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HYDROGRAPHIC OBSERVATIONS ON THE MAFF SOFAR FLOAT SITE

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ABSTRACT

CTD, XBT and current meter measurements made in 1984-85 at the MAFF SOFAR float launch site on the Iberia Abyssal Plain (approx 41°25'N, 14°27'W) are presented. Temperature, salinity, density and Brunt-Väisälä profiles have been determined from the CTD data. The mean Brunt-Väisälä profile was used to calculate dynamic modes which are compared with vertical empirical modes calculated from a central full depth current meter mooring.

Geostrophic currents have also been computed at several standard depths and these profiles have been compared with current meter velocity profiles.

The XBT data has been used to determine the depths of several isothermal levels and have, in addition, been used to establish correlation length scales.

RÉSUMÉ

L'on présente les mesures de conductivité, température et profondeur, les mesures faites au bathythermographe sacrifié et au courantomètre en 1984 et 1985 à la station flottante de lancement du SOFAR du MAFF située dans la plaine abyssale ibérique (aux environs du 41°25'N, 14°27'O). La température, la salinité, la densité et les profils de Brunt-Vaisala ont été déterminés à partir des données de conductivité, température et profondeur. Le profil Brunt-Vaisala moyen a permis de calculer des modes dynamiques qui ont ensuite été comparés aux modes empiriques verticaux calculés à partir d'un courantomètre central mouillé à pleine profondeur.

Les courants géostrophiques ont aussi été calculés à plusieurs profondeurs standardisées, et les profils correspondants ont été comparés aux profils des vitesses relevées au courantomètre.

Les données obtenues au bathythermographe sacrifié ont permis de déterminer la profondeur de plusieurs courbes isothermiques, et ont, de plus, été utilisées pour dresser des échelles de corrélation de longueur.

1. INTRODUCTION

Data collected on the Iberia Abyssal Plain during the MAFF SOFAR float programme are presented. The data consist of quasi-synoptic CTD and XBT arrays, a 9-mooring current meter array of 317 days duration and six SOFAR float tracks, four of 410 days duration and two of 270 days duration. The current meters were deployed in June 1984 during RV CIROLANA cruise 6/84, while the SOFAR floats were launched in 2 groups, the first in early October 1984 during RV CIROLANA cruise 8/84 and the second in mid-February 1985 by the Institute of Oceanographic Sciences (IOS), Wormley. The CTD and XBT arrays were also worked over an 8-day interval spanning the first float launch period.

The SOFAR floats are still being tracked.

This paper shows a preliminary analysis of the data, while the future aims are to quantify mixing rates in the waters of the Iberia Abyssal Plain, to examine the processes of such mixing and to investigate the longer term circulation of the area.

2. THE AREA

Figure 1 is a bathymetric chart showing the location of the experimental site on the Iberia Abyssal Plain as well as the float-launch and autonomous listening station (ALS) positions. The topography is generally flat, with a mean water depth of 5350 m. However, there are several small seamounts within the area and there is more prominent topography to the south and west.

3. THE DATA

(a) CTD array

The positions of the CTD stations in October 1984 are shown in Figure 2(a). As indicated, there are 3 full depth stations and 6 to mid-depth (2500 m). The instrument used, a Guildline Model 8705, was calibrated as described by Medler (1985) and the data were then latch filtered and salinity and density were derived using UNESCO algorithms (UNESCO, 1983). The data were then linearly interpolated to integer 2 dB intervals.

Here, we will only discuss CTD data in the depth range 10 to 2500 dB, this being the range covered by the majority of the casts.

(b) XBT array

The XBT station positions are shown in Figure 2(b). There are 72 stations in all, with 62 being of the T7 type (750 m) and 10 of the T5 type (1200 m). The data have been contoured to show the depths of specific isotherms and hence reveal the temperature structure of the area (section 4b).

(c) Current meter array

Nine current meter moorings were deployed, as shown in Figure 2(a), but only 7 were recovered, as indicated in the figure. Each current meter recorded speed, direction and temperature. The speed and direction were converted to east (u) and north (v) components of velocity and along with the temperature were low passed with a Gaussian filter with a half-power level at 0.25 cpd. This gives an effective energy cut off at 0.5 cpd. The series was then subsampled once per day. Mooring information and relevant statistics for each of the recovered meters are given in Table 1. Each mooring had a meter located at an approximate depth of 2450 m (Table 1) to coincide with the target depth of the SOFAR floats. In this paper we shall be concerned only with meters at this depth along with the full depth central mooring.

The central mooring included 5 current meters, the top, middle and bottom of which were of the Aanderaa RCM5 type used by MAFF, while the remaining two were VACM's belonging to the Belgian Ministerie Van Volksgezond leid En van Het Gezin. There was a fairly large percentage of stall speeds (approximately 30% for the bottom two meters) which were treated differently in the processing of the Aanderaa's and VACM's by the two separate institutes: the Aanderaa stall speeds were replaced by the threshold velocity (1.5 cm/s) while the VACM's stall speeds were left at zero. At present, this means that we cannot compare the kinetic energies of the two different meter types. For this reason we have decided to present results only for the Aanderaa current meters until reprocessing of the VACM's takes place.

(d) SOFAR float data

The SOFAR floats were launched in two groups, the first group of 5 in early October 1984 and the second group of 4 in mid-February 1985. As can be seen from Table 2, only 4 floats from the first deployment and 2 from the second functioned. Float signals were recorded by four autonomous listening stations provided, launched and recovered by IOS Wormley (Figure 1).

The ALS's were recovered and relaid in May 1985 and again in November 1985, both times in their original positions (Table 2). A current ALS deployment will be recovered in November 1986. The SOFAR float data presented, therefore, cover the first two deployments spanning 410 days. The data for the second ALS deployment have only recently been processed and, hence, only tracks and telemetry for this period are available as there has not been sufficient time for further analysis (section 4e).

4. DISCUSSION

(a) Water masses

Figure 3 is a T-S plot for all 9 CTD stations, and shows three main water types present in the upper 2500 m: (1) Northeast Atlantic central water with a clear quasi-linear T-S relationship between approximately 13°C, 35.75 ppt and 11.0°C, 35.5 ppt; (2) an intermediate salinity maximum, due to Mediterranean water, with a maximum salinity varying between 35.8 and 36.1 ppt across the array. The salinity maximum occurs at a temperature of 10.5°C which corresponds to a depth of 1000 m (see Figure 4(a)). There is also an increase in the depth range of the salinity maximum from east to west across the array (Figure 4(b)); (3) the deep layer which displays a very tight T-S relationship with both T and S decreasing with depth.

(b) Temperature distribution

Figure 5(a and b) shows the contoured depths of the 12°C and 13°C isotherms determined from the XBT data. The most notable feature is that the isotherms are predominantly zonal and lie deeper in the south.

(c) Current meter analysis

(i) Vertical Structure

Figure 6(a) shows the vertical distribution of kinetic energy at the central mooring. There is strong surface intensification, which is mirrored by the structure of the first vertical empirical orthogonal function (EOF) (Figure 6(b)). The first EOF accounts for 52% of the available energy, the second, which is quasi-barotropic, accounts for 30% and the third 13%.

The frequency dependence of the vertical structure has been examined by cross-spectral analysis between the zonal and meridional velocities at the central mooring using the Blackman-Tukey method (Blackman and Tukey, 1959) with 100 lags. The frequency range covered by the analysis is therefore 0.5 to 0.005 cpd (periods of 2 to 200 days).

The lower two levels, which are located below the main pycnocline, are coherent at the 95% level in the period range 18-200 days for both the zonal and the meridional components. Coherence at higher frequencies are significant only for the meridional component and only for periods between 7 and 11 days.

Motions coherent at the 95% level throughout the water column are limited to the lowest 2 frequency bands (40-200 days) and to the zonal component. There is no coherence between the top and either of the lower two levels in any frequency band for the meridional component.

The results therefore indicate that much of the energy is concentrated above the main pycnocline, with only energy in the lowest frequency bands being coherent throughout the water column. These results are in agreement with those for the Tourbillon Area (Mercier and Colin de Verdiere, 1985) in that only the lowest frequencies are coherent across the main pycnocline.

(ii) Horizontal scales

Figure 6(c) shows the spatial correlations for the transverse and longitudinal velocity components and temperature at the 2450 m level. Each curve contains 4 points, the first of which is the average of all correlations in the separation range 41-53 km, the second in the range 63-71 km, the third in the range 92-95 km and the fourth in the range 102-107 km. Although all the transverse velocity correlations are negative, a zero crossing of approximately 42 km can be extrapolated. This figure compares with a value of 32 km at 3000 m for the Tourbillon Area (Mercier and Colin de Verdiere, 1985; Le Group Tourbillon, 1983), and 100 km at 600 m for the Polymode Local Dynamics Experiment (LDE) region (Owens, 1985). The zero crossing for the temperature correlations is much greater (approximately 90 km) than that for the velocity. As described by Owens (1985) this is consistent given a low vertical mode structure and quasi-geostrophic dynamics.

The internal Rossby radius of deformation defined as

$$\int_{-H}^{0} (N(Z)/f_0)dZ$$

where, N(Z) is the Brunt-Väisälä frequency

fo is the coriolis parameter

H is the ocean depth

was calculated from the mean Brunt-Väisälä profile (determined from all 9 CTD casts as described by Emery et al. (1984)) and was found to be 80 km. This compares with values of 50 km and 100 km at the Tourbillon and Polymode LDE areas respectively, and is consistent with the transverse velocity correlations.

(iii) Time scales

Eulerian autocorrelation functions for the zonal and meridional velocity components for lags up to 100 days are shown in Figure 6(d). The plots are averages over all 7 meters at the 2450 m level. The zero crossing for the meridonal component is 40 days while that for the zonal component is 69 days. This is in agreement with the SOFAR float data for the first ALS deployment where the zero-crossing of the u component was greater than that of the v component. However, the Eulerian autocorrelation functions have zero crossings twice those of the Langrangian. This same trend was found by Mercier and Colin de Verdiere (1985) in the Tourbillon area, where Langrangian integral time scales were much smaller than the Eulerian.

