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Variability of Currents off Cape Hawke, New South Wales 1978–1979

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VARIABILITY OF CURRENTS
OFF CAPE HAWKE, NEW SOUTH WALES 1978-1979*

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Abstract

Recent investigations have suggested that the East Australian Current tends to separate from the coast at preferred headlands, one of which is Sugarloaf Point. Studies of the temporal variability of the currents and the hydrological structure are being made across the shelf and to 110 km offshore in this area.

The results of five cruises to date indicate that, on a monthly-to-seasonal time scale, there are large variations in the flow beyond the shelf-break. Strong southerly currents of 1 or 2 m/s are associated either with the East Australian Current (identifiable from satellite photographs as a warm ribbon of water extending down most of the coast) or with large anticyclonic eddies, while weaker northerly countercurrents are probably due to cyclonic eddies.

Currents on the continental shelf have been measured using self-recording current meters for two periods: 12 days in July-August 1978, and 45 days in March-May 1979. The flow oscillates northerly/southerly with a period of a few days. Maximum speeds of more than 1 m/s at mid-depths near the shelf-break are related to the East Australian Current overlapping onto the shelf and then meandering offshore. Northerly countercurrents of over 0.5 m/s occur sporadically, and do not appear at this stage to be directly wind-driven.

During a cruise in winter, the water on the shelf was isothermal from surface to bottom, but at other times the shelf water was strongly stratified with a well-defined bottom mixed layer.

INTRODUCTION

At the beginning of this century, the East Australian Current (EAC) was depicted in current charts and atlases as a broad southerly stream sweeping down the east coast of Australia from the Tropic of Capricorn to the southern Tasman Sea, where it merged with the West Wind Drift off Bass Strait (e.g. Halligan 1906). This general pattern was not greatly changed when Wyrtki (1960) analysed ship drift data to show up the seasonal changes in the Tasman and Coral Sea circulations; his charts reveal smaller-scale details of the flow, as well as zones of convergence and divergence. With the advent of classical hydrology surveys undertaken by the CSIRO using the R.V. "Derwent Hunter" in the 1950's and various naval frigates in the 1960's, the high variability in the current system became apparent (Hamon 1961, 1965; Boland and Hamon 1970). It was shown that the current field is

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frequently dominated by anticyclonic eddies, and "even the existence of an 'East Australian Current', in the sense of a flow from the Coral Sea to say 35°S that is continuous along the continental margin at any given time, seems to be doubtful" (Boland and Hamon 1970). The recent use of drifting satellite-tracked buoys has clearly shown the complex nature of the flow in the eddy system, but demonstrated at the same time how stable the eddies can be over a period of months (Cresswell 1978). Recently, Boland and Church (submitted) have analysed data on Tasman Sea circulation from R.V. "Sprightly" for 1978, and Nilsson and Cresswell (in press) have described in detail the evolution and structure of the eddies.

Currents on the New South Wales shelf have been studied in far less detail than those in deeper water. An analysis of coastal ship-drift data between Cape Moreton (27°30'S) and Sugarloaf (32°25'S) showed a reversing current system, with a period and length-scale of the order of 100 days and 100 km respectively (Hamon *et al.* 1975). Current patterns tend to move southwards at a speed of about 9 km/day (10 cm/s); mid-shelf currents are weaker than those at the shelf-break, and current variability at mid-shelf lags the shelf-edge fluctuations by 7 to 10 days. North of Coffs Harbour (30°20'S), summer currents are appreciably stronger than those in winter, but south of Coffs Harbour there is far less difference between the two seasons. Garrett (1979) interpreted these results in terms of topographic Rossby waves propagating shorewards from the open ocean. The behaviour of the East Australian Current on the shelf has been examined by Godfrey *et al.* (1980), who found that the Current frequently separates from the coast at Sugarloaf Point; there is a marked difference in the current systems north and south of this separation point, with a tendency for northerly currents on the shelf past Port Stephens (32°40'S) towards Sugarloaf Point.

It is clear that the Sugarloaf area is one of great oceanographic interest, so a standard line of stations has been worked at irregular intervals since July 1978 to study scales of variability in the flow, and especially the behaviour of the East Australian Current. Details of the Cape Hawke Section, which is only 17 n miles north of Sugarloaf, are given in the next section.

This paper consists of four sections:
(a) brief description of the bathymetry of the Cape Hawke area, and the stations on the Cape Hawke Section;
(b) outline of large-scale current systems off the shelf;
(c) variability in the surface currents and thermal structure off Cape Hawke;
(d) variability in subsurface currents on the Cape Hawke shelf.

The presentation is descriptive, and the dynamics of the system are not considered in any detail.

CAPE HAWKE SHELF BATHYMETRY, AND THE CAPE HAWKE SECTION

The shelf-break in the vicinity of Cape Hawke is well defined and relatively straight for about 150 km in the north, and curves gently south-westward south of Sugarloaf. The break in slope can be taken as the 140 m isobath, and lies 020°/200° off Cape Hawke (Figs 1 and 2). The mid-shelf region is less regular, and the 100 m isobath has some undulations but these are of little topographic importance because of the gentle nature of the mid-shelf plain; the 100 m contour lies approximately 010°/190° off Cape Hawke. Closer inshore, the bathymetry reflects the indented shape of the coastline. Along the Cape Hawke Section, the mean slope of the inner shelf region (say to 80 m depth) is about 9 m/km; the mid-shelf plain (say 80 m to 140 m) is 2.3 m/km, and the upper slope (say 200 to 300 m) is 40 m/km.

Table 1. Standard stations on Cape Hawke section

Station Reference	Approximate Depth (m)	Distance off Cape Hawke (n miles)	Latitude S	Longitude E
A	80	5	32°13.2'	152°39.7'
B	100	10	"	152°45.5'
C	115	15	"	152°51.4'
D	150	20	"	152°57.3'
E	~1000?	25	"	153°03.2'
F		30	"	153°09.0'
G		40	"	153°20.6'
H		50	"	153°32.5'
I		60	"	153°44.2'

The stations are at standard positions (denoted A to I) on a line extending due east of Cape Hawke (32°13'S) out to 60 n miles offshore (Table 1). Bathysonde or XBT profiles are usually obtained at each station, except for F and I where standard Nansen casts to 1500 m (nominal) are made. The sections that have been worked are listed in Table 2.

The stations are occupied as close to the standard reference positions as possible; near the coast, radar is adequate for fairly accurate positioning (and precision electronic fixes have been available on occasion), but further offshore resort has to be made to dead-reckoned position estimates between irregular satellite fixes. Surface currents are routinely estimated from ship-drifts between fixes, and geomagnetic electrokinetograph current measurements have been made during some cruises. (Neither of these methods gives completely reliable estimates of the current, but when they agree the indicated current can be accepted with some confidence).

Table 2. Sections worked off Cape Hawke

Cruise	Dates	Number of Sections
SP10/78	21,22,23,24,26,29 July; 1 Aug. 1978	7
SP 4/79	31 March; 1,2,3,5,6,7,8,9,(10) April 1979	9½
SP 6/79	11,14,16,20 May 1979	4
SP 8/79	17 July 1979	1
SP12/79	14 December 1979	1
	Total	22½

LARGE-SCALE CURRENT SYSTEMS OFF THE SHELF

Satellite photographs have shown the complex patterns of major circulation systems in the Tasman Sea, and have confirmed that Cape Hawke is one of the separation areas of the East Australian Current from the coast. The large anticyclonic (warm core) eddies also feature prominently in latitudes from Cape Hawke southwards. A number of cruises by R.V. "Sprightly" in 1978 and 1979 (following earlier surveys by other vessels) have shown the structure of the East Australian Current and the eddies.

Figures 3, 4 and 5 illustrate three typical situations encountered by "Sprightly" in the Cape Hawke area. These are maps of the dynamic topography (elevation of the sea surface) relative to 1300 m, as determined from XBTs using the method described by Pearce and Hamon (1979) in conjunction with a few standard Nansen stations.

During cruise SP5/78 in April 1978 (Fig. 3), the East Australian Current was flowing strongly down the outer shelf, leaving the coast in the vicinity of Cape Hawke/Sugarloaf as postulated by Godfrey *et al.* (1980). This stream was also associated with a topographic high, i.e. an anticyclonic eddy, centred due east of Cape Hawke. It is interesting that a filament of current in Fig. 3 still followed the shelf break southwestward past Port Stephens.

An example of an anticyclonic eddy probably isolated to a large extent from water further north is illustrated in Fig. 4 (although a reinterpretation of the dynamic heights can be contoured to link some of the water with flow from the north). In comparison with Fig. 3, note that in Fig. 4 the flow across the Cape Hawke Section was south-westerly rather than southerly or south-easterly.

Figure 5 shows an apparently rare situation when there was no strong southerly stream past Cape Hawke, due to separation from the coast probably at Smoky Cape and an eastwards swing north of Cape Hawke. South of this stream, the currents were variable but generally to the northeast (discussed again in the next section). This is in accord with Godfrey *et al.* (1980) for the flow system south of the separation point. As an indication of the rapidity with which the current system can change, cruise SP9/78 a month earlier found a large elongated anticyclonic eddy with steady southerly flow down the shelf from Coffs Harbour at 30°S to 35°S; but by SP10/78 (Fig. 5) the northern section had apparently short-circuited north of Cape Hawke leaving a confused pattern in its wake.

VARIABILITY ON THE CAPE HAWKE SECTION

As listed in Table 2, the Cape Hawke Section was occupied 22 times in 1978 and 1979. Some of the results are presented in Figs 6 to 20 to illustrate features of the flow and thermal structure on two time scales.

(a) Long-term (order of weeks to months)

On this scale there is no obvious relationship between successive pictures although Hamon *et al.* (1975) found the currents along the northern NSW shelf to be correlated for 2 to 6 months. It may be that the variability at Cape Hawke is greater than that further north due to some instability of the currents associated with separation of the EAC at Sugarloaf or Smoky Cape.

In July 1978 (Fig. 6) the flow offshore of the shelf was northerly due to a cyclonic eddy possibly induced by the strong southeasterly stream off Smoky Cape (Fig. 5). On the shelf the water was isothermal and southerly, with a strong front separating the shelf water from that offshore. Note the isotherms sloping upwards away from the coast with the northerly current over the slope.

A fine example of a section across the East Australian Current can be seen in Fig. 7. A very strong surface front of about 4°C was associated with the strong cyclonic shear zone marking the edge of the Current. The water on the shelf was again homogeneous (at least in temperature), and the offshore flow on the shelf is unusual and probably related to the convergence at the front.

In Fig. 8, the EAC is shown close inshore on the continental shelf; the warm surface core was marked by surface fronts both inshore and offshore, and a 4°C thermocline separated the warm core from cool bottom water.

Northeasterly flow from the coast out to at least 40 n miles offshore is shown in Fig. 9, which is otherwise notable for the strong thermocline across the whole section typically associated with summer heating. It can also be seen that surface fronts are not necessarily indicative of changes in the currents.

(b) Short-term (daily variability)

During cruise SP4/79, the Cape Hawke Section was repeated on a daily basis for 11 days (with one gap). See the daily sections in Figs 10 to 19. The currents and surface temperatures are summarized in the space-time plot of Fig. 20. The thermocline between 50 and 100 m was indicative of summer/autumn conditions, and the warm core with strong southerly currents over the outer shelf showed the presence of the East Australian Current.

This general situation prevailed for the rest of the cruise, but dramatic changes occurred on the inner shelf. The relatively small surface temperature front of 1°C at the start of the cruise rapidly developed into a major feature with a temperature differential of about 6°C in 4 km by the sixth day. This was a two-fold process: a pronounced cooling of the inshore water due to a strong upwelling event, and an increase in the temperature of the main Current core. The upwelling is clearly seen in the individual temperature sections, with the bottom temperature on the shelf falling by 4°C as cool water pushed shorewards along the bottom; this was almost certainly a result of both conventional wind-driven upwelling (the wind was generally from the north for the first few days of the cruise) and current-induced upwelling caused by onshore veering of the near-bottom current in the bottom Ekman layer. The dynamics of such a situation are somewhat complex due to the direct wind effect and the inter-relation between the accelerating alongshore current and the increasing cross-shelf pressure gradient. The upwelling reached its peak by the sixth day of the cruise; thereafter the active phase relaxed as the winds changed to the south, but a remnant of the 16°C upwelled water remained in a lens along the inner shelf to the end of the cruise. It is noteworthy that the upwelled water reached the surface between 5 and 10 n miles offshore, so that there was a ribbon of cool water stretching along the coast (also observed on short sections across the shelf at Diamond Head and Sugarloaf Point on the fourth day) and warmer water closer inshore. (It is unfortunate that nutrients were not sampled on the shelf during the upwelling — in hindsight this was a sad omission).

Table 3. Aanderaa moorings off Cape Hawke

Instrument Number	Above Seabed (m)	Water Depth (m)	Distance Offshore (n miles)	Period of Data	Comments
1732/03	30	60	3.1	21/7- 1/8/78	
1731/02*	80	120	17.5	21/7- 2/8/78	
572/11*	40	120	18.0	21/7- 2/8/78	Sank to seabed
1247/x	8	50	2.9	30/3- x	Not recovered
1731/09	22	105	10.6	30/3-16/5/79	
1733/09	5	105	10.6	30/3-16/5/79	
1732/04	60	200	21.8	30/3-15/5/79	
572/13	5	200	21.8	30/3-15/5/79	

*These two instruments were on separate moorings

SUBSURFACE CURRENT MOORINGS

Two experiments have been undertaken using Aanderaa current meters moored across the shelf (see Table 3, and Fig. 2 for the mooring positions).

The first deployment was for only 12 days during cruise SP10/78 (the data in Fig. 21 only cover 10 days because the low pass "tide killer" filter used to eliminate diurnal frequencies has lost a day at each end). Unfortunately the deeper instrument on the outer site sank to the seabed after only a day due to a leak in the subsurface float, but the temperature record is still valid for the water on the seabed.

