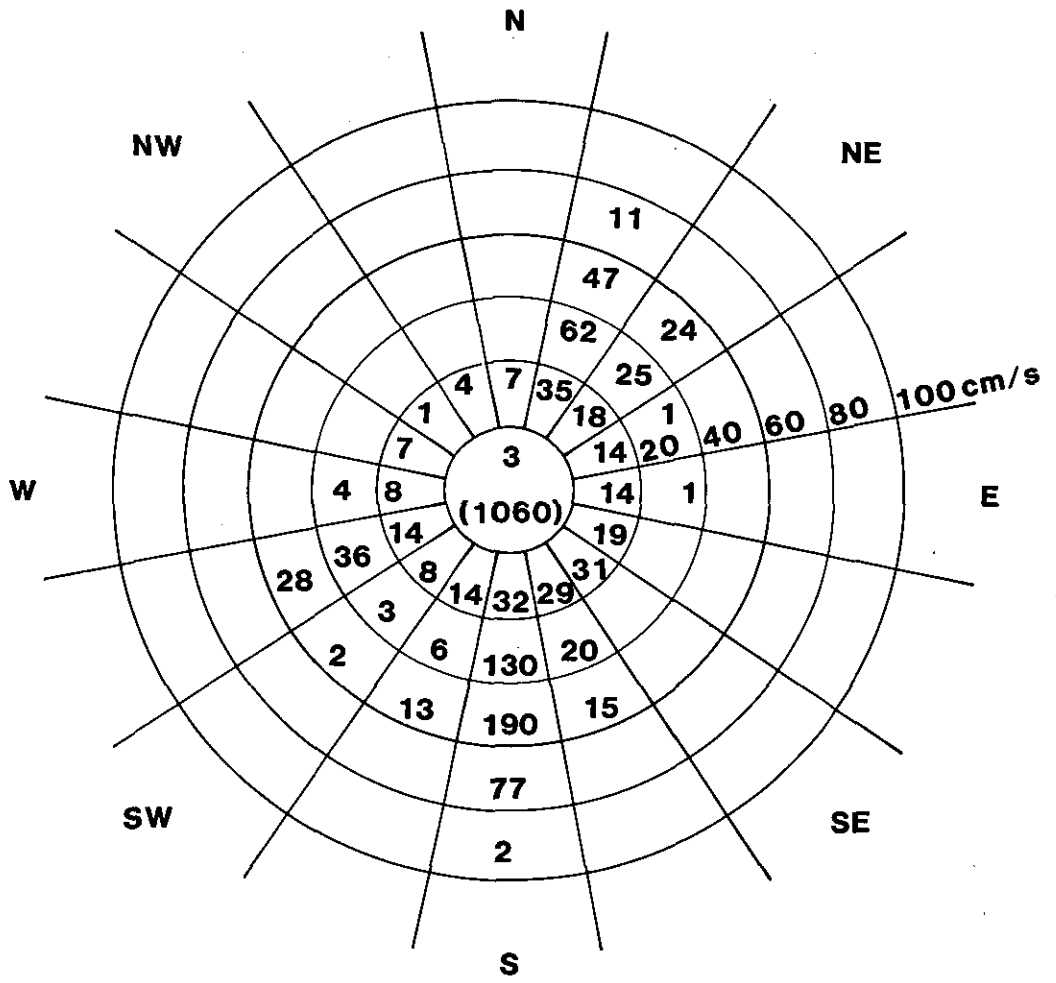
1731/12 : Unfiltered hourly temperatures (above) and Current vectors (below)



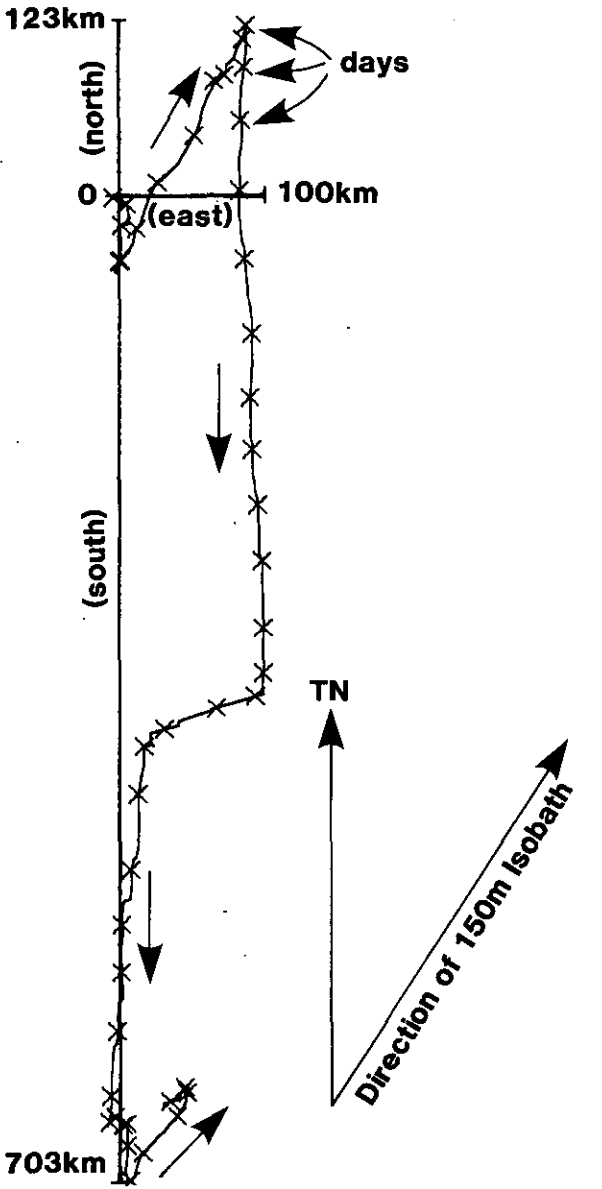


1731/12 : Low-passed temperatures (above) **and Current vectors (below)**





1731/12 : Current rose
(Instrument/Water depths 55/150m)



1731/12 : Progressive vector diagram

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