(d) Dynamic heights

Figure 7(a and b) shows the hand contoured plots of dynamic height for the 500 m and 1500 m levels calculated from the 2 dB CTD data and referenced to 2500 m. At 500 m there is a cyclonic circulation around the centre of the array, with a smaller anticyclonic cell to the south. At 1500 m the pattern has changed somewhat; although there is still a low in the centre of the array with its associated cyclonic circulation, there is also a strong flow to the east and north, again in a cyclonic sense.

(e) SOFAR floats

Analysis of the SOFAR float tracks and associated statistics has only just begun and therefore we can only present the float track (Figure 8(a-f)) and some preliminary observations.

Comparisons between the first group of floats to be launched and current vectors determined from the current meter data at the 2450 m level for the 10-day period which brackets the float launch in October 1984 (Figure 7(c)) show consistency between the SOFAR floats and current meters. However, as this work progresses, it is planned to make more detailed comparisons by objectively mapping the stream function field at 2450 m at 10-day intervals for the whole period that the floats remain within the current meter array.

There is evidence for a cyclonic eddy being present in the area, which is most clearly described by float 26 which exhibits consistent high speed and cyclonic direction of rotation for over 200 days.

The target depth of the SOFAR floats was 2500 m. However, due to an error in ballasting, the first group of floats only descended to approximately 1900 m. Figure 8(g) is the pressure and temperature telemetry from float 25 indicating the rate at which it is sinking to its target depth due to the effects of creep.

5. CONCLUSION

It is clear from the current meter records and SOFAR float tracks that there is a great deal of low-frequency variability of relatively small spatial scale in this low-energy region.

Eddy kinetic energy estimates obtained are smaller than those from the Tourbillon area in the Eastern North Atlantic and in fact from a global min in k_E (Dickson, 1983 p324).

It is shown that length scales and possibly time scales are longer than those of the Tourbillon area to the north. This agrees with the idea of Mercier and Colin de Verdiere (1985) that the scales of mesoscale motions are linked by some kind of weak turbulent dispersion relation.

It is evident from the estimates of the transverse velocity correlation function that any attempt to objectively map the stream function field at 2450 m depth would result in large uncertainties due to the low spatial correlation at the minimum mooring separation of 40 km. It is, therefore, difficult to make comparisons between current meter and SOFAR float tracks, though the limited comparisons that have been made show generally good agreement between floats and current meters.

6. REFERENCES

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Table 1. Flow statistics for all current meter records used. Eastward (u) and northward (v) velocities are denoted. Over bars denote an average over the whole record and deviations from these averages are denoted by a prime. K_E denotes the kinetic energy of the eddy motion and K_M the kinetic energy of the mean motion.

Identifier	Latitude N (° ')	Longitude W (° ')	Water Depth (m)	Sampling Depth (m)	Data Duration (Days)	Start Date	Stability Factor (%)	$\overline{u'^2}$ ($cm^2 s^{-2}$)	$\overline{v'^2}$ ($cm^2 s^{-2}$)	K_E ($cm^2 s^{-2}$)	K_M ($cm^2 s^{-2}$)
8403-1	41 25.3	14 24.6	5343	410	317	10.7.84	35.0	7.35	13.49	10.42	1.14
-2				1480	126	10.7.84	55.6	0.90	2.86	1.88	0.47
-3				2590	317	10.7.84	29.7	2.35	3.73	3.04	0.22
-4				3450	313	10.7.84	46.8	0.30	1.01	0.65	0.09
-5				4500	249	10.7.84	32.4	1.36	3.03	2.20	0.19
8401-1	41 0.5	14 26.8	5350	1430	316	11.7.84	25.3	6.68	4.48	5.78	0.34
-2				2560	302	11.7.84	47.7	3.67	2.62	3.15	0.75
8406-1	41 24.6	15 1.0	5340	1410	317	11.7.84	29.0	1.93	2.14	2.04	0.14
-2				2470	317	11.7.84	54.7	1.53	1.94	1.73	0.56
8408-1	41 52.1	14 28.5	5339	1300	315	13.7.84	61.1	3.64	1.66	2.65	0.95
-2				2390	315	13.7.84	29.1	3.08	2.33	2.70	0.20
8409-1	41 49.9	13 54.1	5347	2320	275	14.7.84	37.1	2.45	1.53	1.99	0.28
-2				3430	312	14.7.84	49.3	1.53	1.41	1.47	0.39
8410-1	41 23.5	13 53.4	5353	1330	312	14.7.84	14.1	4.65	4.77	4.71	0.08
-2				2430	312	14.7.84	14.2	1.80	6.37	4.09	0.07
8411-1	41 00.1	13 55.0	5352	2330	312	14.7.84	8.9	5.41	4.27	4.84	0.03
-2				3430	312	14.7.84	13.5	4.65	4.77	4.71	0.08

Table 2. SOFAR float launch positions and ALS positions.

Identification	Launch Position N	Launch Position W	Launch date	Comments
22	41 20.5	14 44.7	5.X.84	
24	41 35.0	14 38.7	3.X.84	
25	41 35.0	14 15.9	3.X.84	
26	41 12.3	14 27.5	5.X.84	
31	41 35.5	14 16.5	29.IX.84	Bad ballast, sunk to bottom
32	41 24.9	14 27.5	17.II.84	Died soon after launch
63	41 20.2	14 42.2	18.II.84	
66	41 19.9	14 12.2	18.II.84	
67	41 11.0	14 27.1	18.II.85	Died just after launch

ALS Positions

N	W
42 43.3	19 00.2
37 18.2	18 39.0
41 30.1	13 28.7
44 49.5	15 03.2

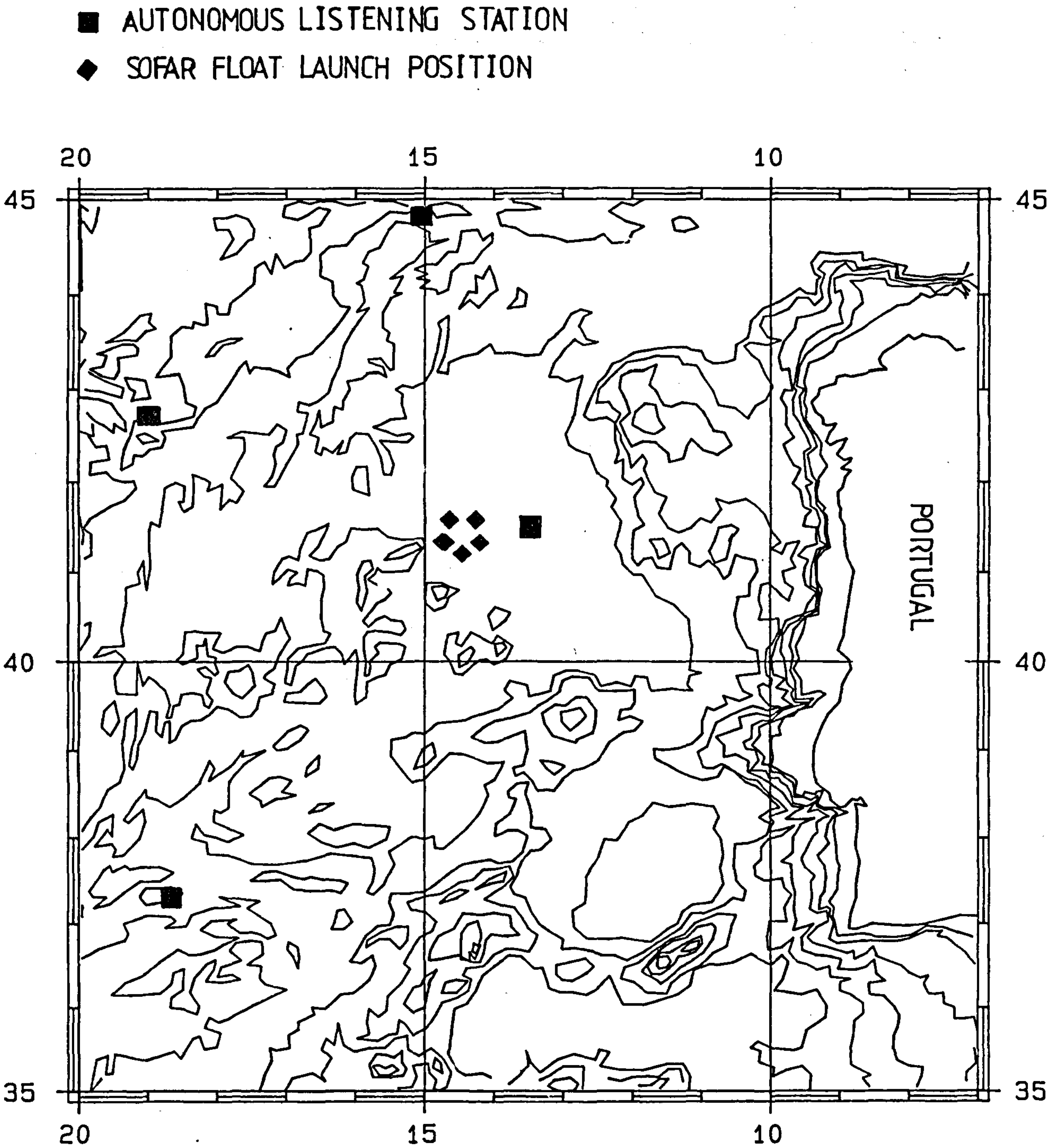

Figure 1. Position of the experimental area: ALS Stations and SOFAR float launch positions.