The temperature section for SP10/78 (Fig. 6) confirms that the shelf water was virtually isothermal at the start of the cruise. Current meter data in Fig. 21 indicate that the currents were southerly at both sites at the beginning of the period. Cooler water then intruded onto the outer shelf along the sea bottom within 3 days (Fig. 21d), and 5 days later had risen 80 m to the level of the upper instrument at that site (Fig. 21c); this was accompanied by a reversal of the shelf-edge current from southerly to northerly, although the return to southerly flow a day later did not result in an influx of warmer water again. (This discussion is in 2-dimensional terms because of the restricted coverage of the data, whereas in truth alongshore effects are almost certainly important). The inner shelf was isolated from this event (Fig. 21b) as neither the strong countercurrent on 29/30 July nor the cooling were experienced at the 60 m mooring.

The wind data (Fig. 21a) are from Williamtown (32°50'S), and reflect the generally westerly winds that prevail during winter in that area. It is likely that the winds on the Cape Hawke shelf (ignoring seabreeze effects) were similar, in which case there is little evidence of any correlation between the wind and the currents. The effects of an offshore wind on homogeneous coastal water may be two-fold: in shallow water near the coast, the direct wind stress will drive the surface water offshore and an upwelling shorewards along the bottom; and in deeper water a northerly drift will be superimposed on this onshore-offshore tendency. The response time of the inshore water to a westerly wind event should be of the order of a day or two, so it is not clear from Fig. 21 whether the water movements on the inner shelf were wind-driven or not. On the outer shelf, the northerly event was presumably linked with offshore processes rather than with local winds.

The longer records obtained from the moorings in April-June 1979 clearly show the reversing nature of the flow along both the mid-shelf and outer shelf regions (unfortunately instrument 1247 nearer the coast was not recovered). These moorings were laid at the start of cruise SP4/79 (Figs 10 to 20) so the first 12 days of data in Fig. 22 can be viewed in conjunction with the results of SP4/79. Over this period, in fact, the East Australian Current on the outer shelf is clearly shown in the rapid southerly flow at the outer mooring (no. 1732 and 572) and the upper meter at the mid-shelf mooring (no. 1731). (The strongly onshore currents at the lower mid-shelf meter (Fig. 22b) may have been partly due to Ekman veering but more likely were caused by local topographic effects). The cooling of the water on the shelf during the upwelling is evident in the temperature data over the first few days. From about 15 April, the EAC either slackened or (more likely) meandered away from the coast, resulting in a marked drop in the current velocity at all four current meters. Thereafter the currents at both sites varied from northerly to southerly with an irregular period of a few days. The visual coherence in the records for the four meters is noteworthy.

CONCLUSIONS

Observations by R.V. "Sprightly" during 1978 and 1979 have shown that major changes in the circulation beyond the shelf-break off Cape Hawke can occur in a period of weeks, if not days. On the shelf and upper slope, the currents can fluctuate from almost 2 m/s southerly to over 0.5 m/s northerly over a few days, probably associated with meandering of the East Australian Current.

A two-week detailed study of the thermal structure and flow off Cape Hawke encountered a strong upwelling event which can be linked with frictionally-driven bottom flow when the EAC was on the outer shelf.

Monitoring of the flow off Cape Hawke is to continue to identify the full range of scales of the variability in that area.

ACKNOWLEDGMENTS

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REFERENCES

Boland, F.M., and Church, J.A. The East Australian Current 1978. (Submitted to *Deep Sea Res.*).

Boland, F.M., and Hamon, B.V. (1970). The East Australian Current, 1965-1968. *Deep-Sea Res*. 17, 777-794.

Cresswell, G.R. (1978). CSIRO's Tasman Sea drifting buoy program, 1977. Report to mariners. CSIRO Division of Fisheries and Oceanography. Unpublished note, 3 p. + 10 charts.

Garrett, C. (1979). Topographic Rossby waves off east Australia: identification and role in shelf circulation. *J. Phys. Oceanogr.* 9, 244-253.

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.

Halligan, G.H. (1906). Sand movement on the New South Wales coast. *Proc. Linn. Soc. NSW.* 31, 619-640.

Hamon, B.V. (1961). The structure of the East Australian Current. Aust. CSIRO Div. Fish. Oceanogr. Tech. Pap. 11.

Hamon, B.V. (1965). The East Australian Current, 1960-1974. *Deep-Sea Res*. 12, 899-921.

Hamon, B.V., Godfrey, J.S., and Greig, M.A. (1975). Relation between mean sea level, current and wind stress on the east coast of Australia. *Aust. J. Mar. Freshwater Res.* 26, 389-403.

Nilsson, C.S., and Cresswell, G.R. The formation and evolution of East Australian Current eddies. *Prog. Oceanogr.* (in press).

Pearce, A.F., and Hamon, B.V. (1979). Mean temperature-salinity curves for the Tasman Sea. Preliminary Report. CSIRO Division of Fisheries and Oceanography. Unpublished report.

Wyrtki, K. (1960). The surface circulation in the Coral and Tasman Seas. Aust. CSIRO Div. Fish. Oceanogr. Tech. Pap. 8.

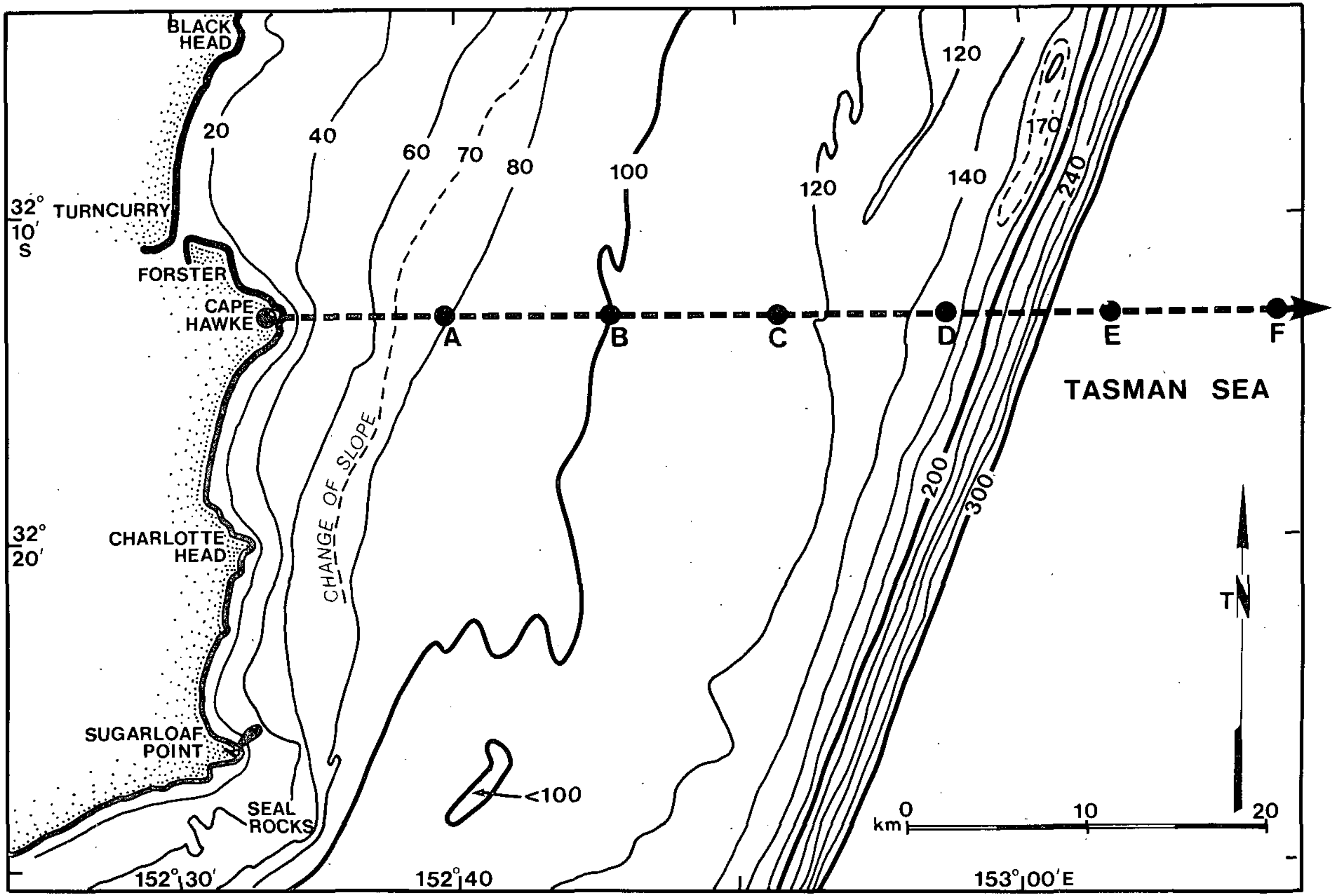

Fig. 1. Seabed topography from the coast to 300 m in the Cape Hawke/Sugarloaf Point area (National Bathymetric Map Series, 1:250 000, sheet SI 56-2 and Part 3). Depths are in metres. The "Cape Hawke Section" with the stations A to F is shown.

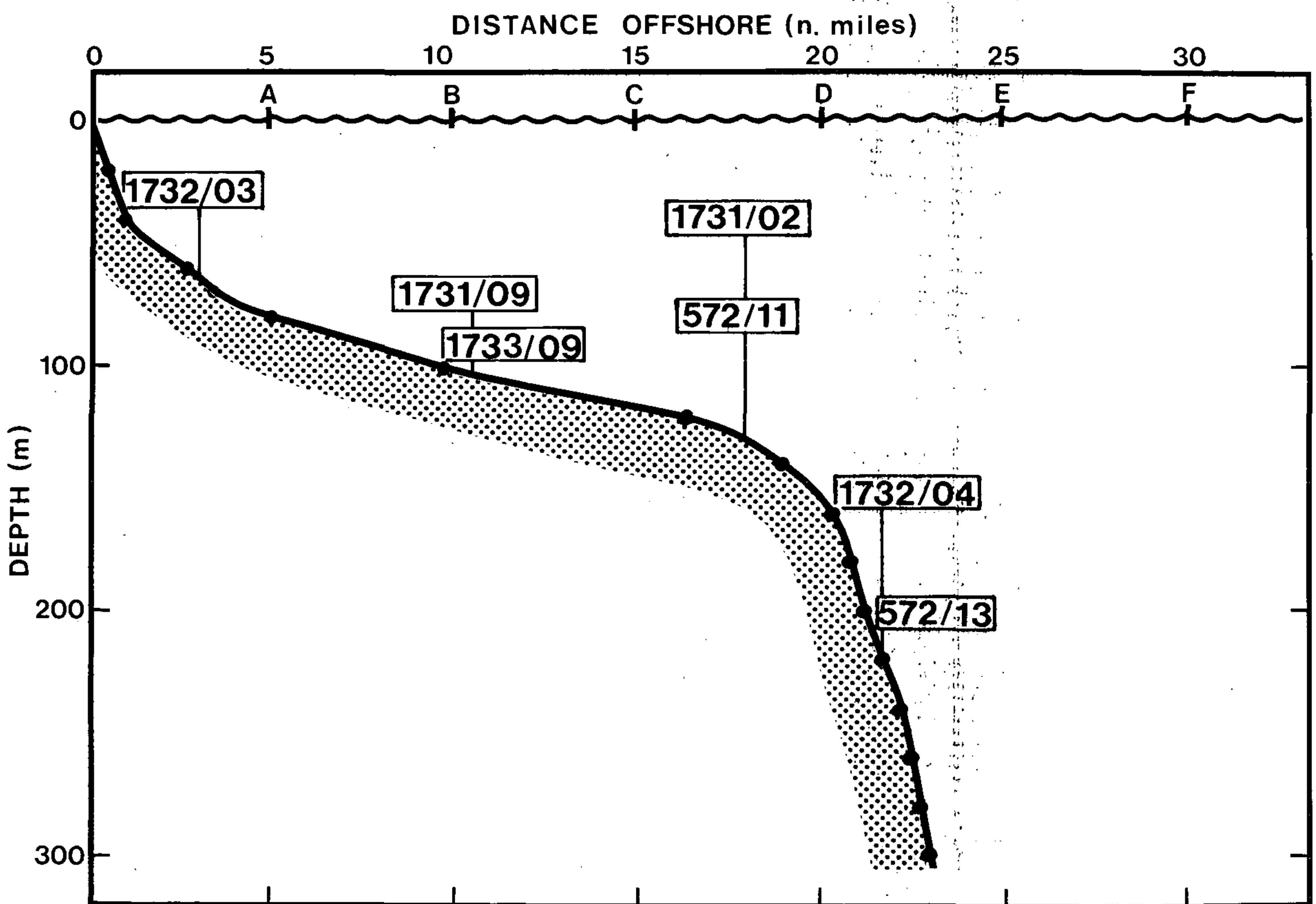

Fig. 2. Vertical bathymetric section due east of Cape Hawke. Aanderaa current meter moorings in July 1978 (nos 1732/03, 1731/02, 572/11) and April/May 1979 (1731/09, 1733/09, 1732/04, 572/13) are as shown. A to F are standard station positions. (For details see Tables 1 and 3).

