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Measurements of Currents and Stratification by FRV "Anton Dohrn" during the GATE Equatorial Experiment

by

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1. Introduction

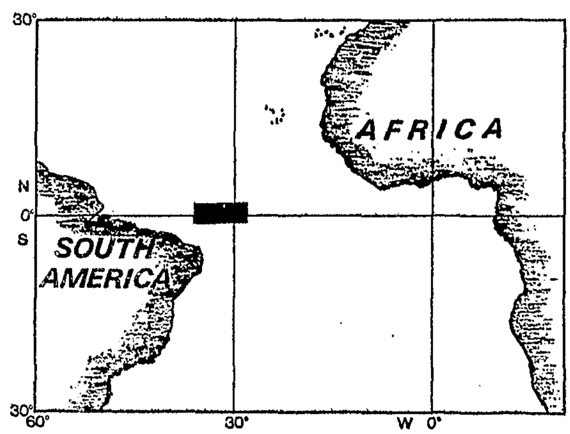
This report is a graphical presentation of oceanographic data obtained during the GATE-Equatorial Experiment in July/August 1974 by the German FRV "Anton Dohrn". The general aim of the international oceanographic experiment has been described by DÜING (1974). The particular aspects of the German oceanographic work were to (i) obtain detailed records of currents and stratification for the Equatorial Undercurrent (EUC) and the South Equatorial Current (SEC) close to the equator and to (ii) investigate the correlation between the depth of the high-shear zone of the EUC/SEC and the intensity/direction of heat and water fluxes between the atmospheric and the oceanographic boundary layer. Preliminary results on the kinematics of the equatorial currents have been published by DÜING et al (1975) and MEINCKE (1975).

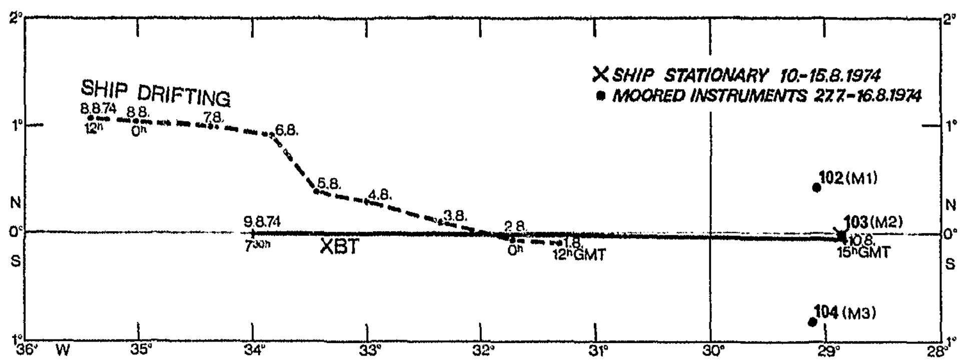
2. Working Area, Navigation

Originally it was planned to keep the FRV "Anton Dohrn" stationary on the equator near 29^{o} W from July 28 to August 15 (Phase 2 of GATE). An array of three current meter systems was

Figure 1

Oceanographic activities
of FRV "Anton Dohrn"
during GATE - Phase 2





moored accordingly (Moorings 102, 103 and 104 in figure 1). However, a meteorological spar-buoy could not be kept on a fixed position as planned, therefore it was left drifting freely in the SEC and the "Anton Dohrn" followed it, taking measurements of current shear and stratification with reference to the buoy from August 1 to 8, 1974 (dashed line in figure 1). When steaming back after completion of the drift, an XBT-section was taken along the equator from 34° W to 28°50' W (full line in figure 1). For the period August 10 to 15, 1974, the vessel remained stationary with respect to moored system 103 and obtained profiles of currents and stratification at high vertical resolution (cross-mark in figure 1).

The absolute navigation during the cruise was solely based on astronomic methods. This, however, does not affect the use of the data. During the drift-station the meteorological spar-buoy served as radar-reference. Drifting in the SEC with a thin super surface structure and a voluminous subsurface structure, it integrated over the upper 30 m of the current field and can be assumed to be an excellent reference for meteorological/oceanographical boundary layer studies (see figure 2). This holds similarly for the data from the stationary phase of the ship's work, when she was using the surface buoy of mooring 103 as a radar reference (see also figure 2). The accuracy of the astronomic navigation could be checked by comparing the "Anton Dohrn"-values for the positions of moorings 102, 103 and 104 against those