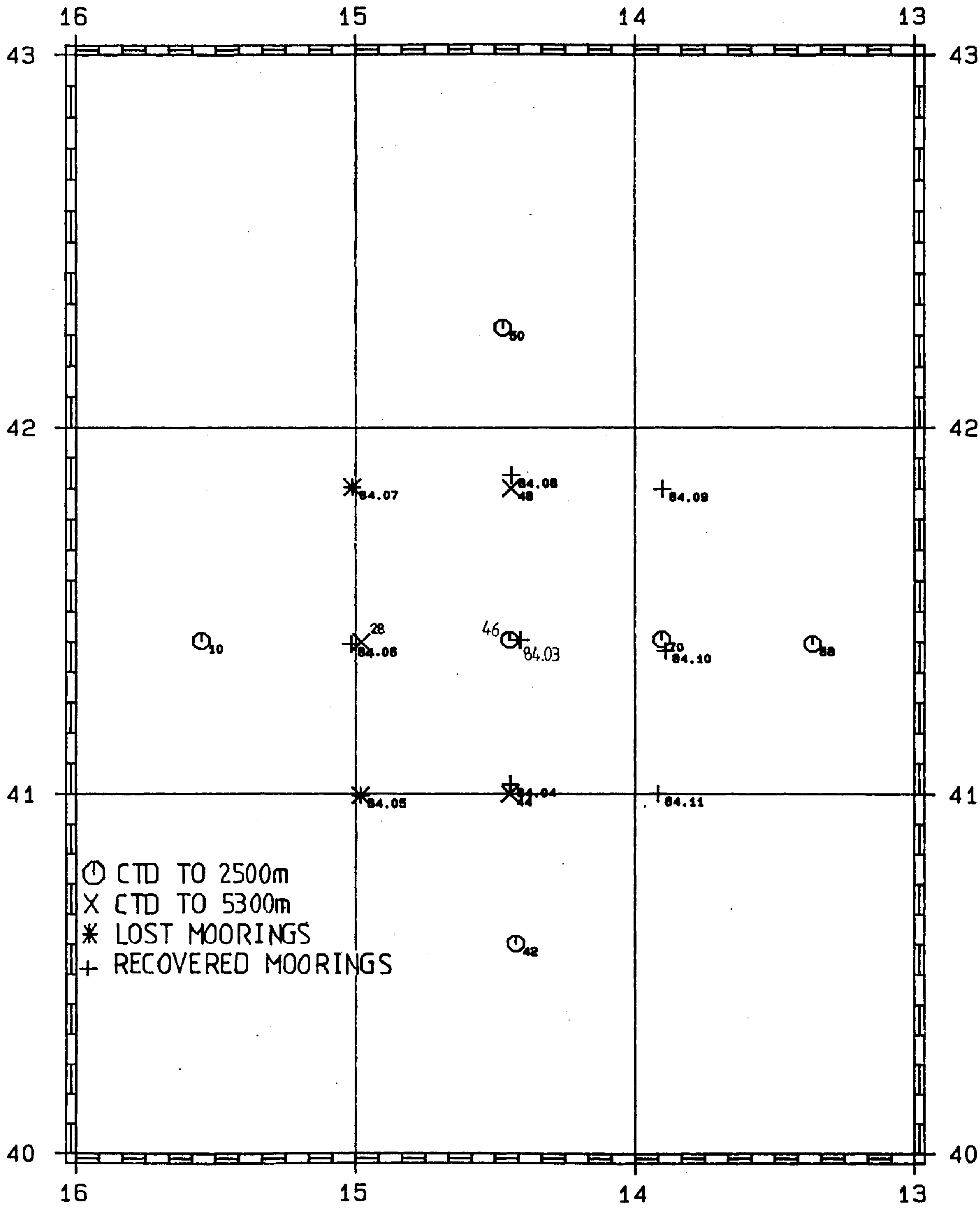

Figure 2(a). Current meter and CTD positions.

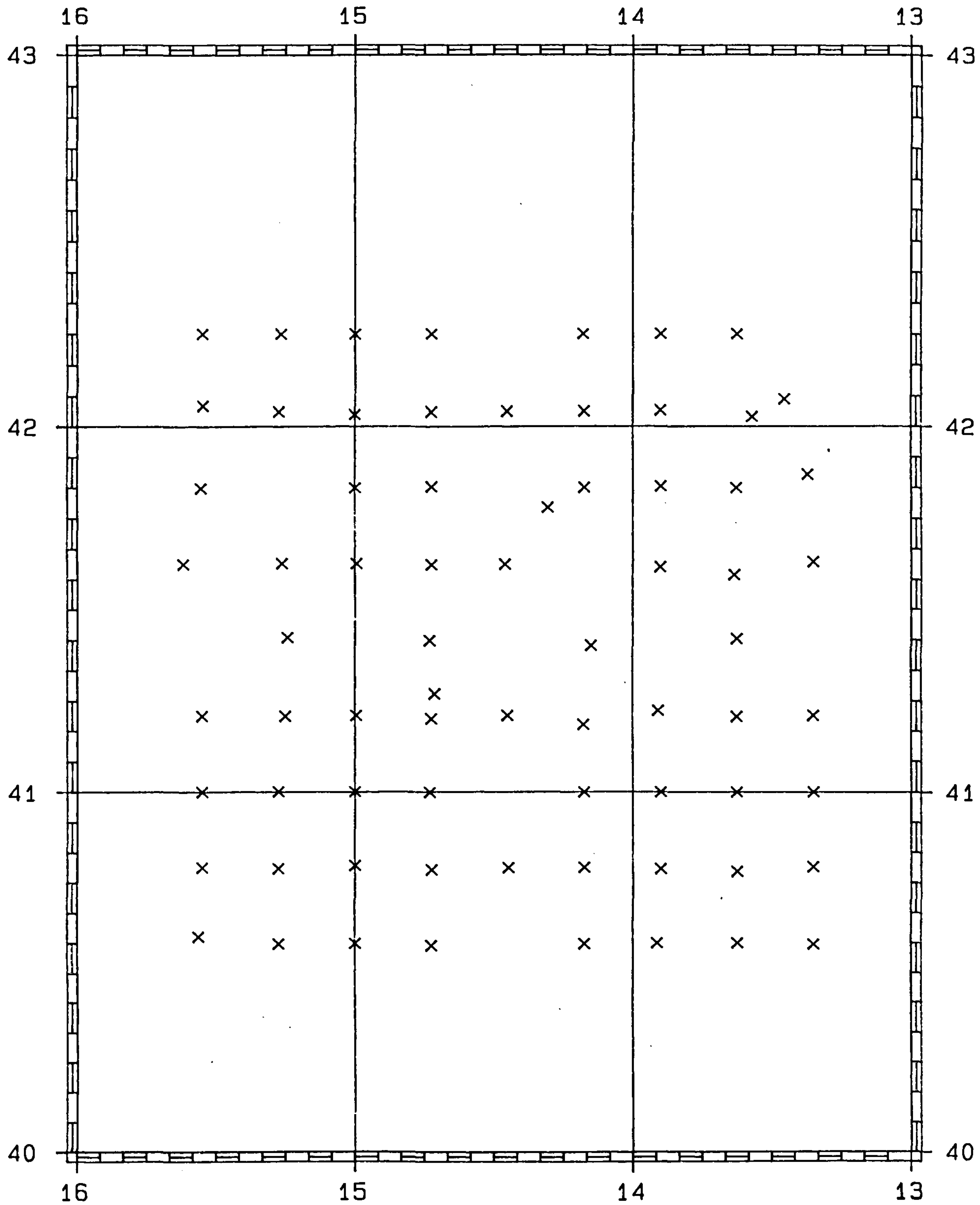

Figure 2(b). XBT positions for CIROLANA 8/84.

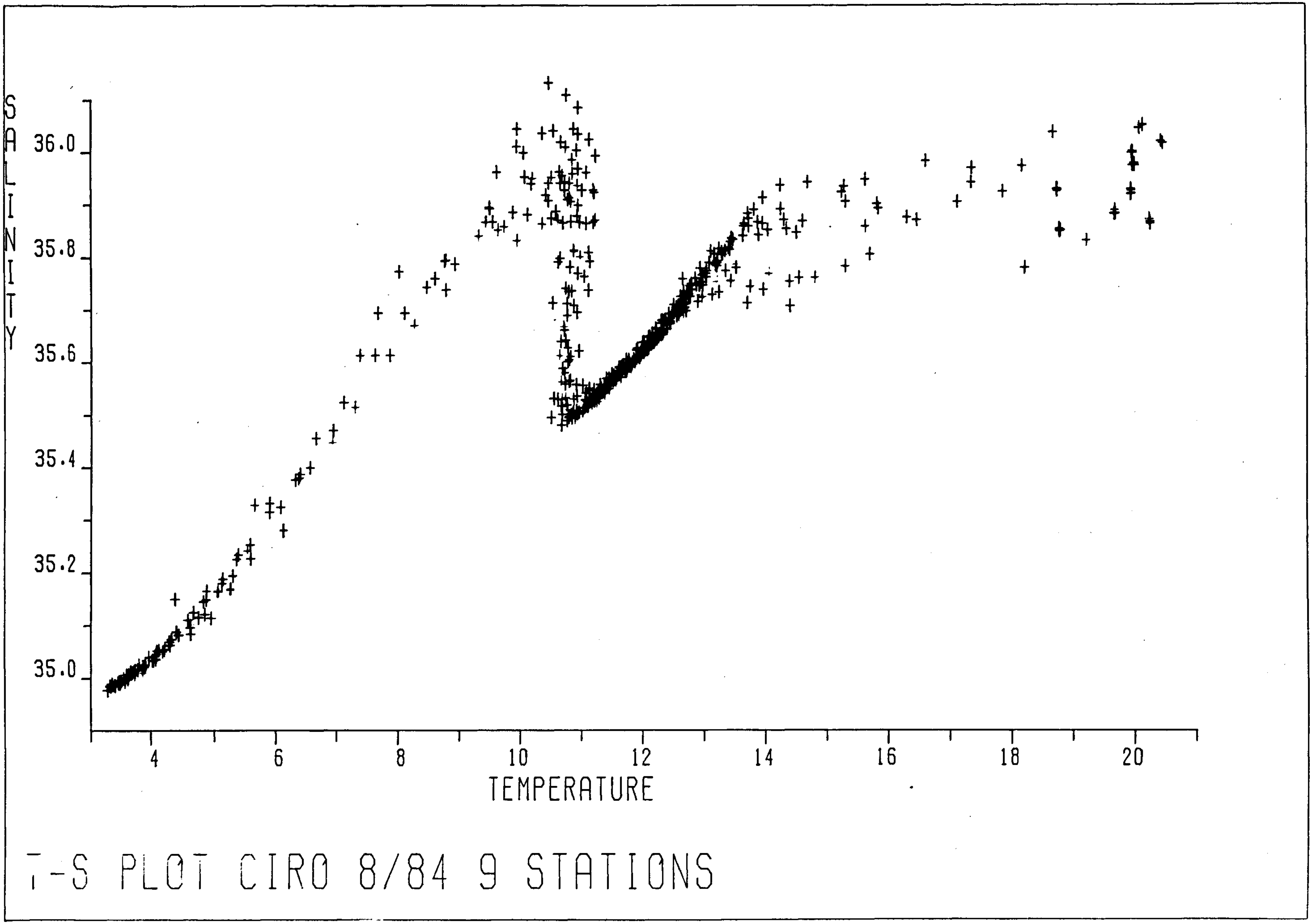

Figure 3. A temperature vs salinity plot for all 9 CTD stations.