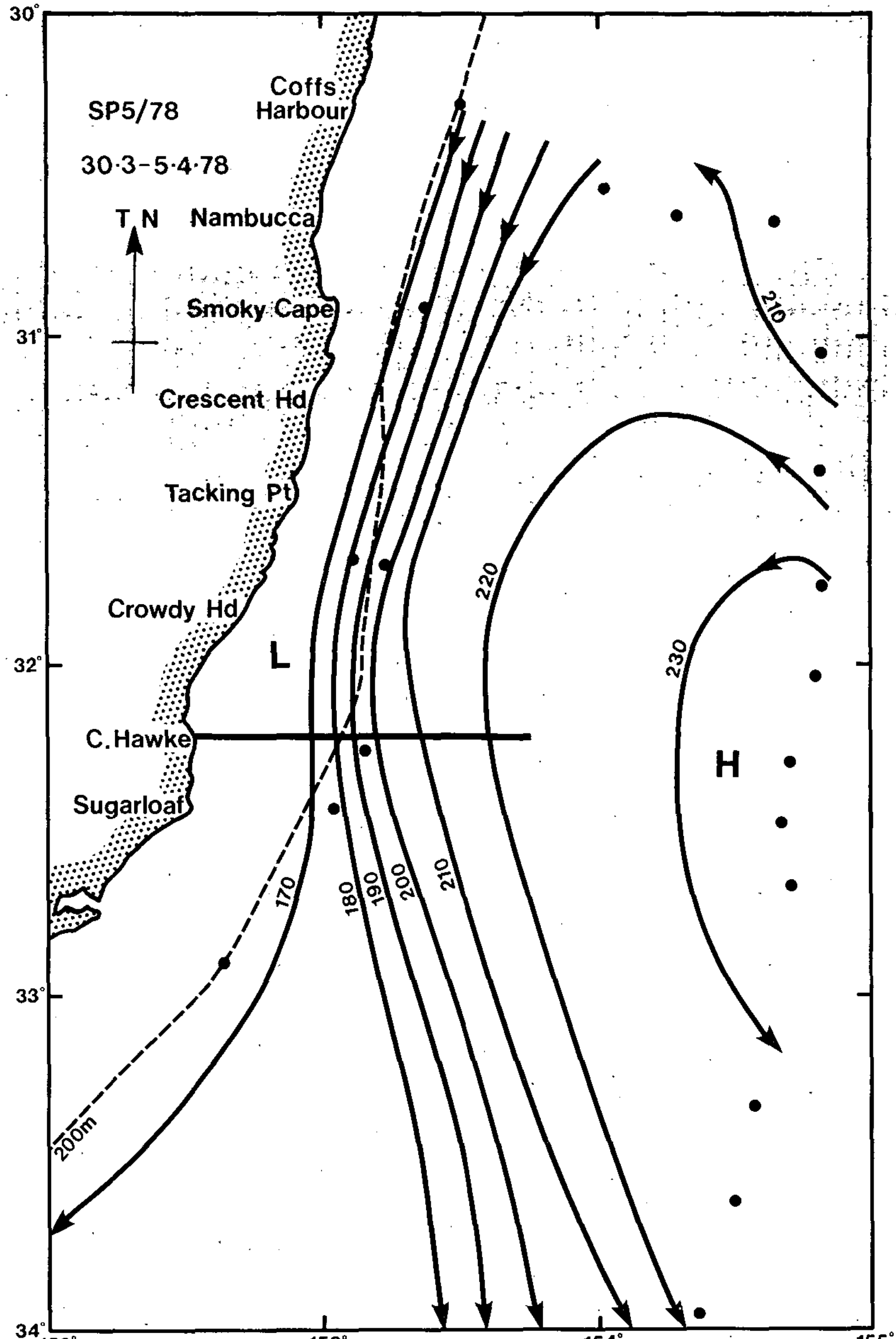

Fig. 3. Dynamic topography (cm) relative to 1300 m for cruise SP5/78, taken from Boland and Church (submitted). Dots show station positions; other stations south of 34°S were also used.

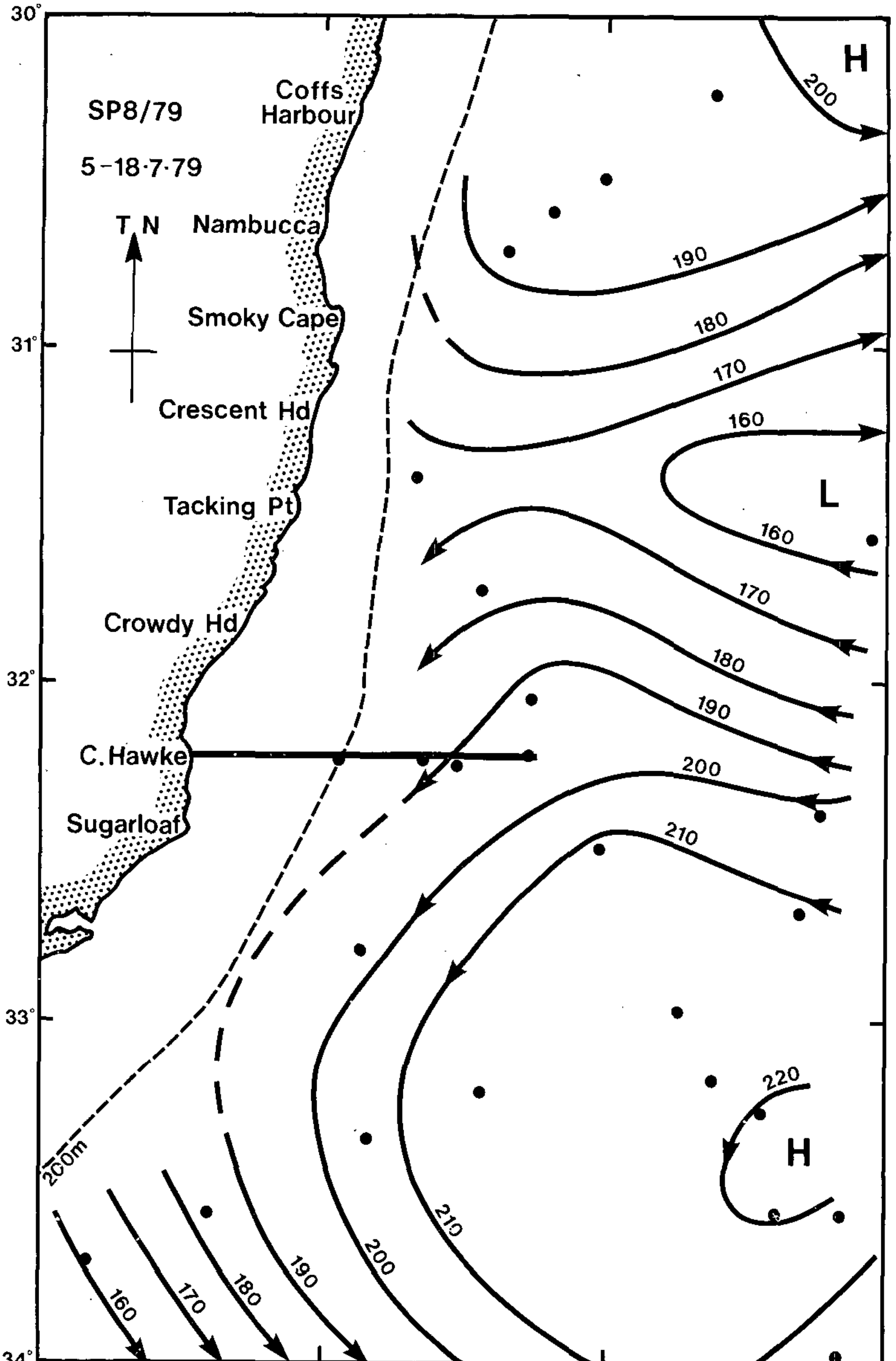

Fig. 4. Dynamic topography (cm) relative to 1300 m for cruise SP8/79, from Greig (pers. comm.). Dots show station positions, and other stations outside this chart were also used.

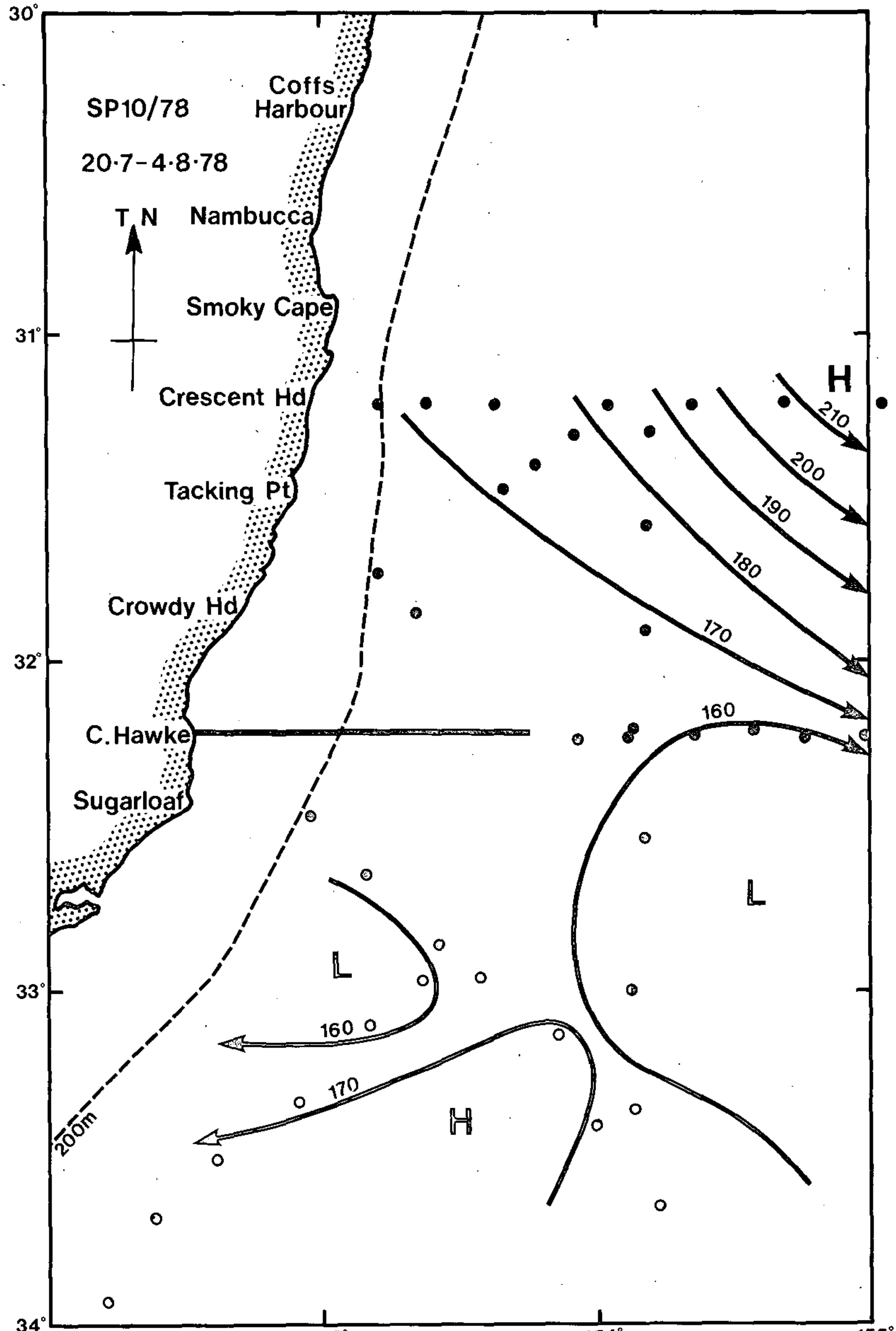

Fig. 5. Dynamic topography (cm) relative to 1300 m for cruise SP10/78. Dots show station positions.

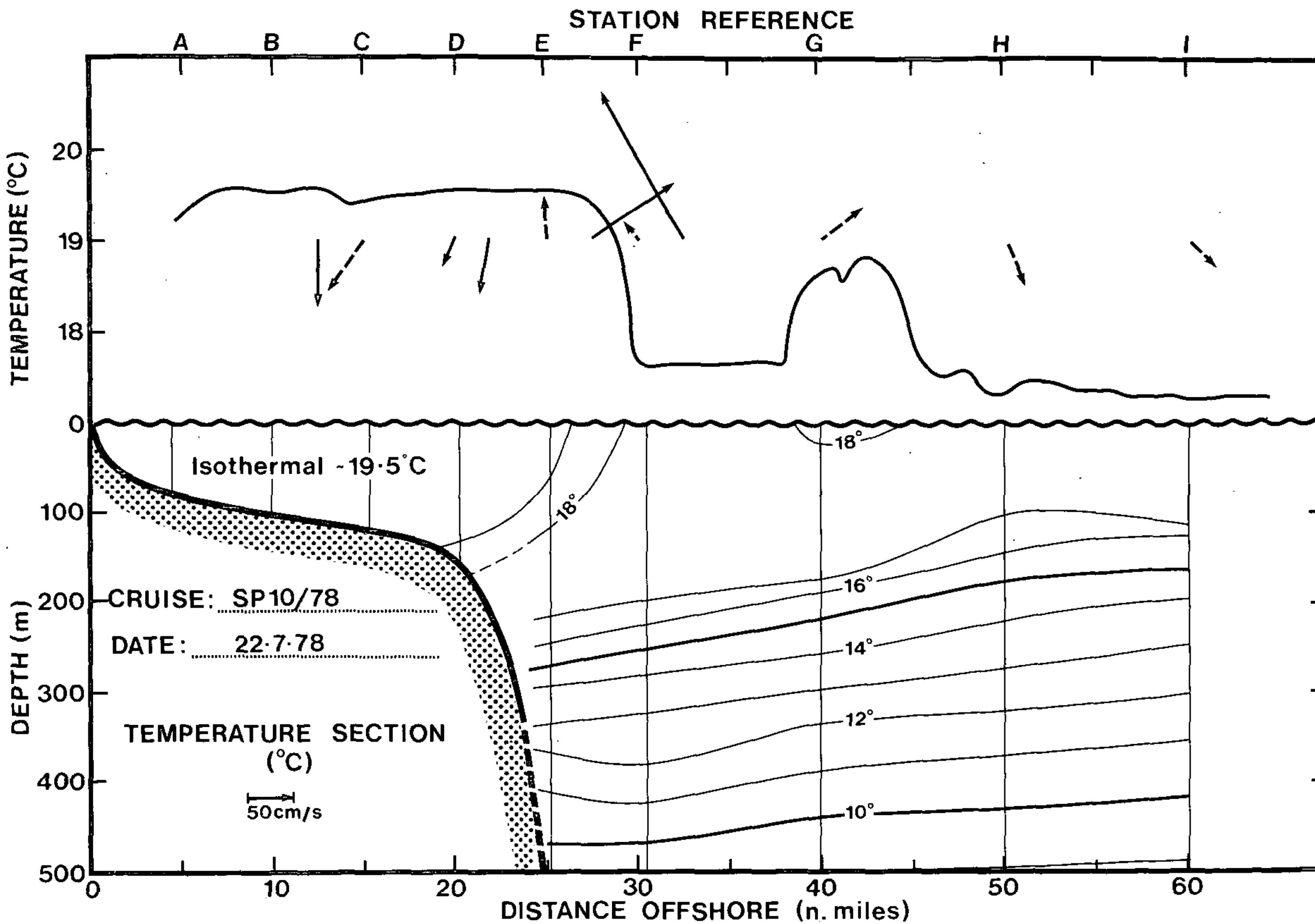

Fig. 6. Vertical temperature section from XBTs off Cape Hawke on 22/7/78, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