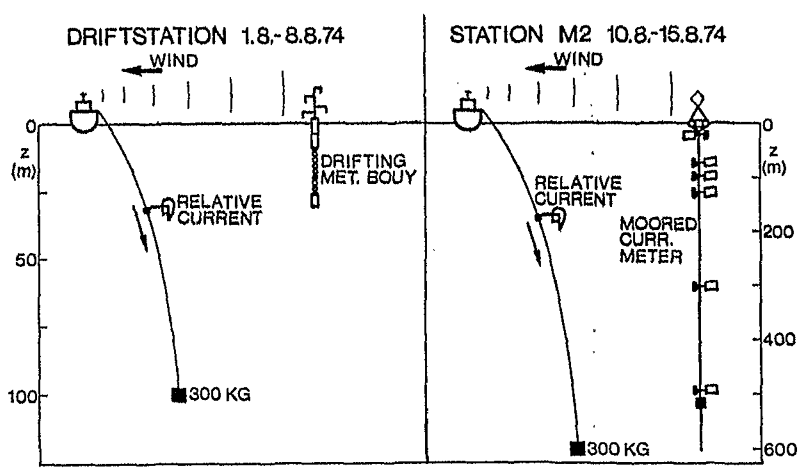


Figure 2
Schematic diagram on the use of the profiling current meter

obtained by repeated satellite fixes from RV "Columbus Iselin". They all showed to be within ± 1 nm.

3. Instrumentation and Data Reduction

The instruments used for the oceanographic programme were a CTD, an XBT, a profiling current meter and moored systems containing current meters and thermistor cables.

a) The CTD used was a Bathysonde T 87/3 manufactured by Howaldt. Data treatment, calibration and reduction has been described by PETERS (1976). The accuracy of pressure, temperature and salinity can be safely given as ±1dbar, ±0.01° C and ±0.01 °/oo.

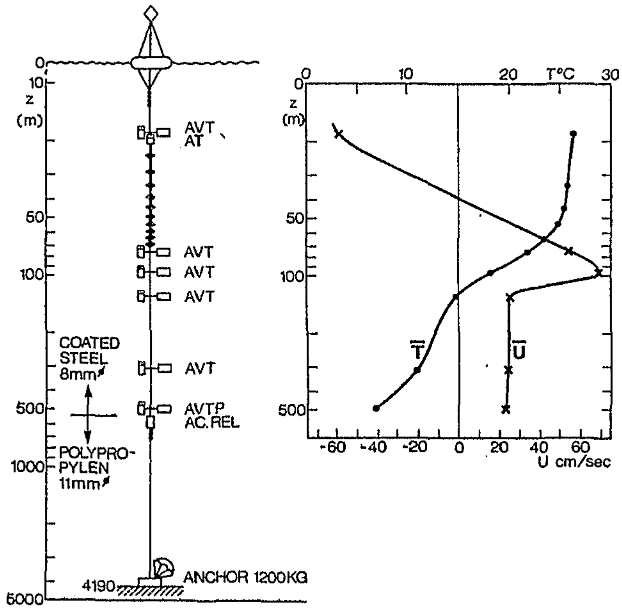
b) The expendable bathythermograph (XBT) produced by Plessey (Sippican) was used with 450 m-probes. The analogue records were digitized with 5 dbar resolution and checked against the readings of a continously recording PT 100 mounted at 3.5 m depth. The accuracy can be given to be ±0.2° C.

c) The profiling current meter (PCM) consisted of a Bergen self-recording current meter (Aanderaa model RCM-4) mounted to a frame which is adjustable in its buoyancy. The system is trimmed to sink at a rate between 6 and 12 m per minute. After the hydro-wire was lowered the PCM was attached to the wire and was allowed to slide down to the bottom weight. On its way it recorded the speed and the direction of the flow relative to the hydro-wire at a rate of 1 cycle per 30 seconds. The ship's drift vector during the descent of the PCM was determined from radar-readings every 10 minutes. The operation principle for the drifting and for the stationary phase of the ship's work is demonstrated in figure 2. The relative errors are less than ±10 cm/sec and the absolute errors are less than ±20 cm/sec for the current components and ±2 dbar for the pressure (for details see MEINCKE et al, 1977).

d) Three moorings were deployed (positions 102, 103 and 104 in figure 1) which contained 6 Aanderaa RCM-4 current meters and an Aanderaa thermistor cable with 11 thermistors over a length of 50 meters. A schematic diagram on the mooring configuration and on the mean profile of temperature and current speed in the upper 500 m are given in figure 3. The mooring was a taut-wire system. Since the toroidal surface-buoy was the only buoyancy in the mooring, the depth

<u>Figure 3</u>

Schematic diagram on the moored systems and 18-day average of temperature and the easterly current component.
A = Aanderaa Instrument
V = Velocity
T = Temperature
P = Pressure



variations of the instruments remained less than 3 dbar as recorded with pressure sensors on the lower current meters. No attempt has been made to analyse possible horizontal mooring displacements and their effect on current speed and direction in particular. The instrumental accuracies of the RCM-4 are ±2 % of the speed value, ±5 degrees for the direction and ±0.1° C for the temperature. The accuracy for the temperature values from the thermistor cables is also ±0.1° C.

4. Acknowledgements

The engaged help of K.-H. Prien and the crew of FRV "Anton Dohrn" during the cruise is highly appreciated. M. Bock and H.-P. Cornus helped processing the data and the cartography group of the institute prepared the graphs. The field experiment was financed by the Deutsche Forschungsgemeinschaft.