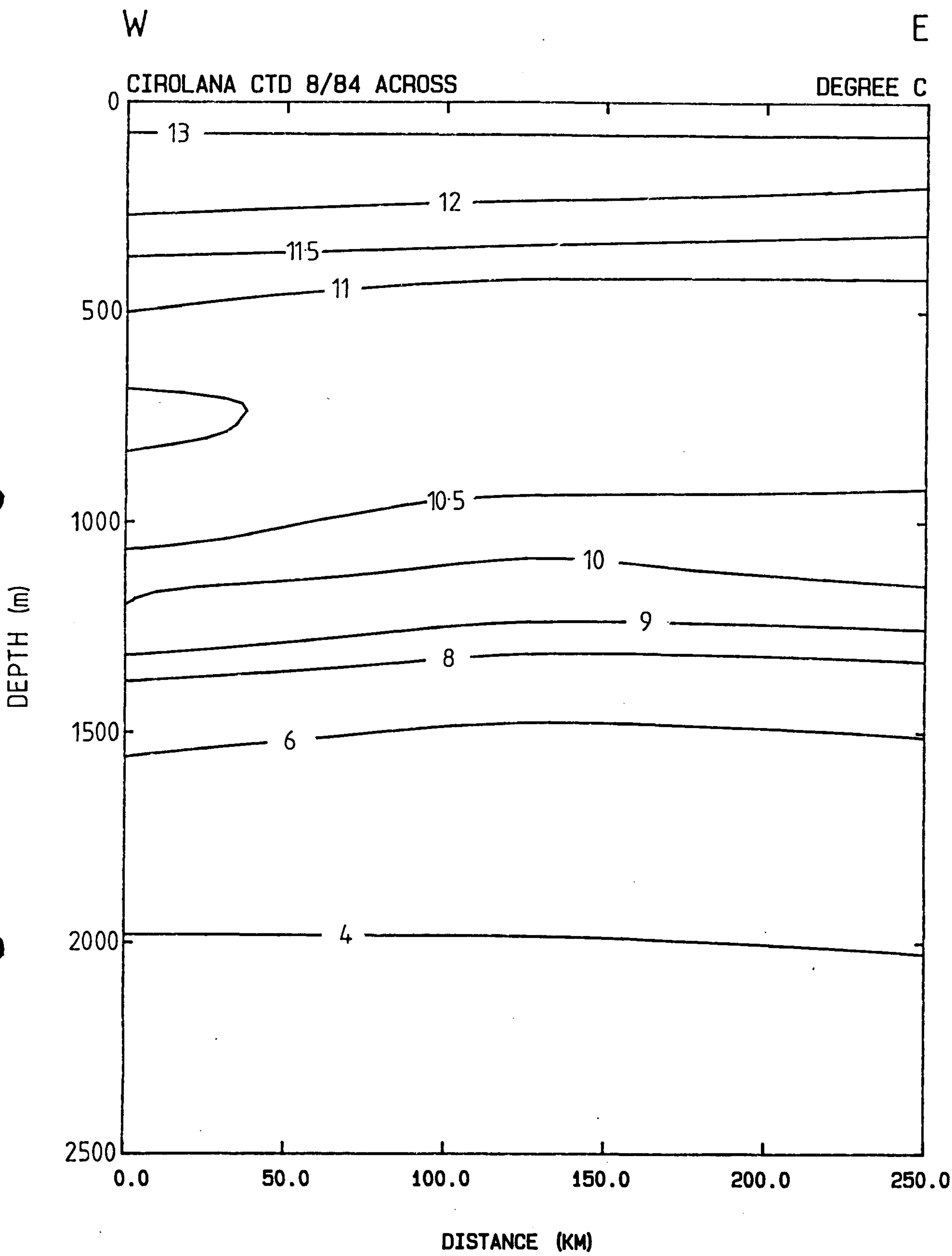

Figure 4(a). A zonal section of temperature across the centre of the CTD array.

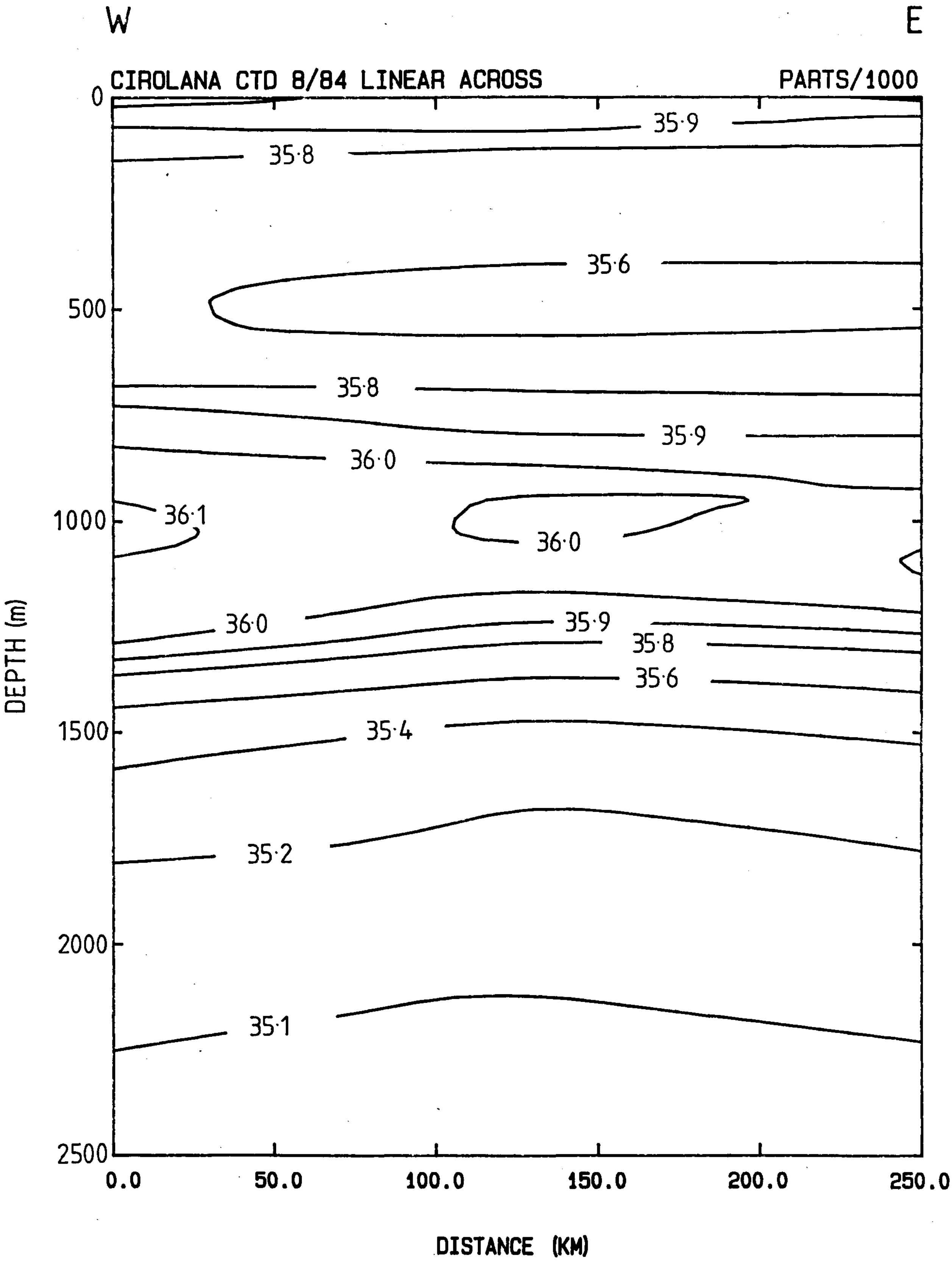

Figure 4(b). A zonal section of salinity across the centre of the CTD array.