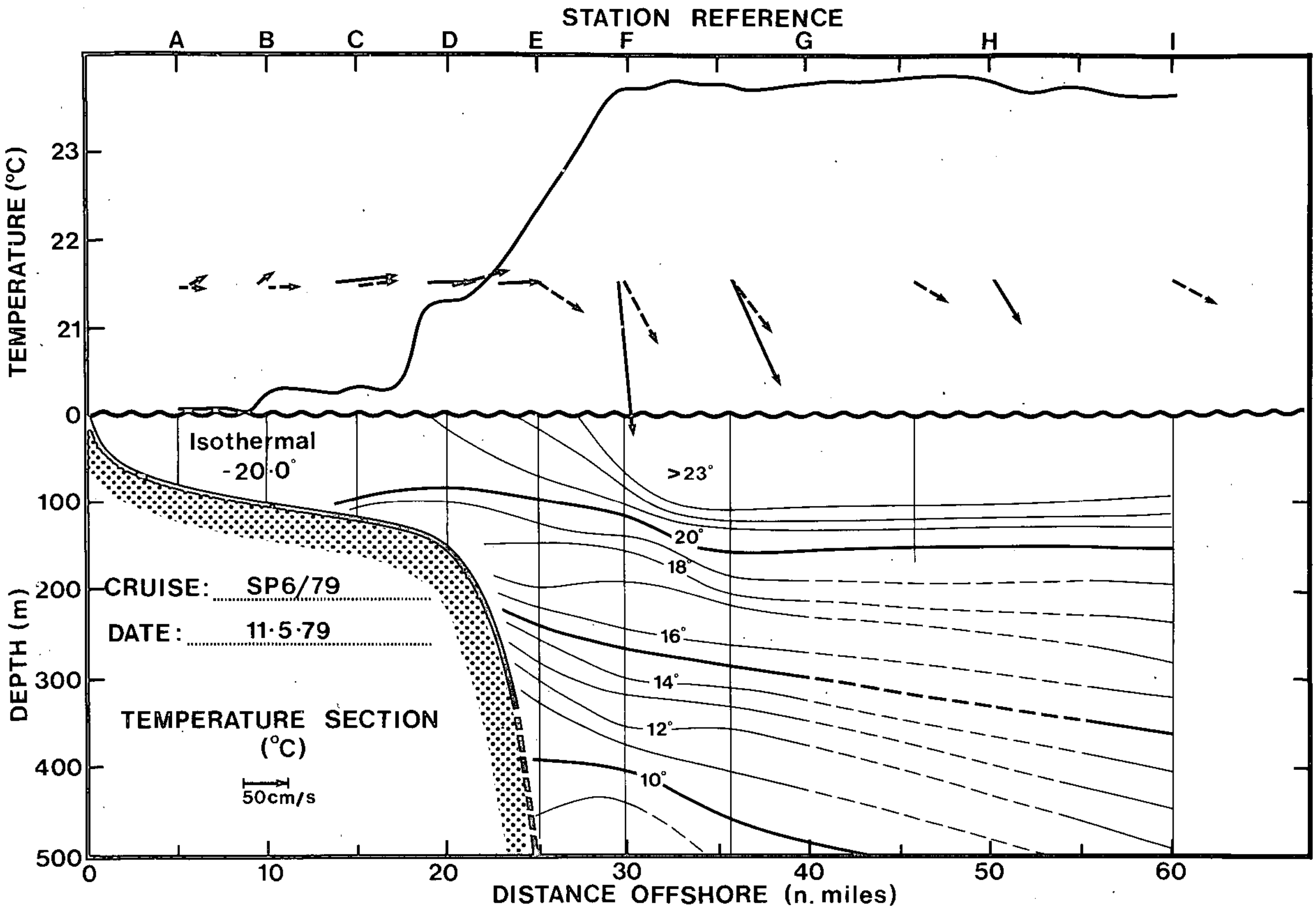

Fig. 7. Vertical temperature section from XBTs off Cape Hawke on 11/5/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown. The XBT at H failed below 200 m.

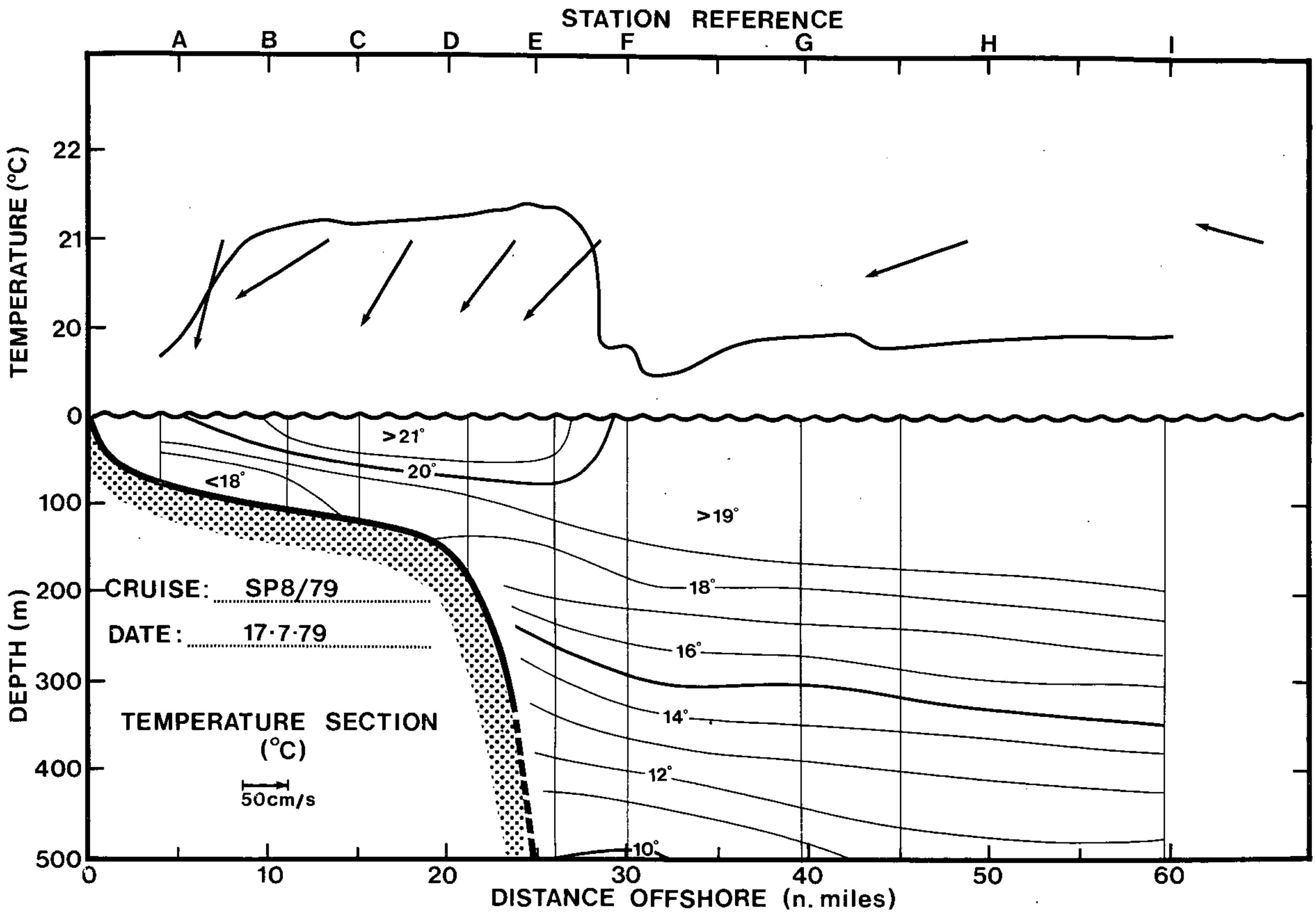

Fig. 8. Vertical temperature section from XBTs off Cape Hawke on 17/7/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale as shown.

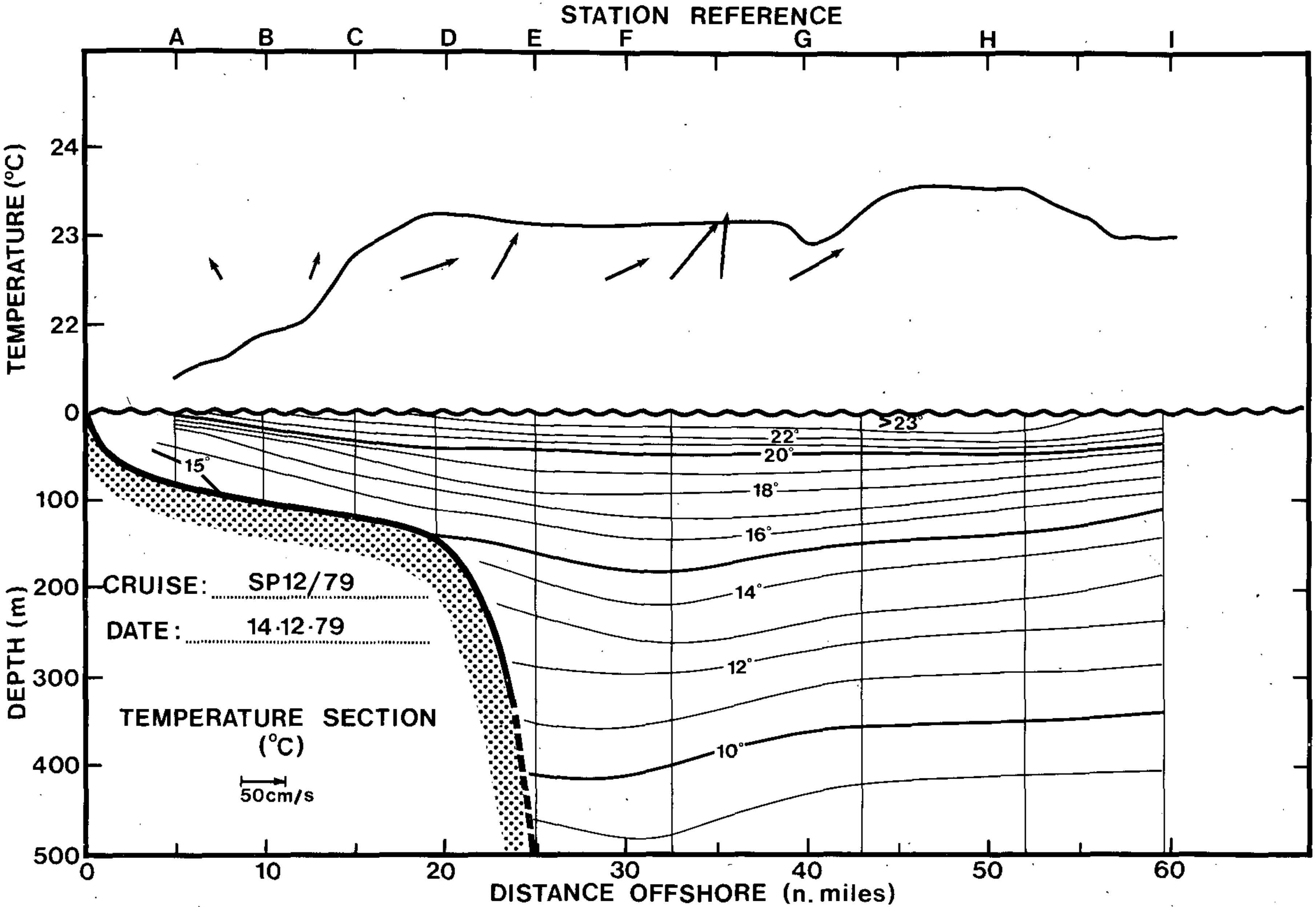

Fig. 9. Vertical temperature section from XBTs off Cape Hawke on 14/12/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