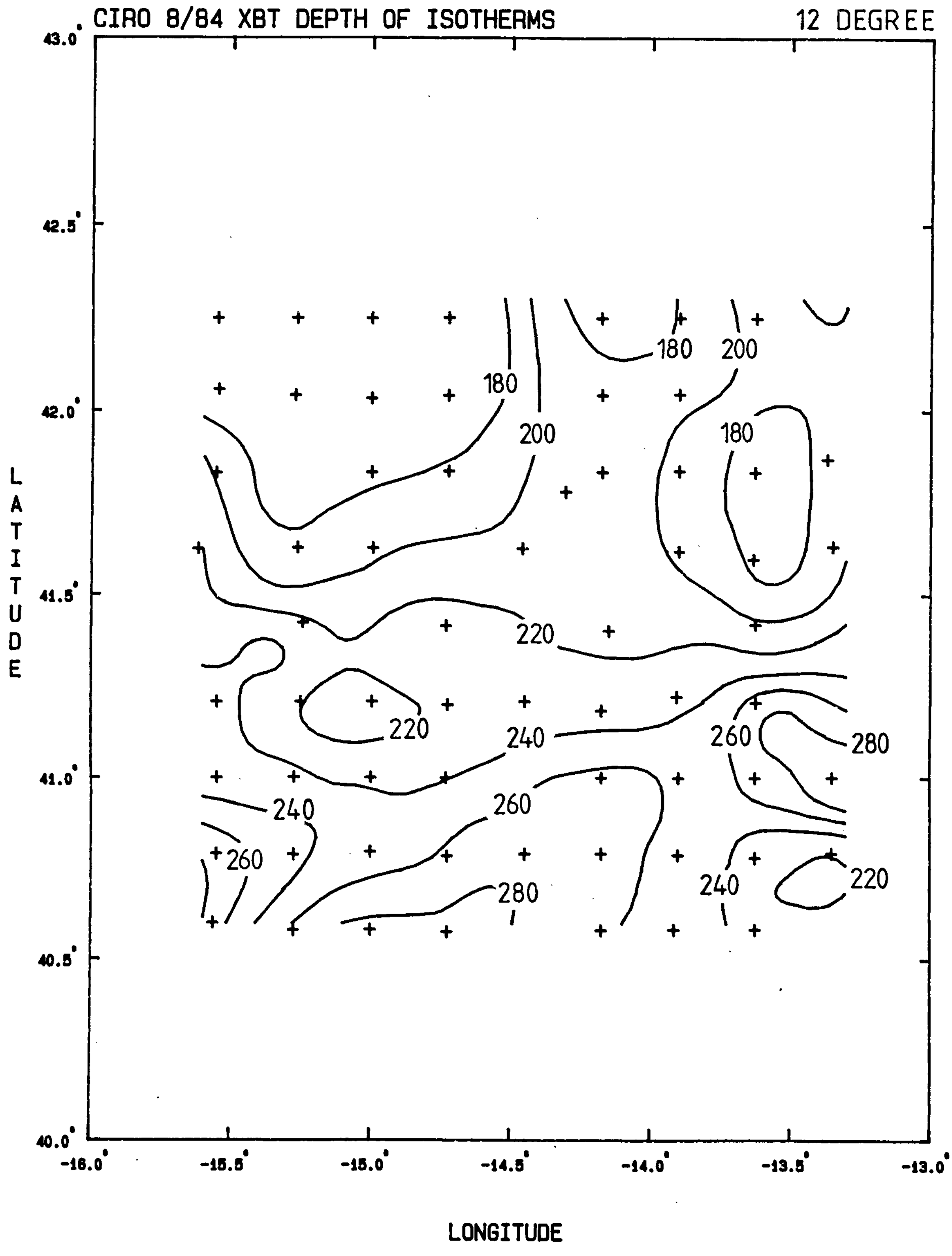

Figure 5(a). A contour plot of the 12 degree isotherm calculated from XBT's.

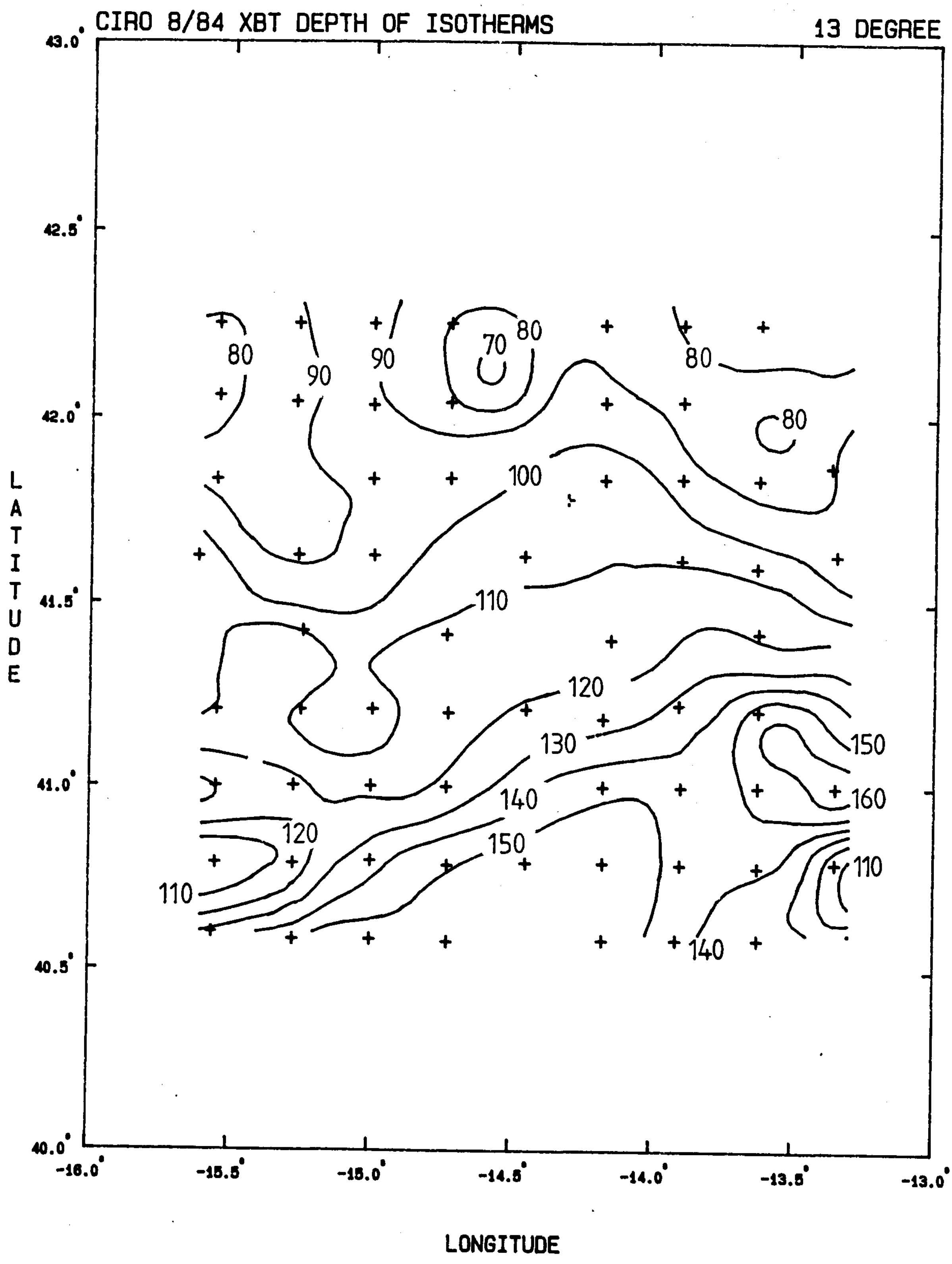

Figure 5(b). A contour plot of the 13 degree isotherm calculated from XBT's.

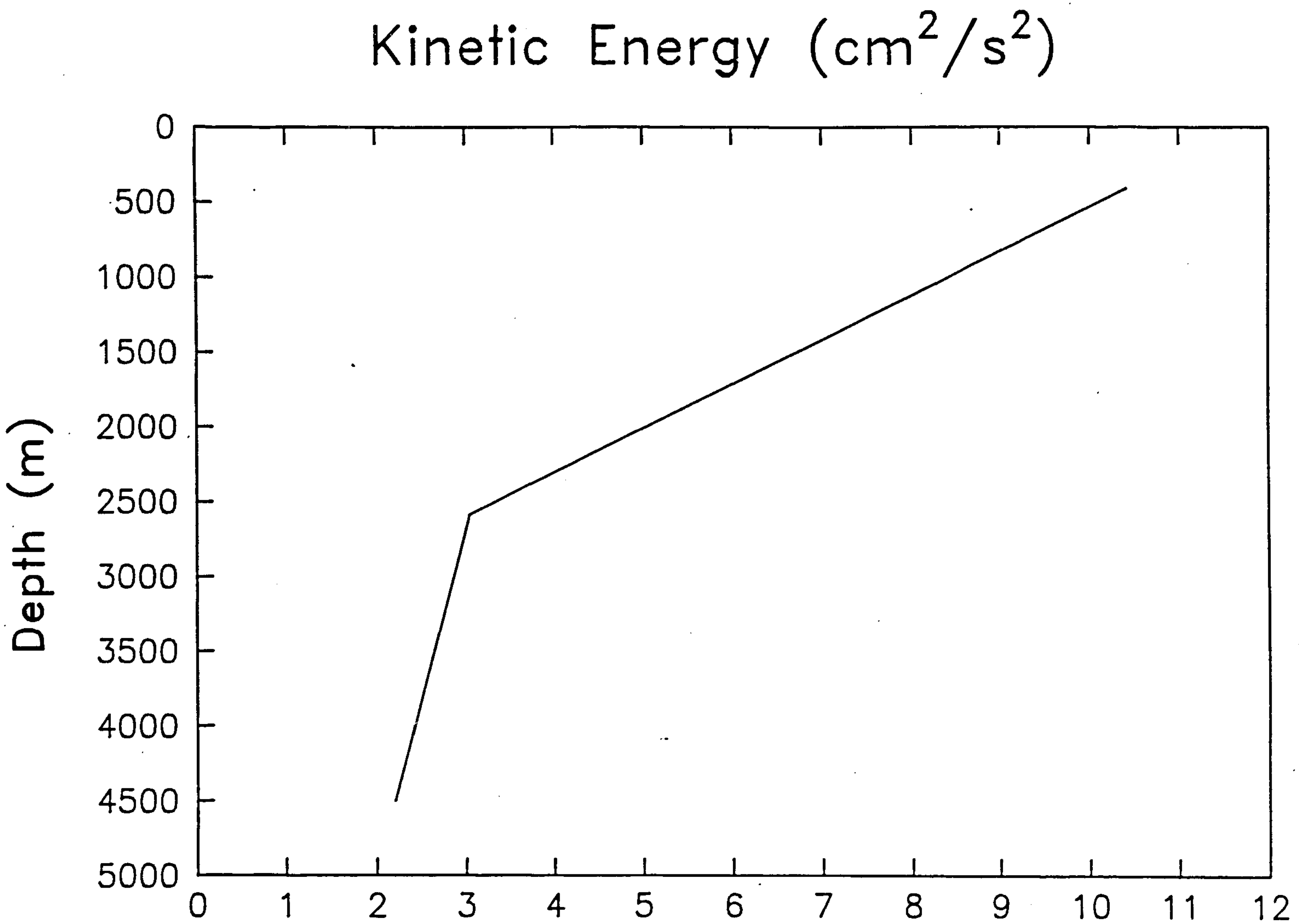

Figure 6(a). The vertical distribution of kinetic energy at the central mooring.