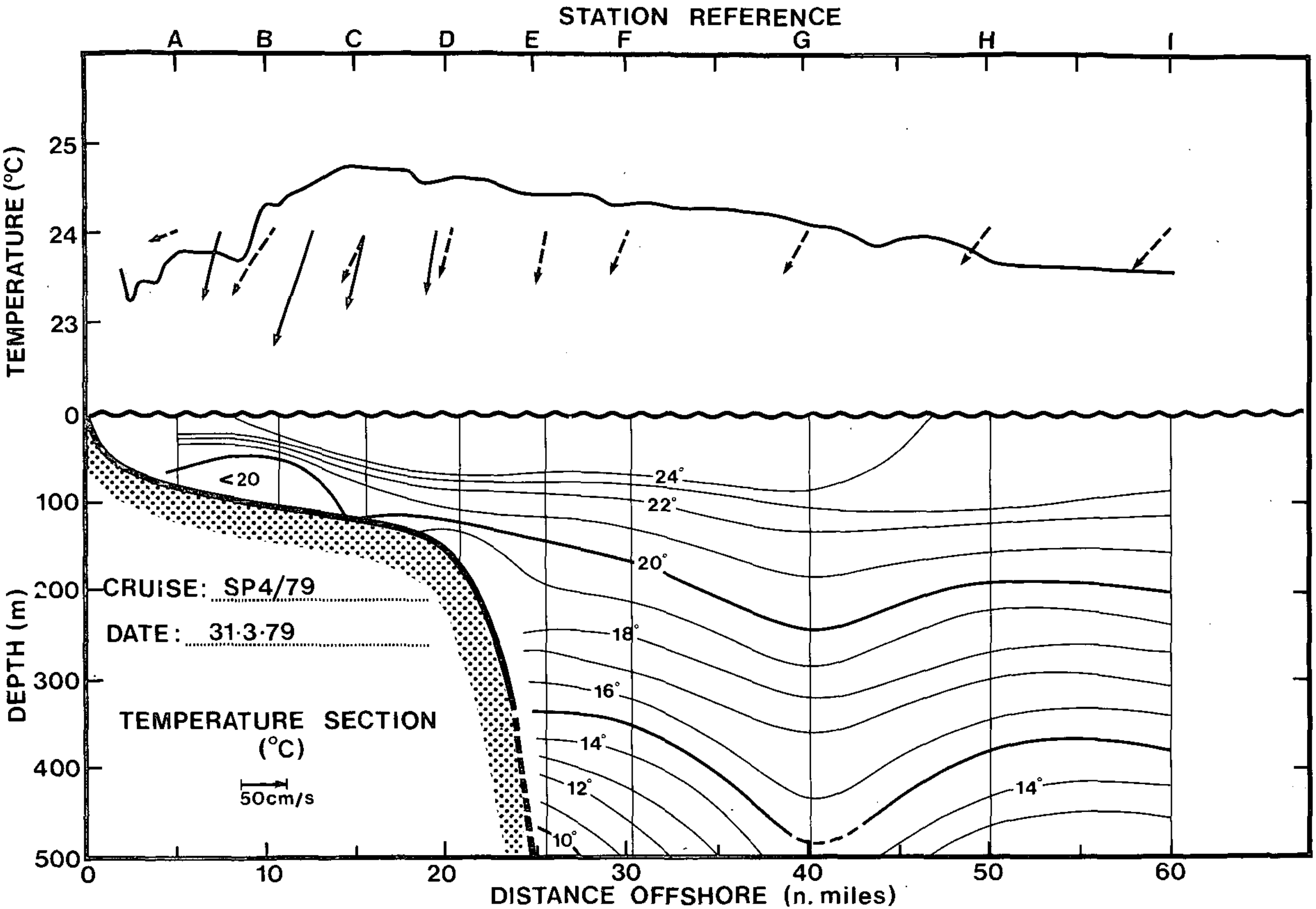

Fig. 10. Vertical temperature section from XBTs off Cape Hawke on 31/3/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

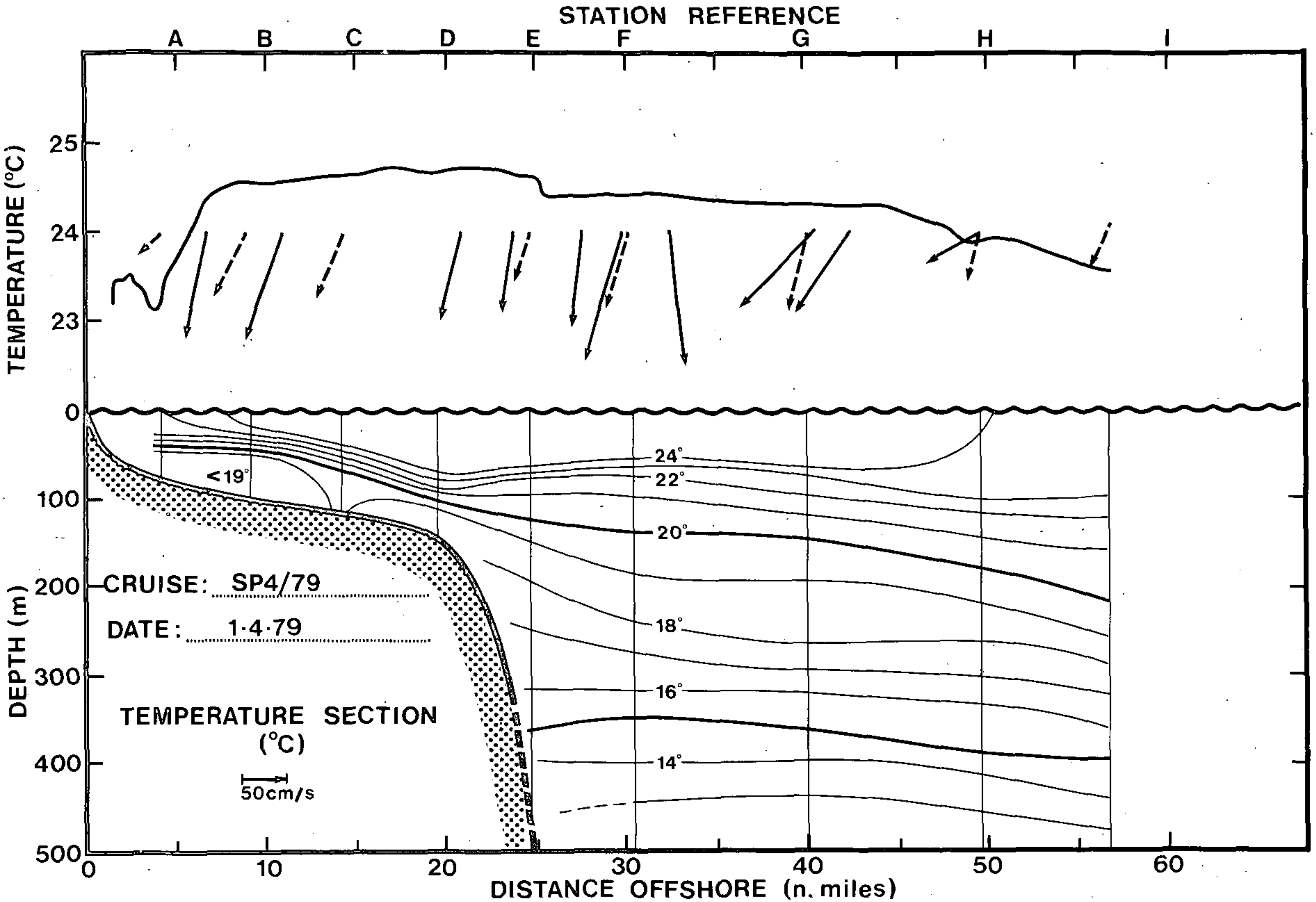

Fig. 11. Vertical temperature section from XBTs off Cape Hawke on 1/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

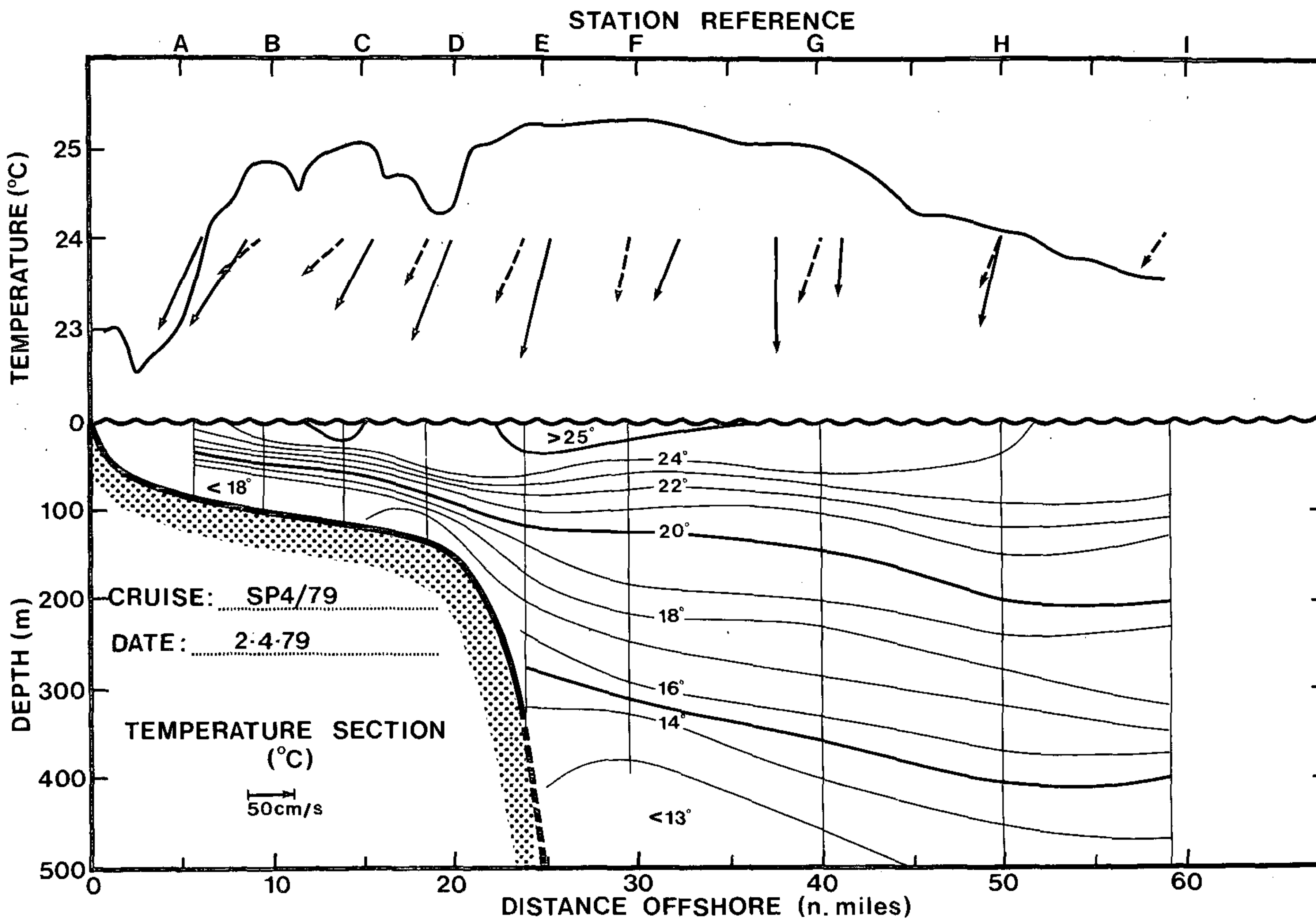

Fig. 12. Vertical temperature section from XBTs off Cape Hawke on 2/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

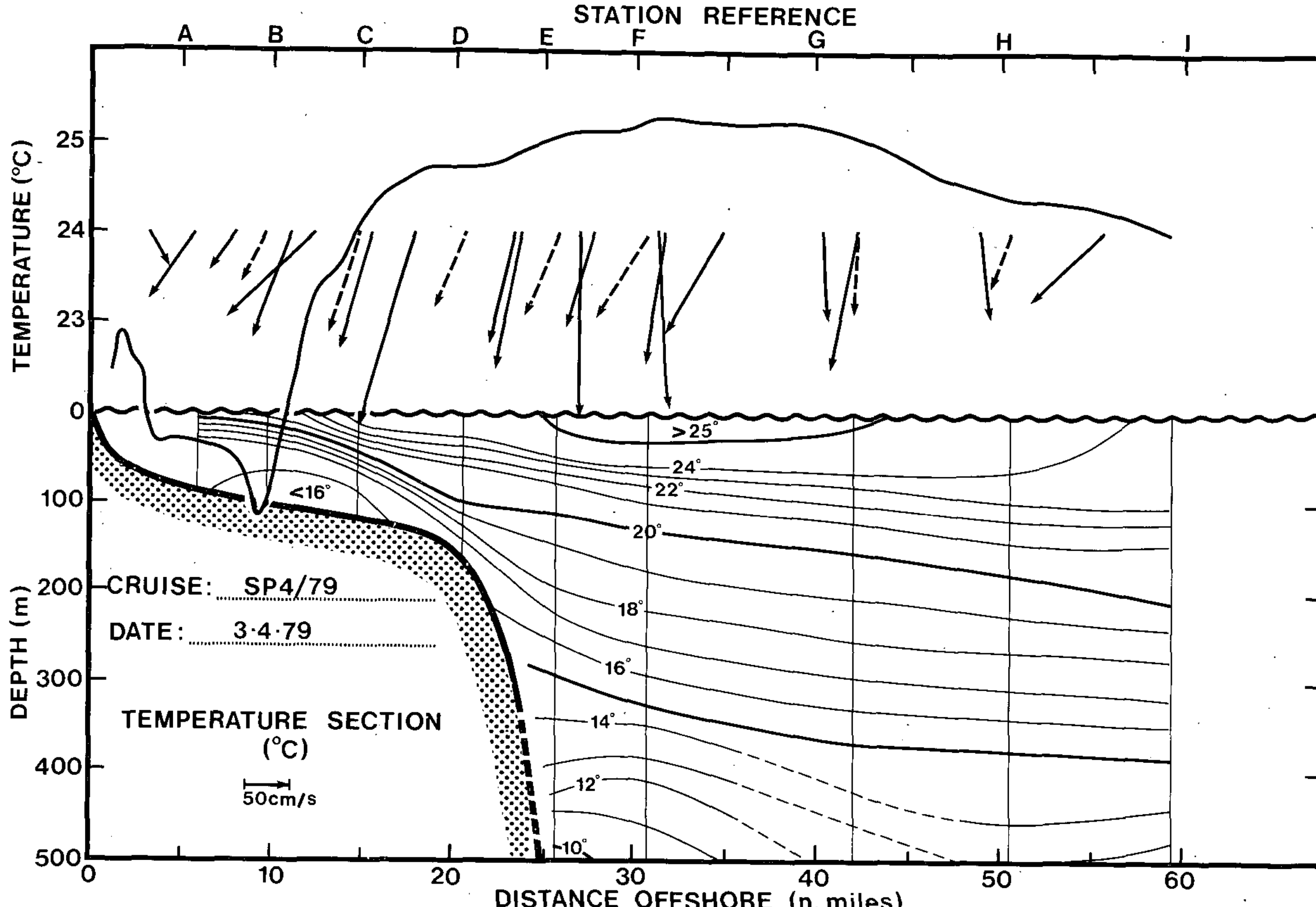

Fig. 13. Vertical temperature section from XBTs off Cape Hawke on 3/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown. The XBT at G failed below 350 m.