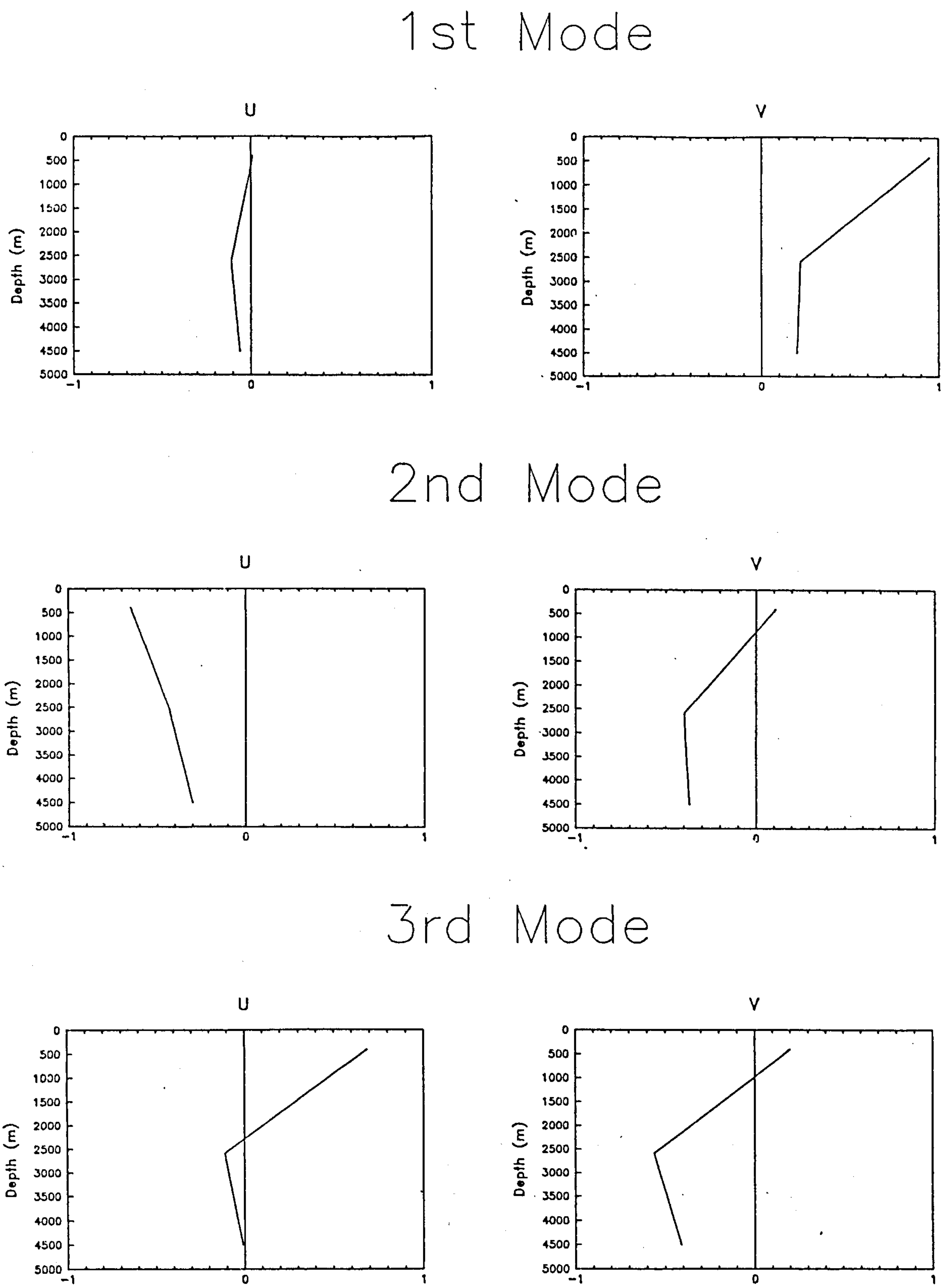

Figure 6(b). The first three vertical empirical orthogonal functions for horizontal velocity.

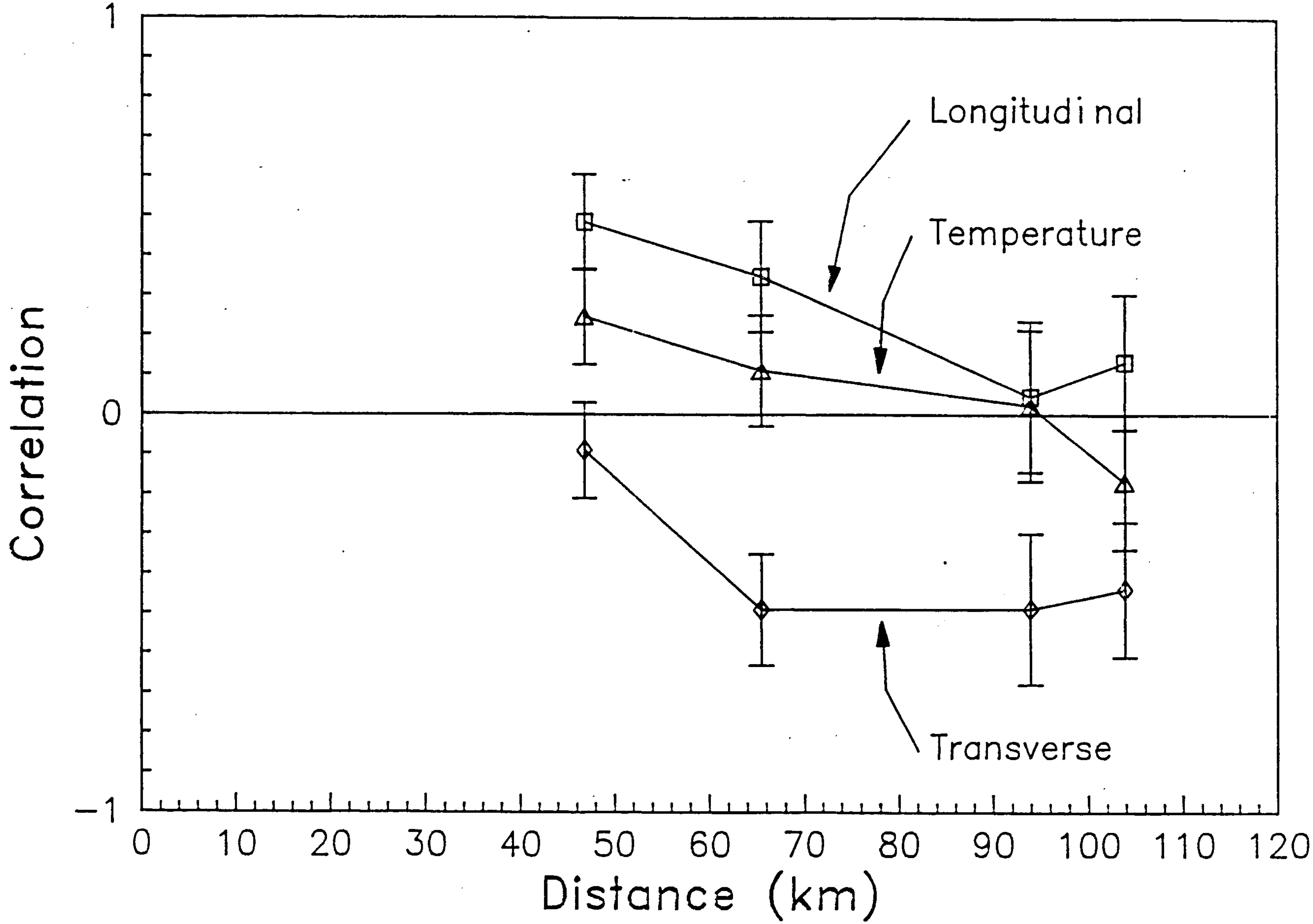

Figure 6(c). Spatial correlation functions as a function of horizontal separation.

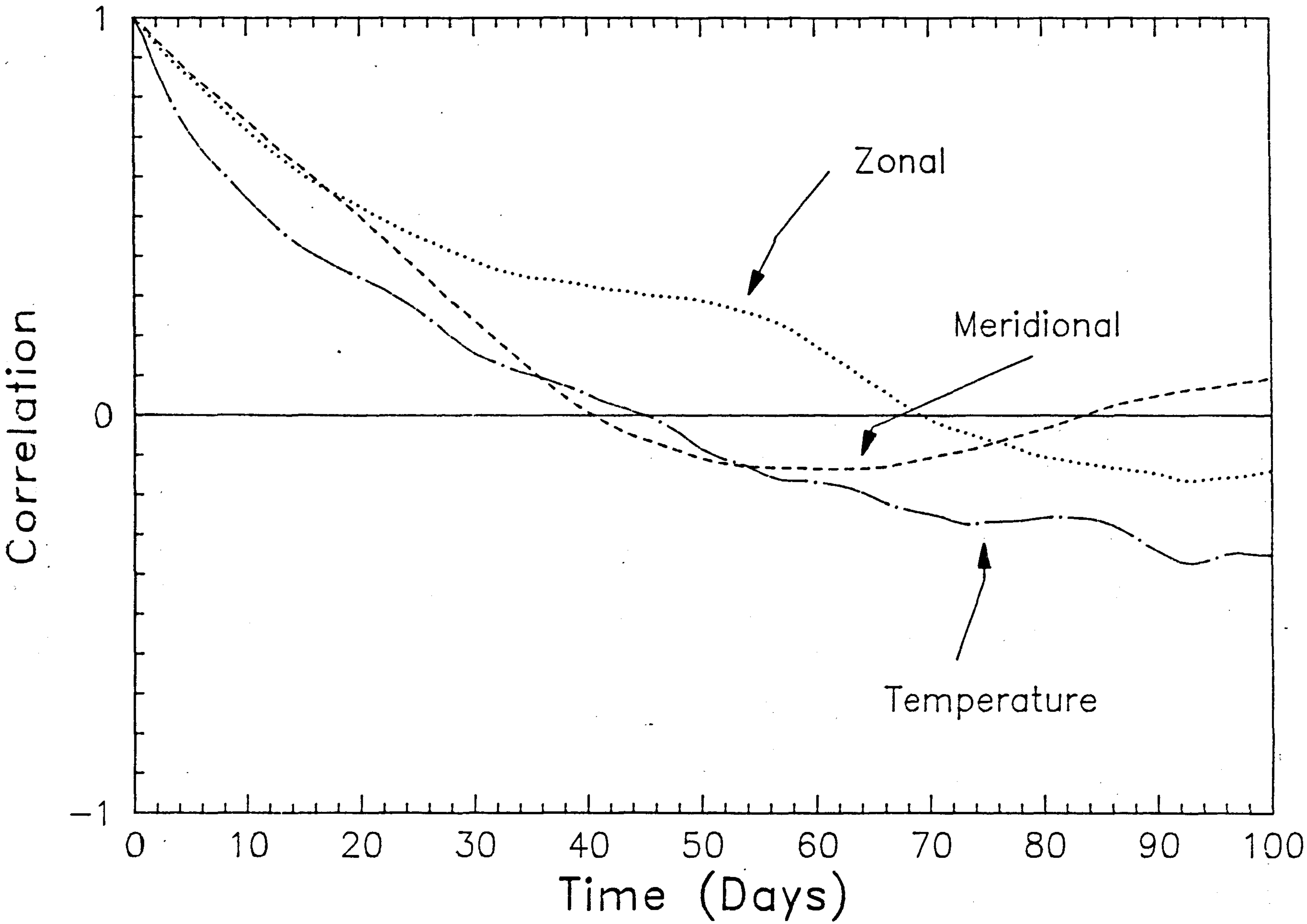

Figure 6(d). Temporal autocorrelation for variables u, v and T at 2450 m.

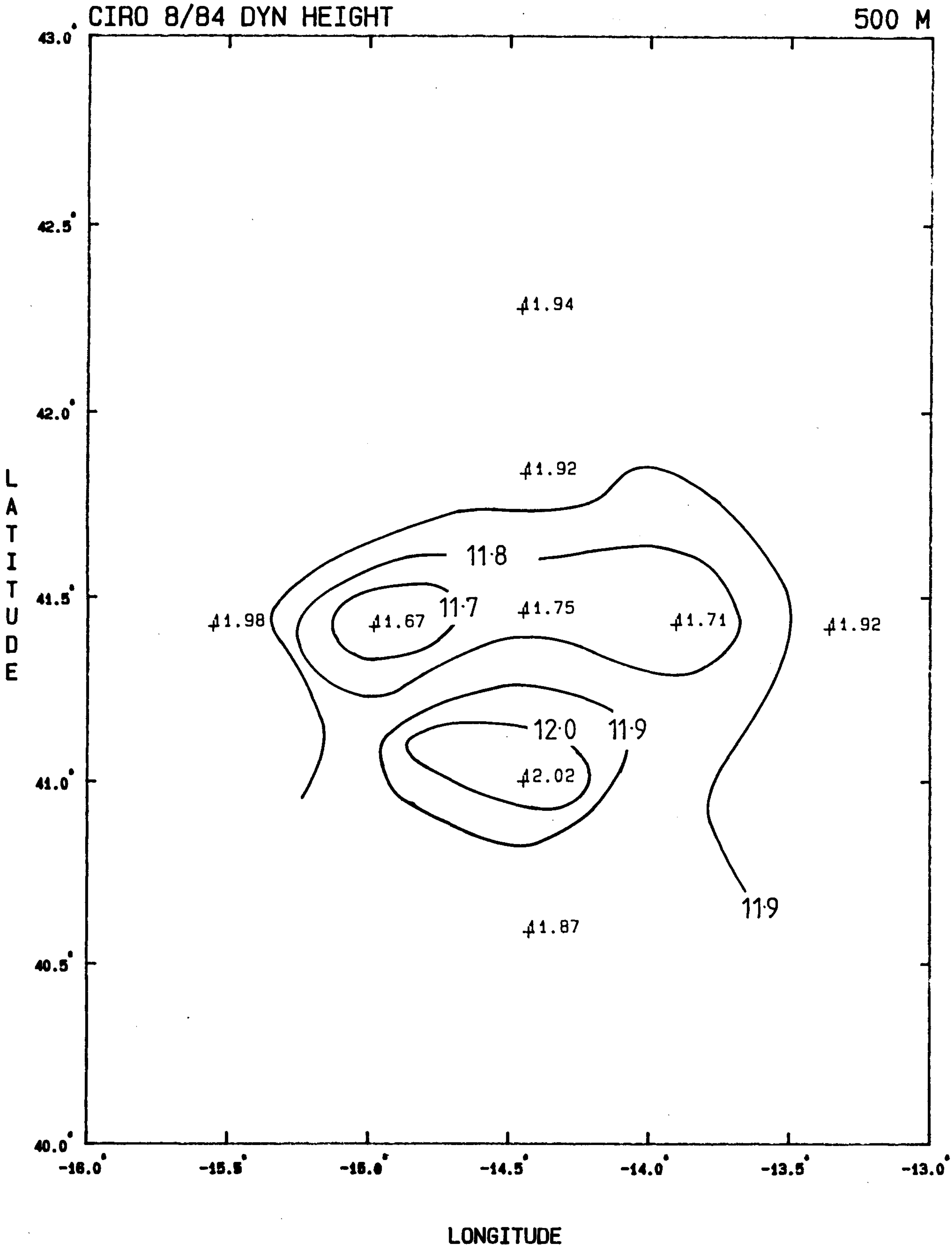

Figure 7(a). A hand contoured plot of the dynamic height at 500 m referenced to 2500 m.

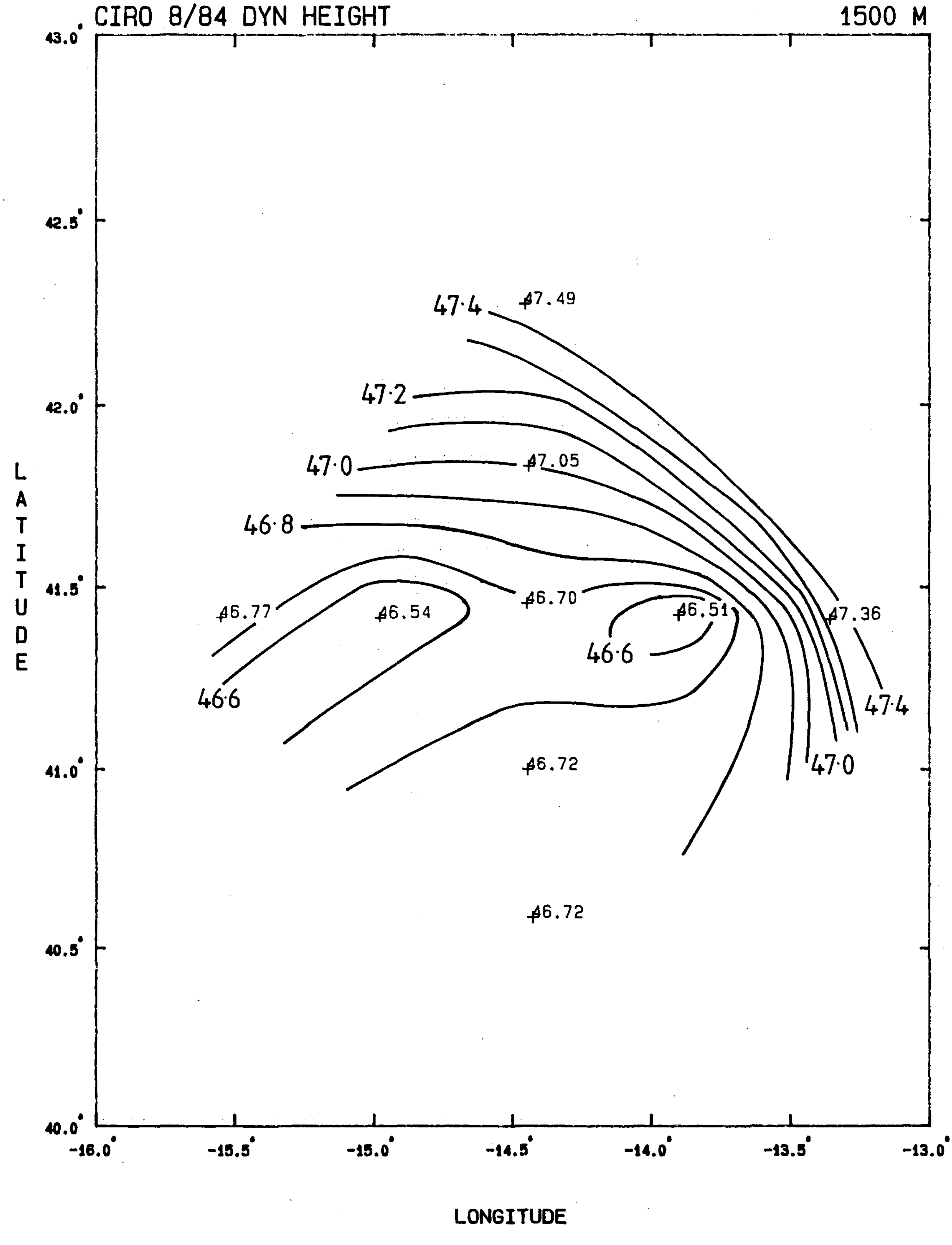

Figure 7(b). A hand contoured plot of the dynamic height at 1500 m referenced to 2500 m.