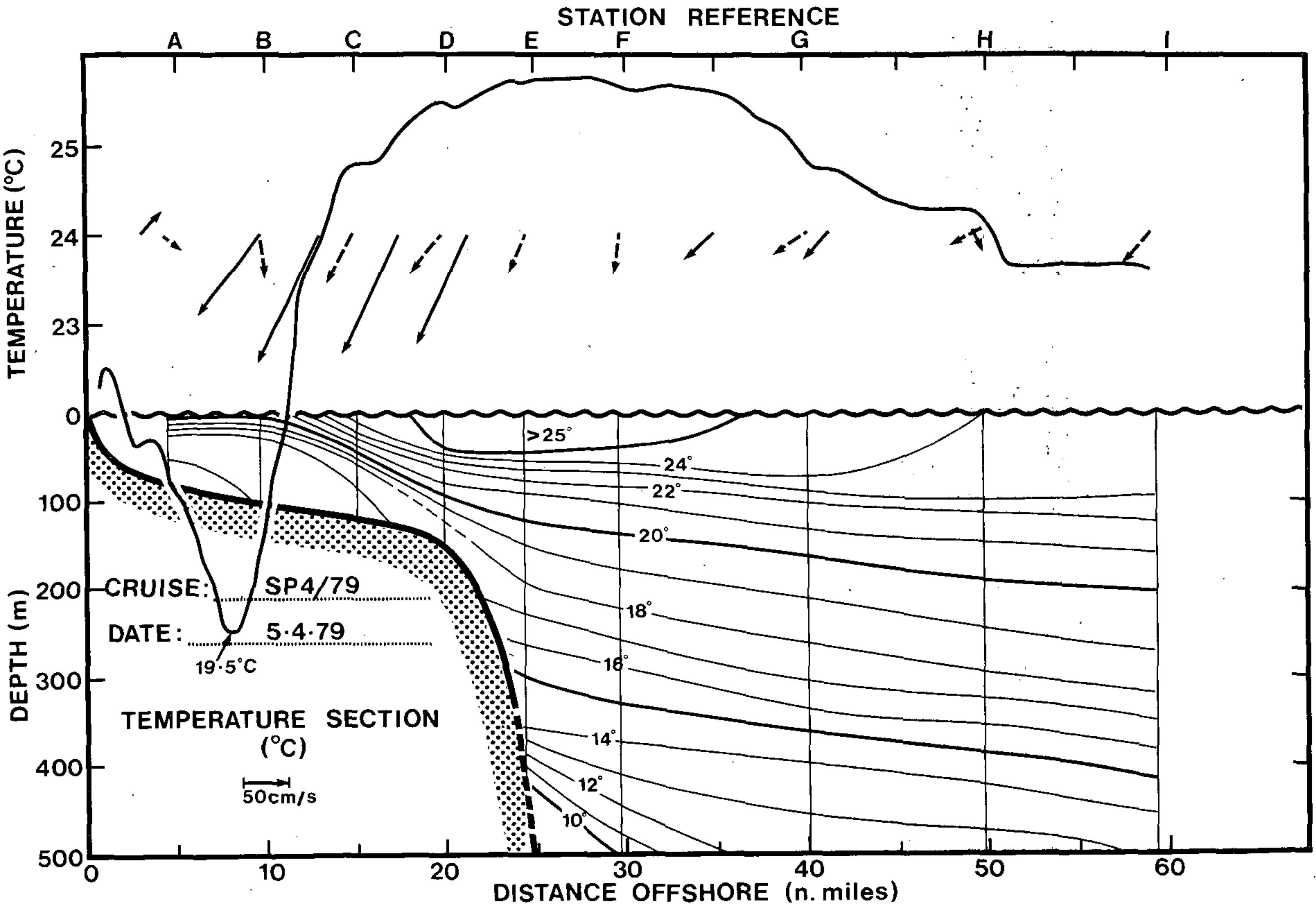

Fig. 14. Vertical temperature section from XBTs off Cape Hawke on 5/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown. (There was no section on 4/4/79).

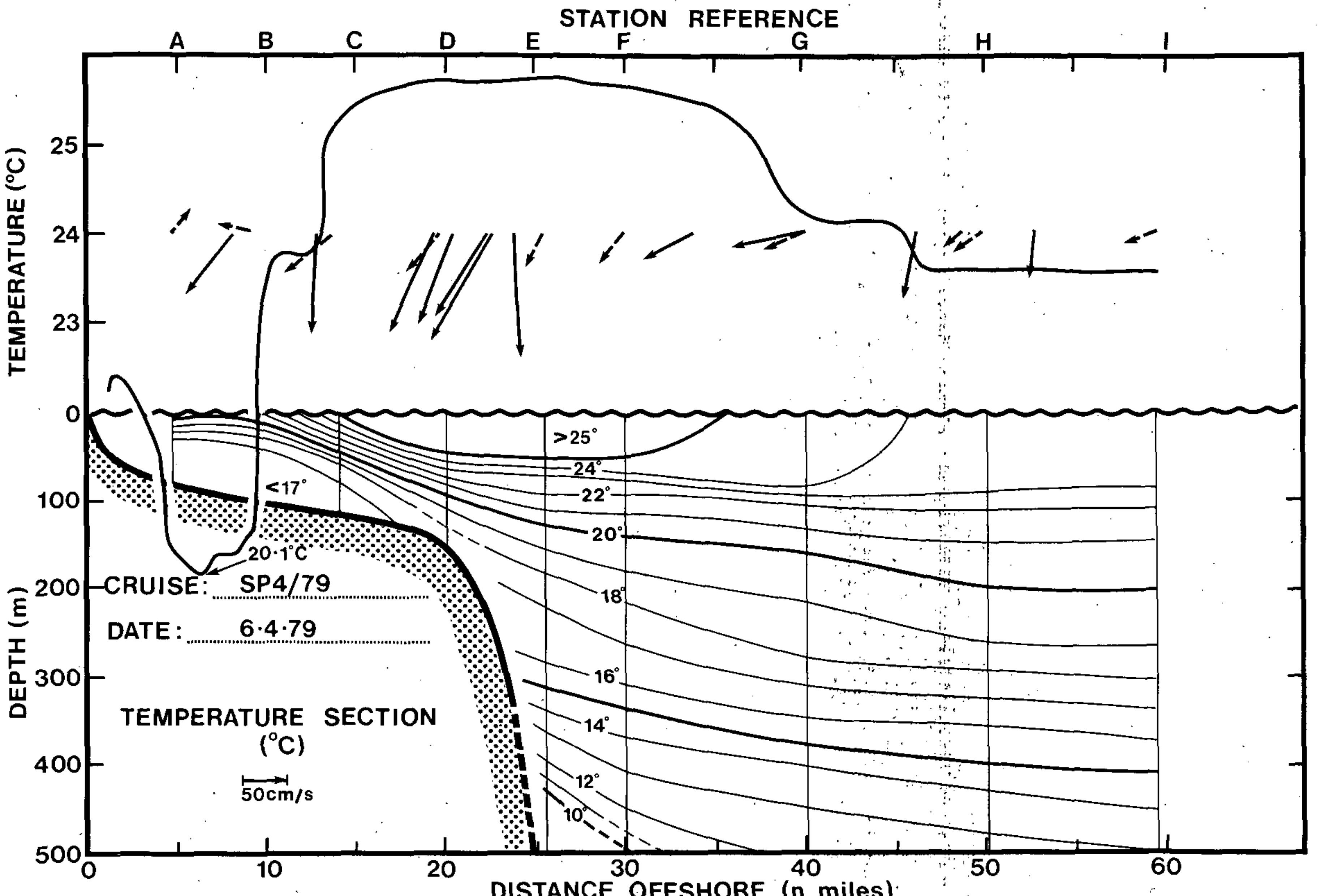

Fig. 15. Vertical temperature section from XBTs off Cape Hawke on 6/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

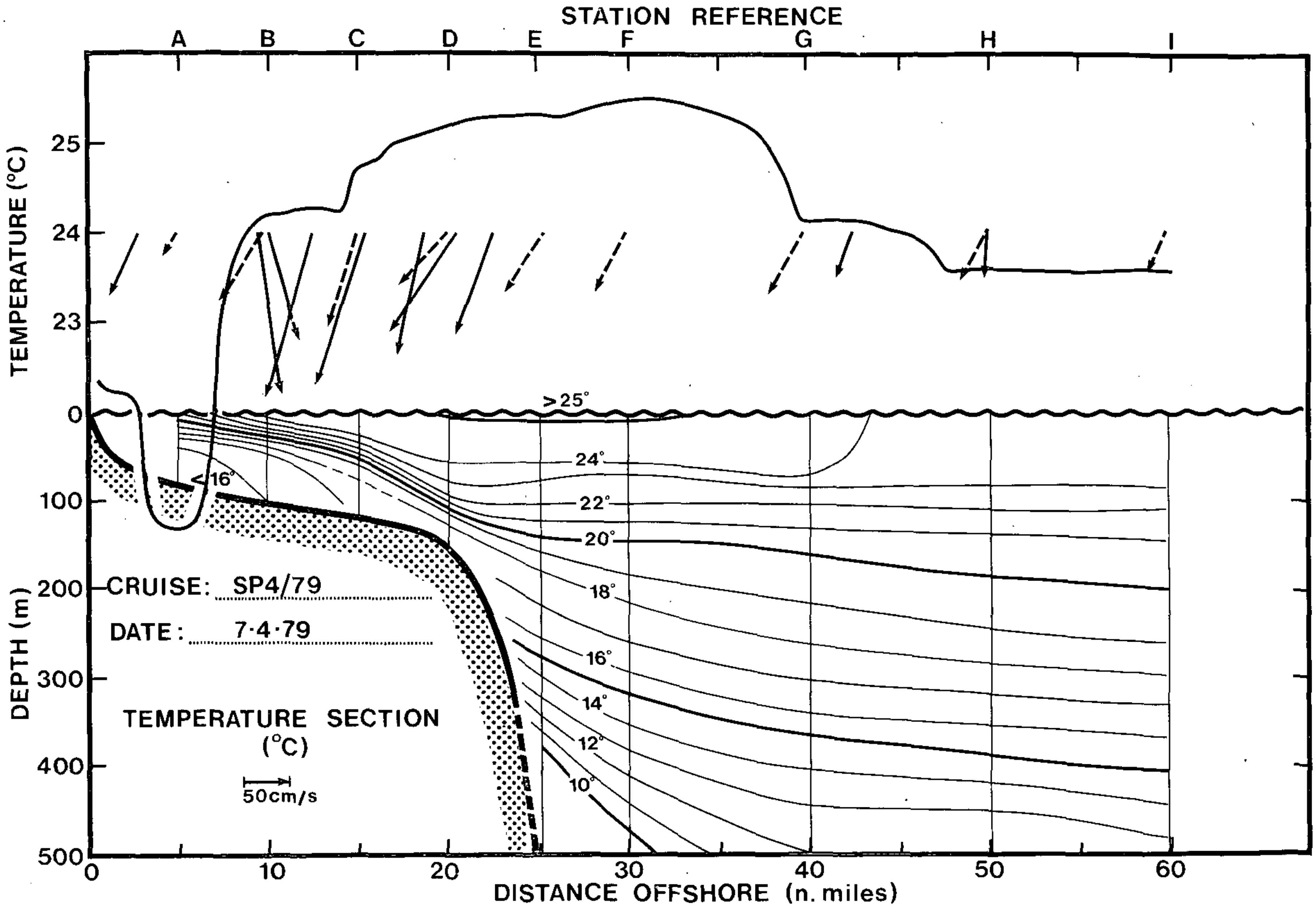

Fig. 16. Vertical temperature section from XBTs off Cape Hawke on 7/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

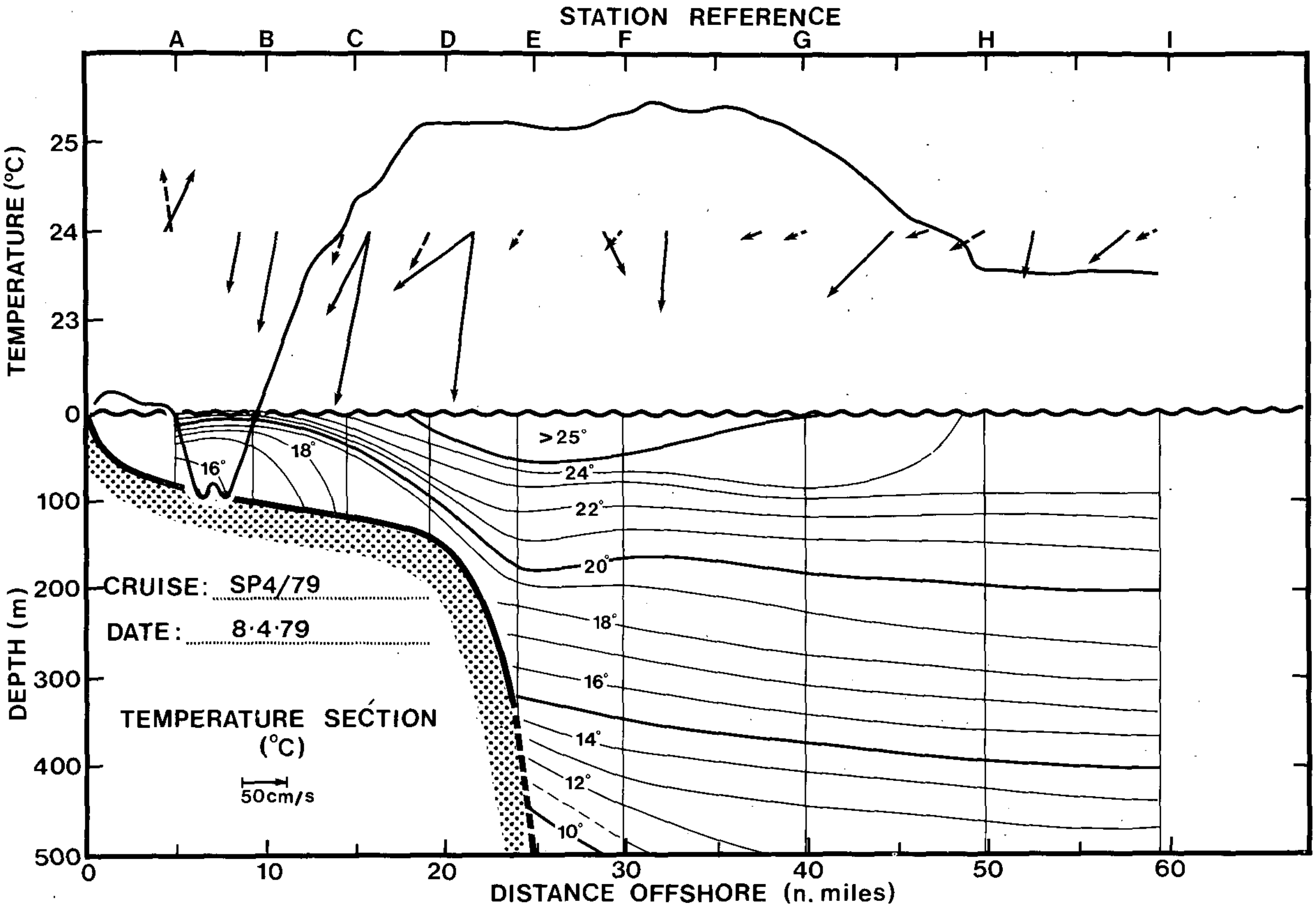

Fig. 17. Vertical temperature section from XBTs off Cape Hawke on 8/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

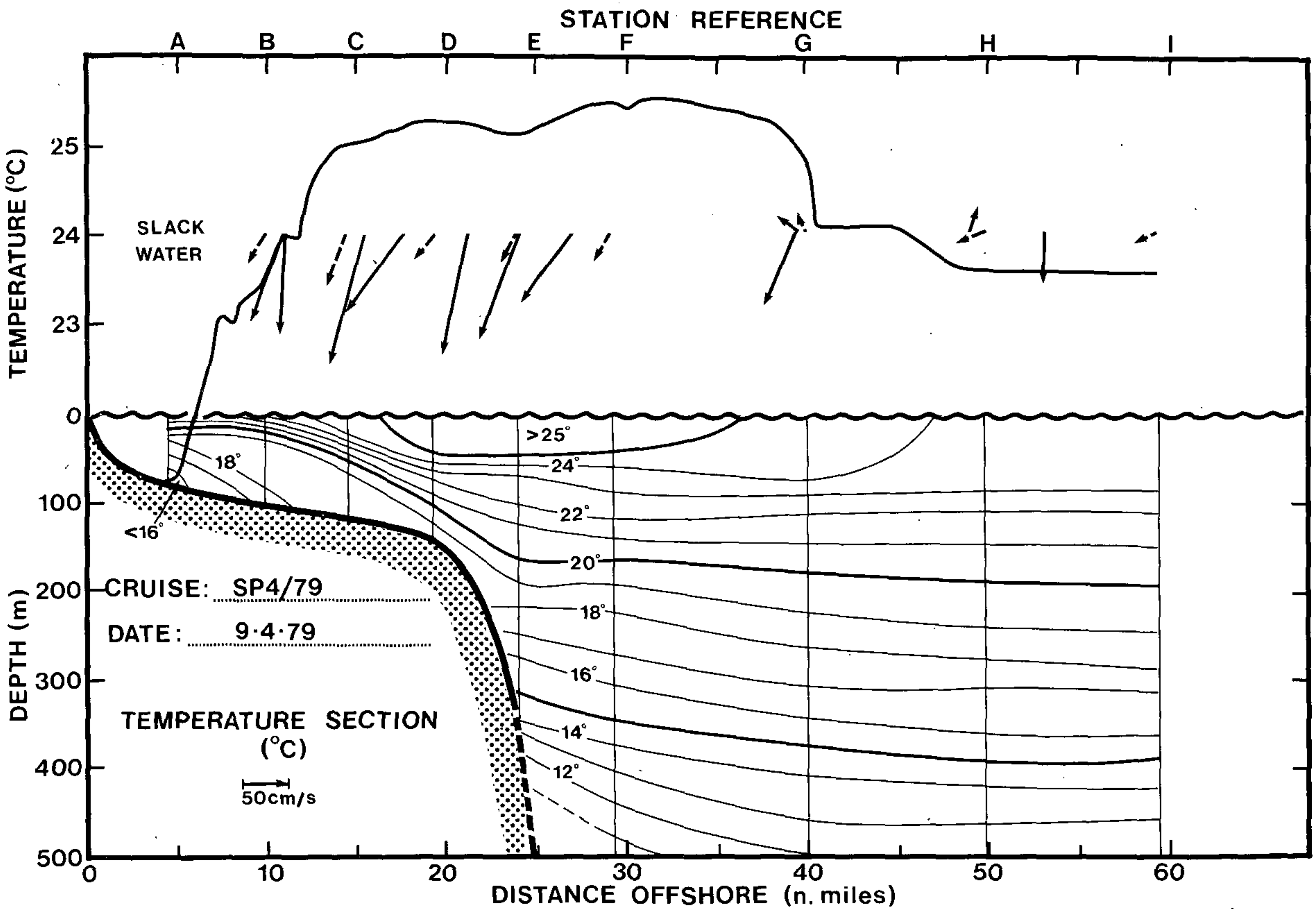

Fig. 18. Vertical temperature section from XBTs off Cape Hawke on 9/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

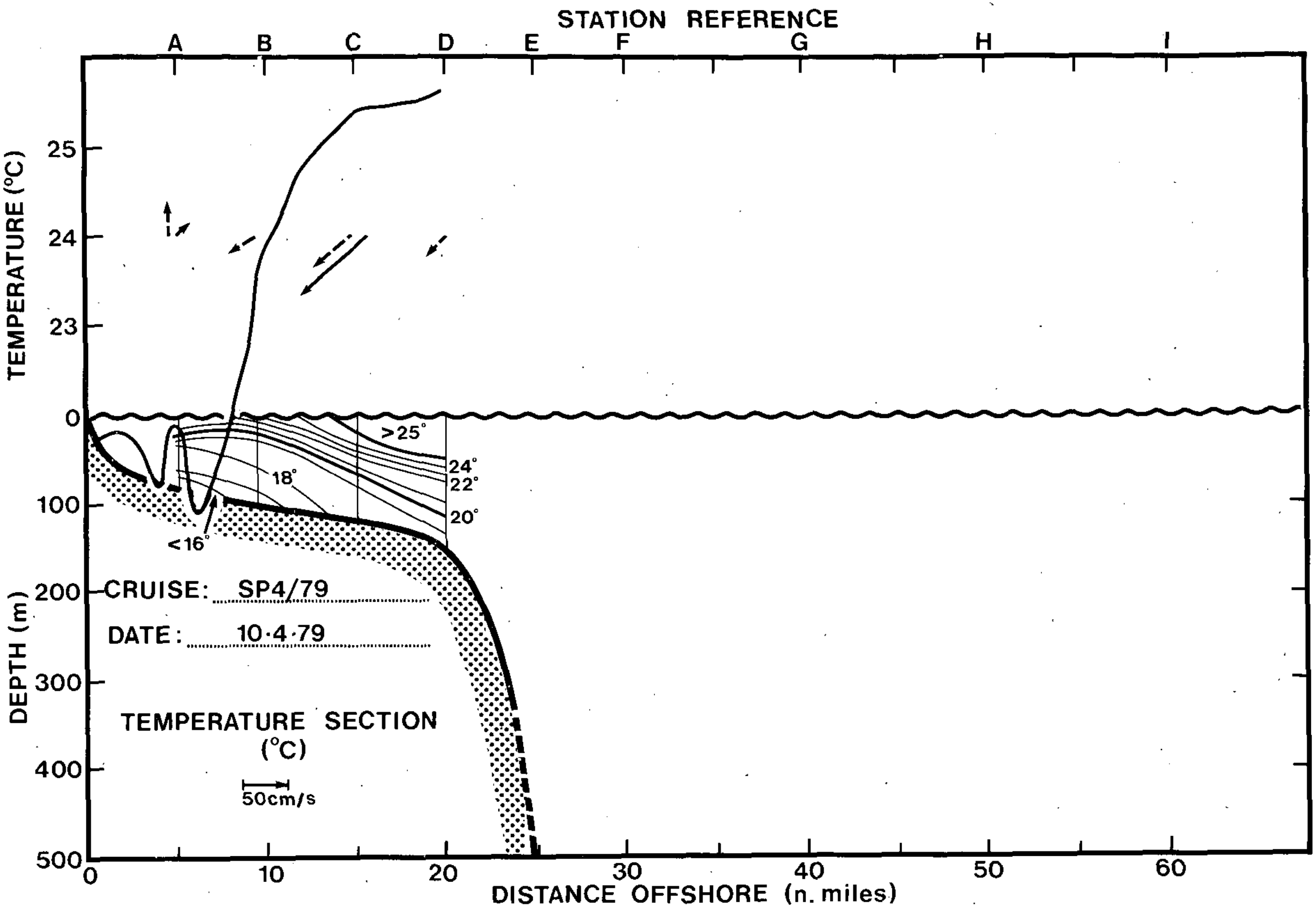

Fig. 19. Vertical temperature section from XBTs (tc shelfbreak only) off Cape Hawke on 10/4/79, and surface temperature (thermograph) trace. Solid vectors are shipdrifts, dashed vectors are GEK, velocity scale is as shown.

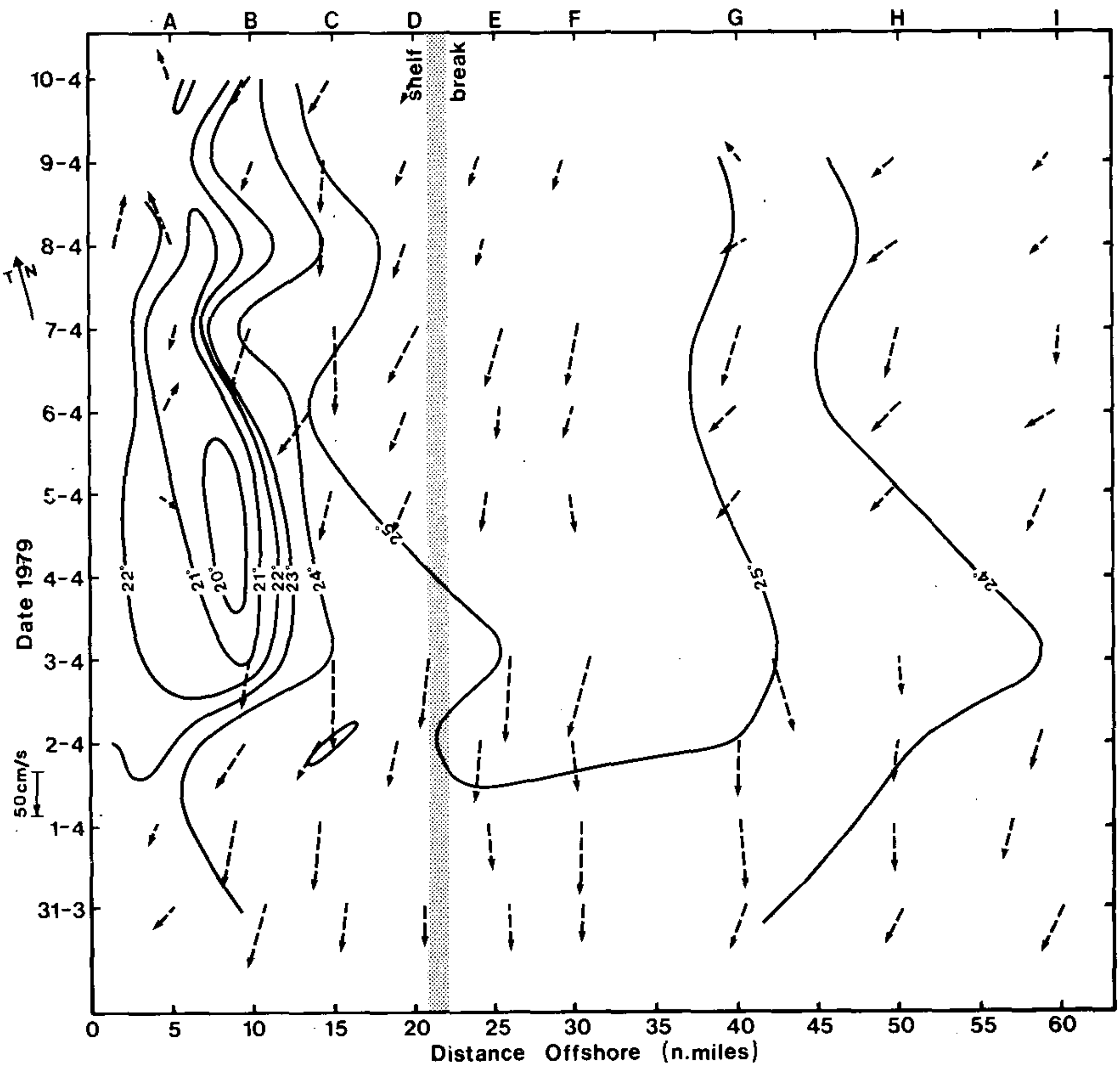

Fig. 20(a). Space-time diagram for surface temperature and GEK vectors for cruise SP4/79. Time runs from bottom to top, as if the pattern is advecting southwards past Cape Hawke. The shaded region represents the shelf break. The velocity scale and the direction of true north are as shown; the vectors have been rotated by 15° to be relative to the topography.