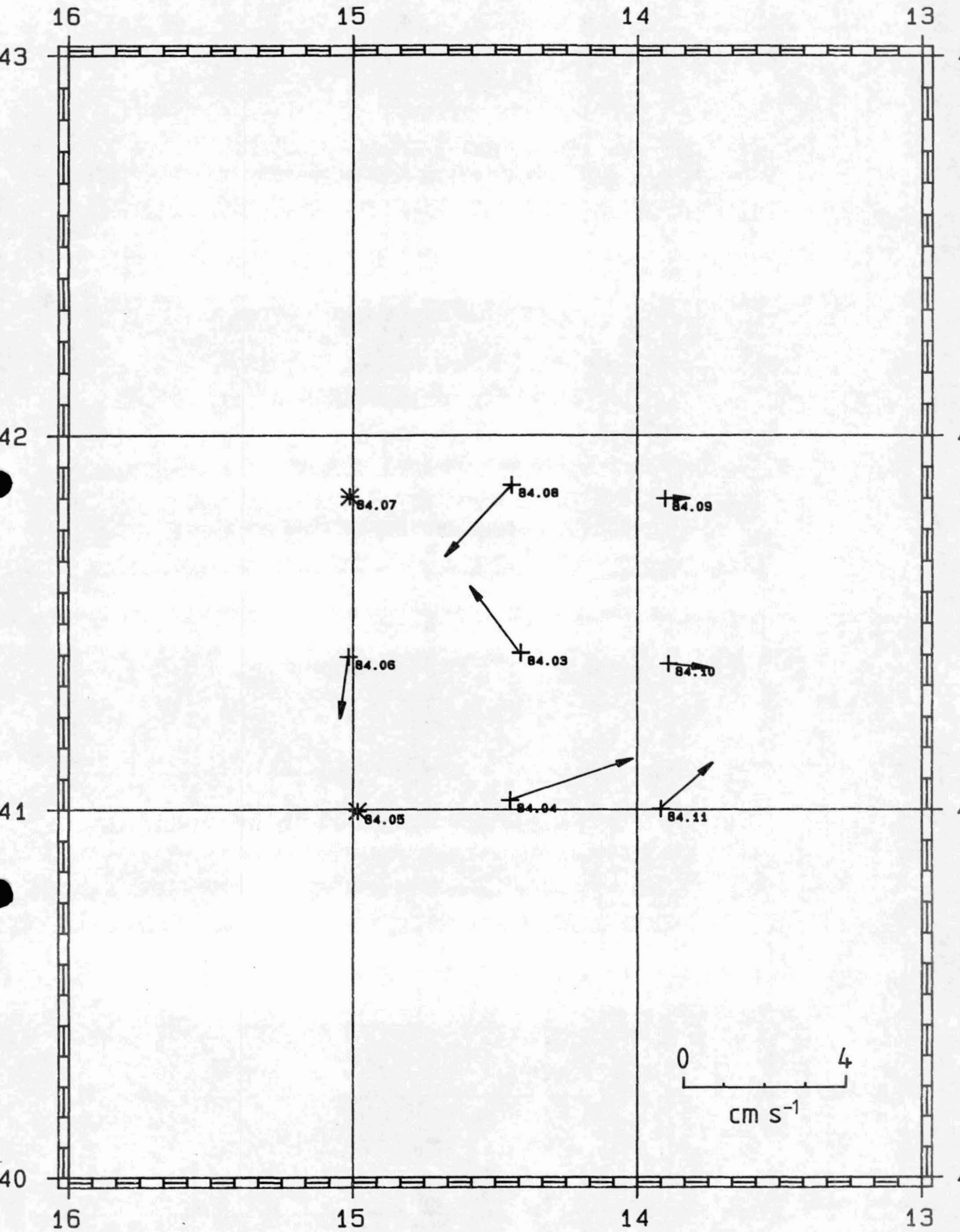

Figure 7(c). Ten day current vectors for the period of CTD survey.

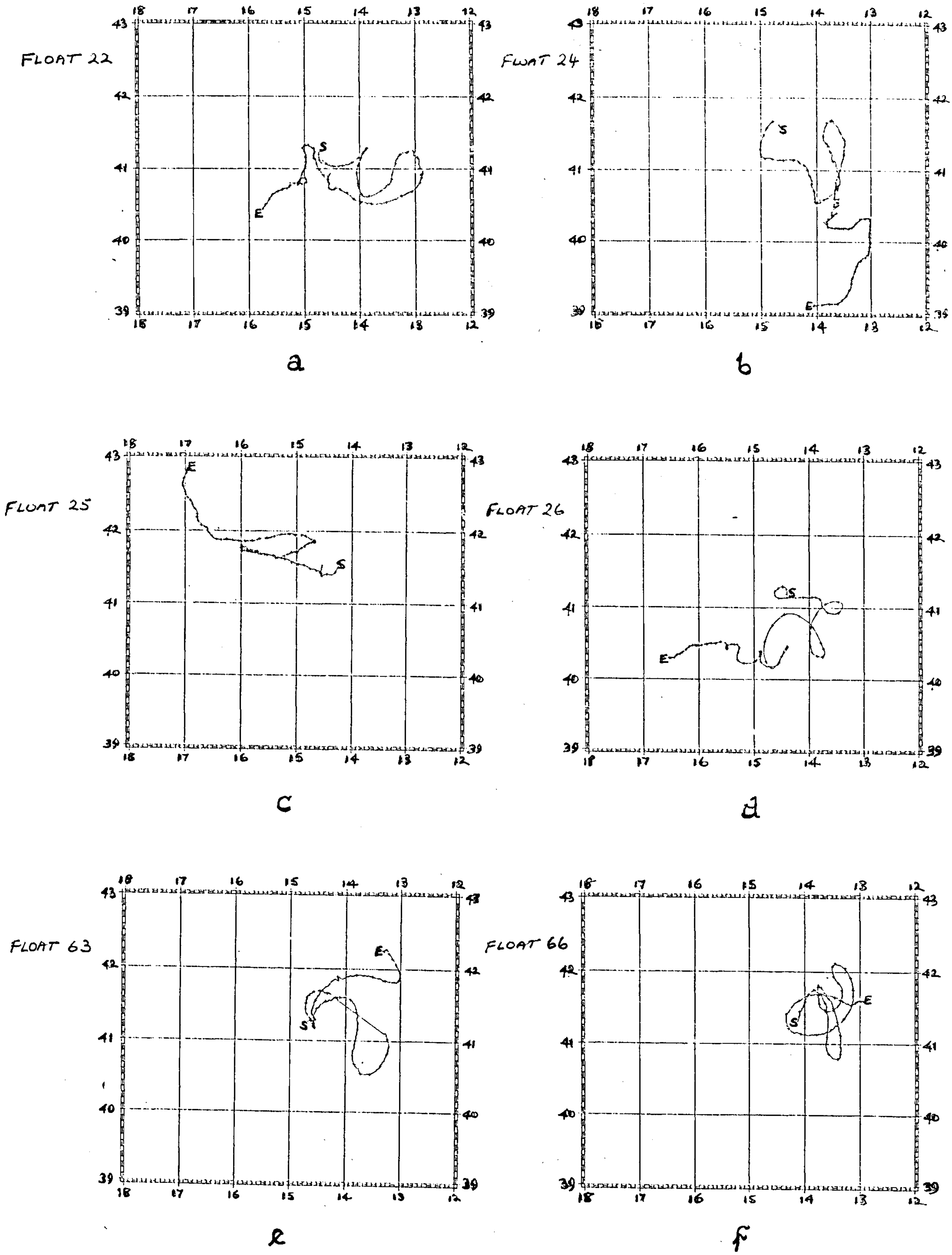

Figure 8(a to f). SOFAR float tracks: S denotes the start position; E the end.

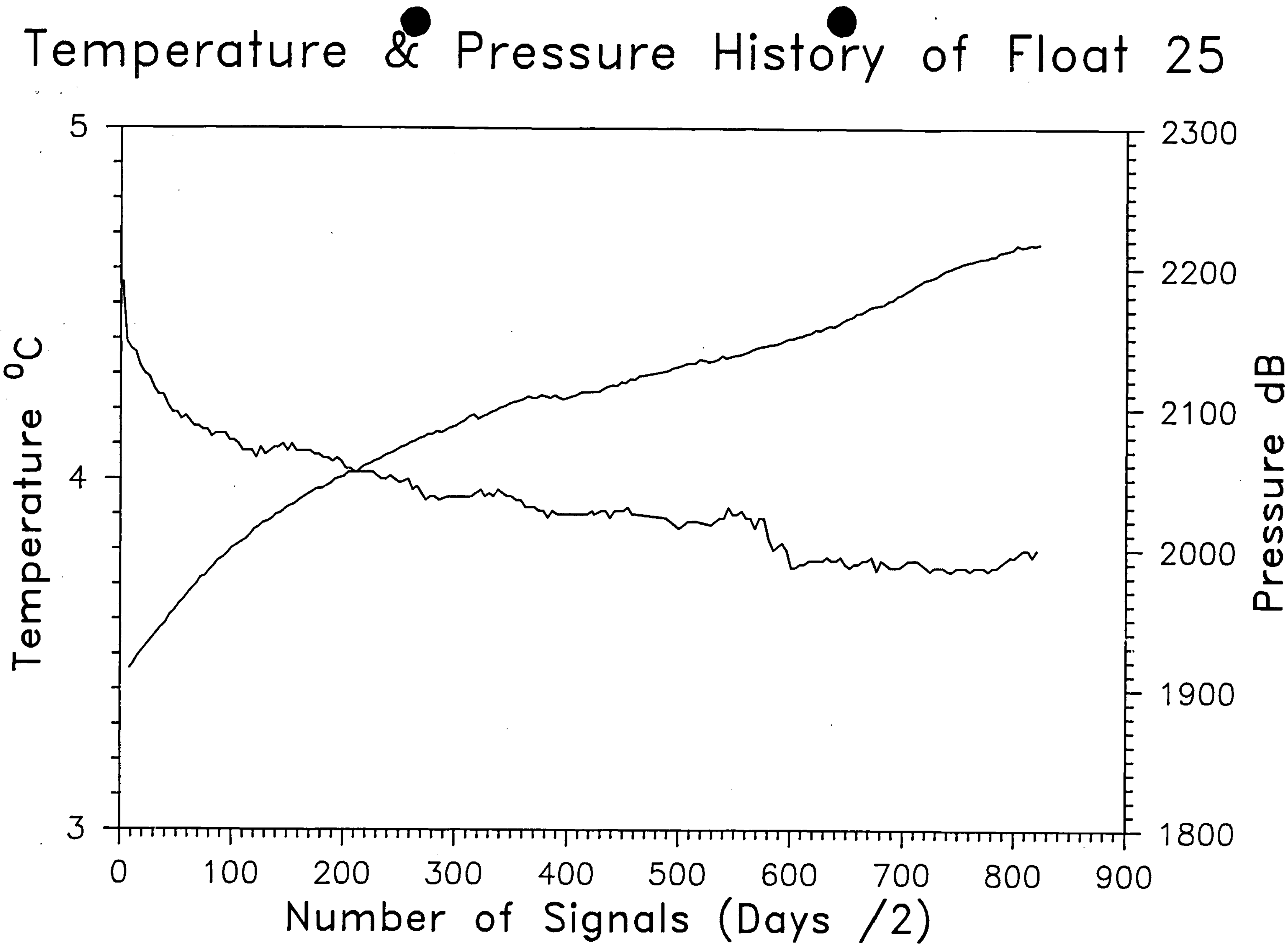

Figure 8(g). Telemetry from Float 25 indicating temperature and pressure.