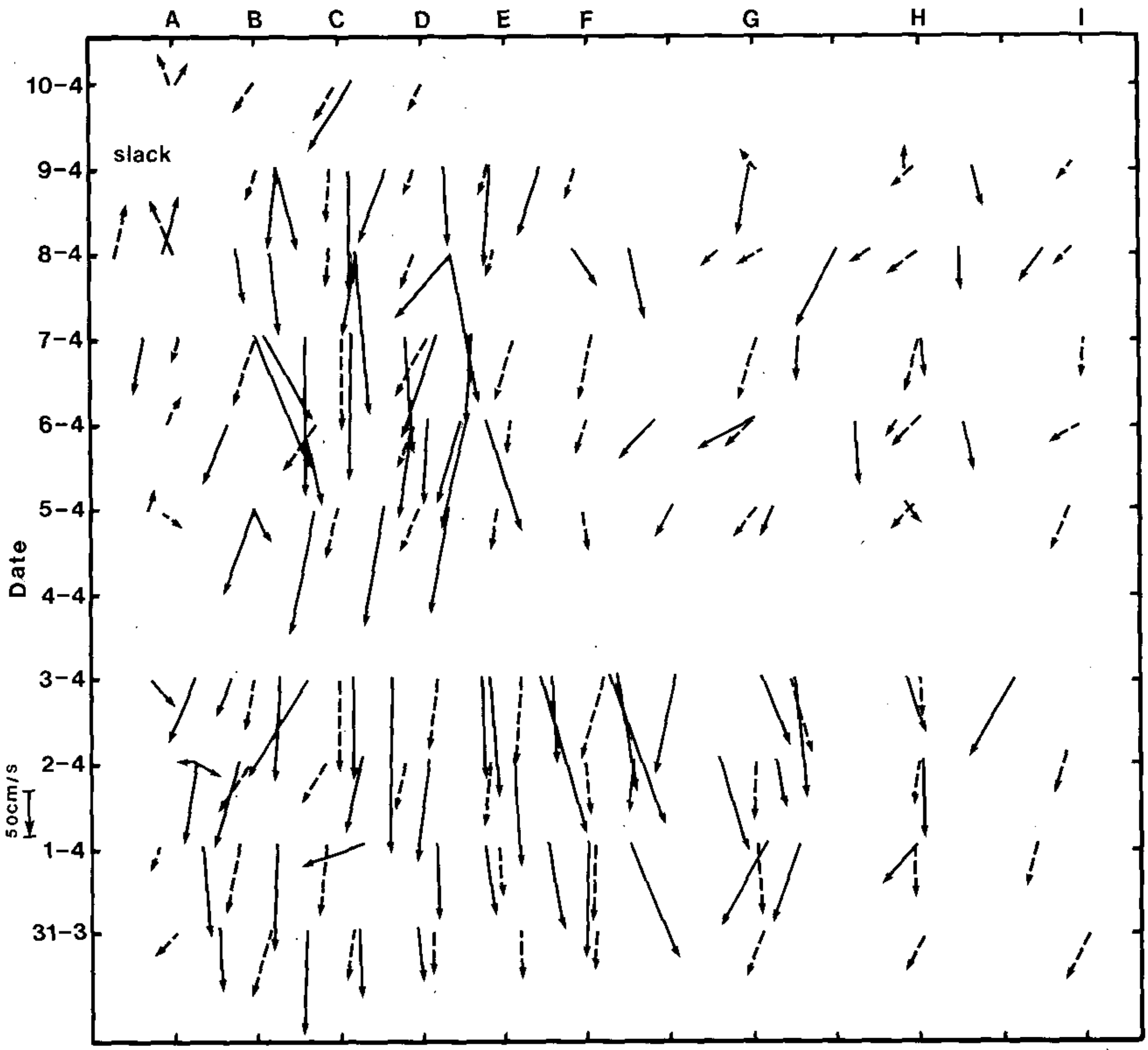

Fig. 20(b). Space-time diagram, as in Figure 20(a), but showing comparison of shipdrift vectors (solid) and GEK vectors (dashed). It is evident that the shipdrift vectors are (in some cases) appreciably greater than the GEK, but the general current patterns are the same.

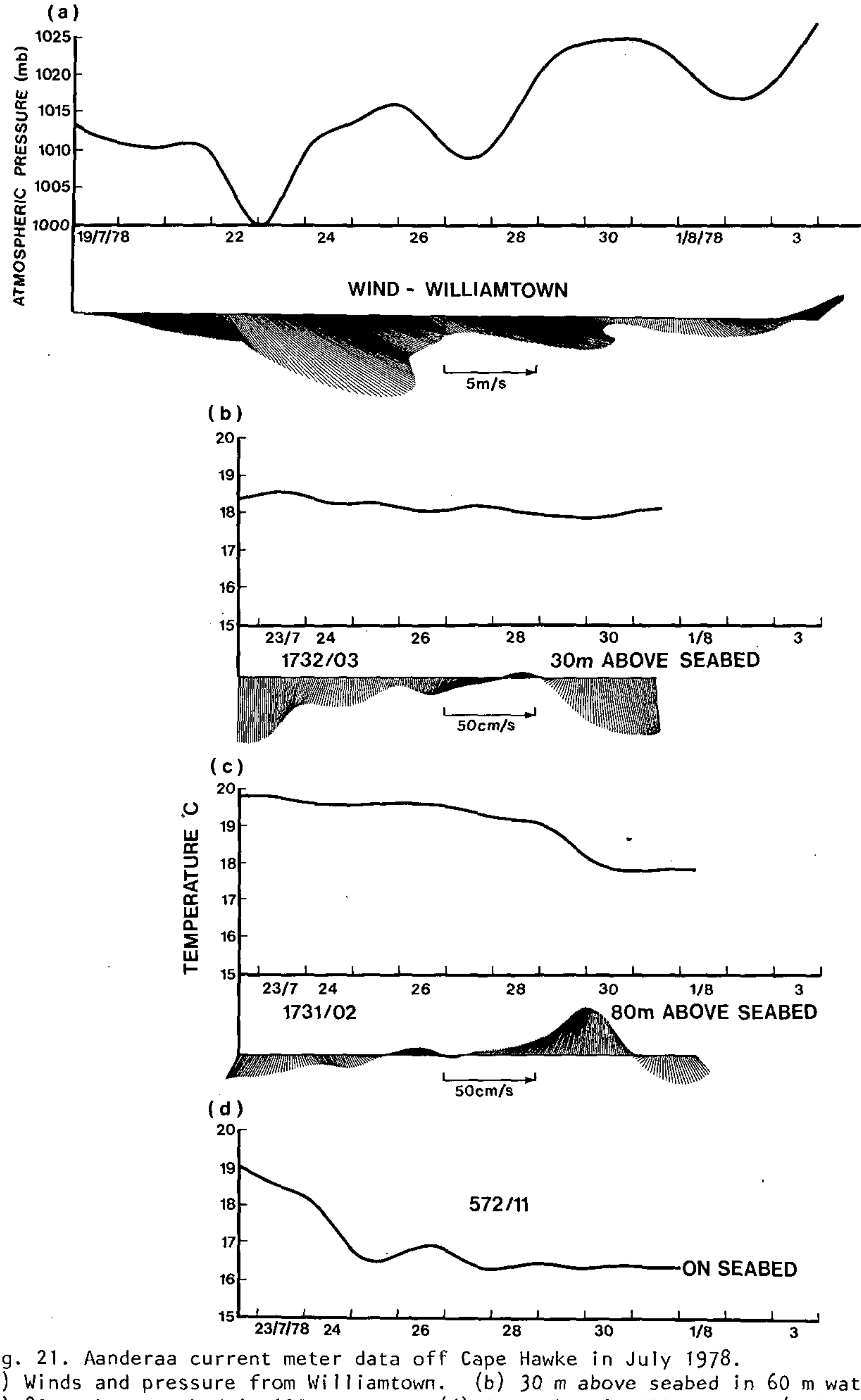

Fig. 21. Aanderaa current meter data off Cape Hawke in July 1978.
(a) Winds and pressure from Williamtown. (b) 30 m above seabed in 60 m water. (c) 80 m above seabed in 120 m water. (d) On seabed in 120 m water (originally moored 40 m above seabed but it sank to the bottom on the 30/3, so no vectors are shown.)

All data are filtered to remove diurnal and higher frequencies (for details see text). The velocity and temperature scales are shown.

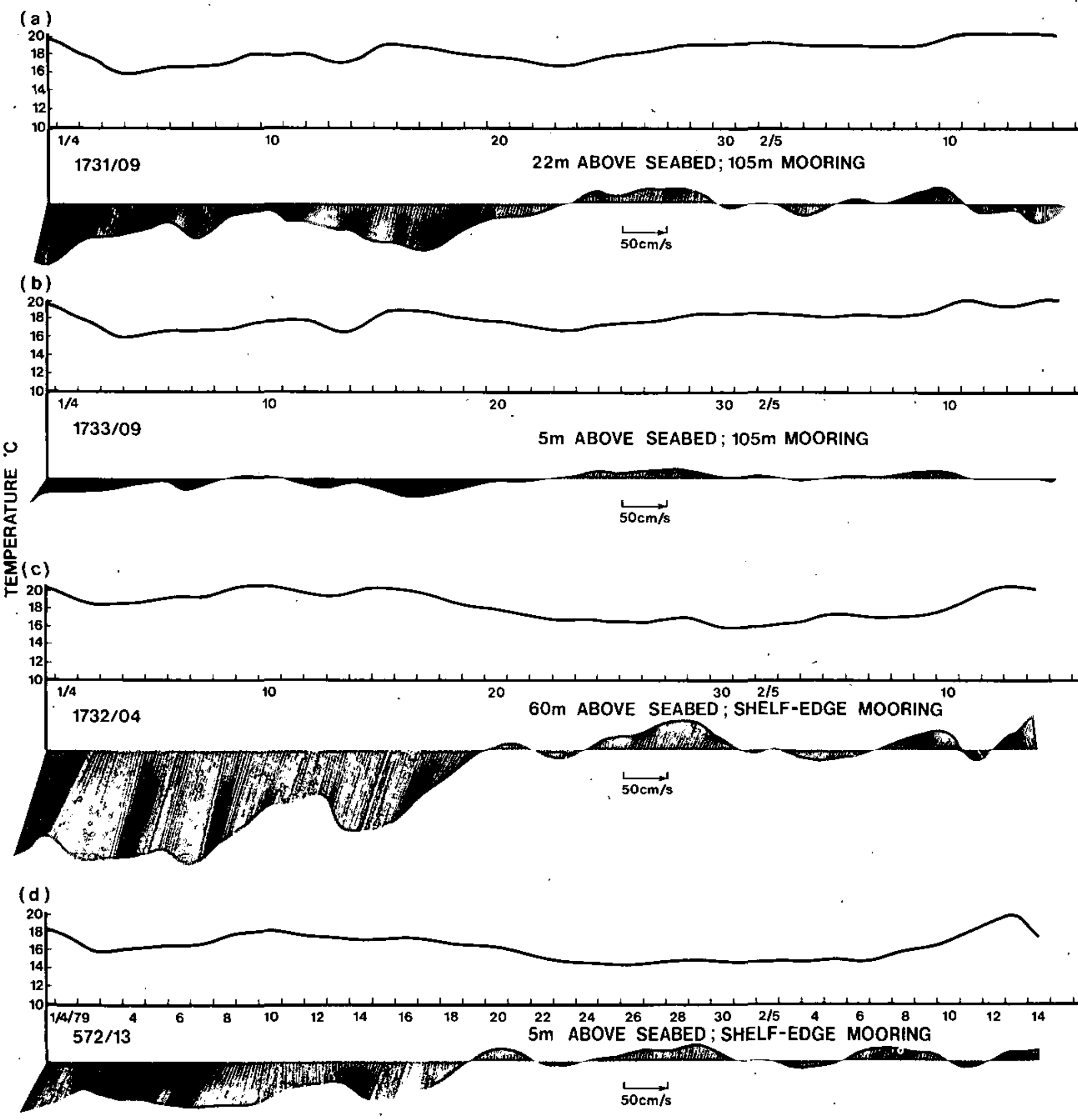

Fig. 22. Aanderaa current meter data off Cape Hawke in April/May 1979.
(a) 22 m above seabed in 100 m water. (b) 5 m above seabed in 100 m water.
(c) 60 m above seabed in 200 m water. (d) 5 m above seabed in 200 m water.

All data are filtered to remove diurnal and higher frequencies (for details see text). The velocity and temperature scales are shown.

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