5. References

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6. <u>Results of Ship-bound Measurements</u>

The following pages show data as obtained by means of a CTD, a profiling current meter and an XBT.

<u>Remarks on individual parameters</u>

a) T, S, σ_t from CTD: All graphs have been prepared after the computed and edited data were interpolated to 1 dbar and after a running mean over 3 values was taken.

b) U, V: The graphs have been prepared after the data were corrected for the ship's drift and after obvious errors were removed by hand. No interpolation for depth and no smoothing was applied.

c) Ri: The gradient Richardson numbers were computed from

$$Ri = \frac{g}{\bar{\rho}} \frac{\Delta\rho \cdot \Delta p}{(\Delta U)^2 + (\Delta V)^2}$$

g = acceleration due to gravity

$\bar{\rho}$ = mean density between two successive data points

$\Delta\rho$ = density difference between two successive data points

Δp = pressure difference between two successive data points

ΔU, ΔV = velocity component's difference between two successive data points

The successive data points used were those determined by the availability of U- and V-values

d) T from XBT's: Computer-contoured by using linear interpolation between values at 5 dbar intervals.

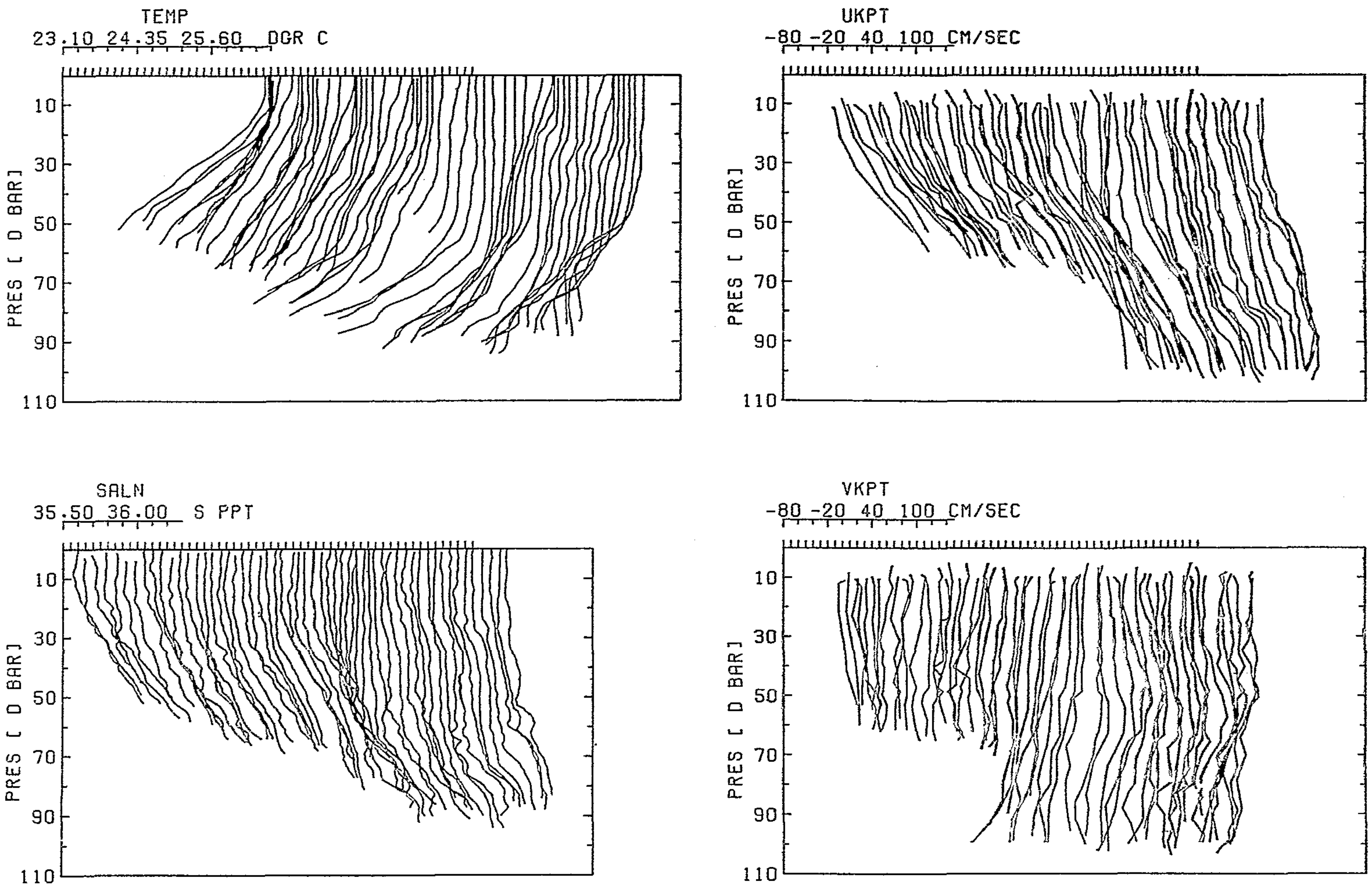
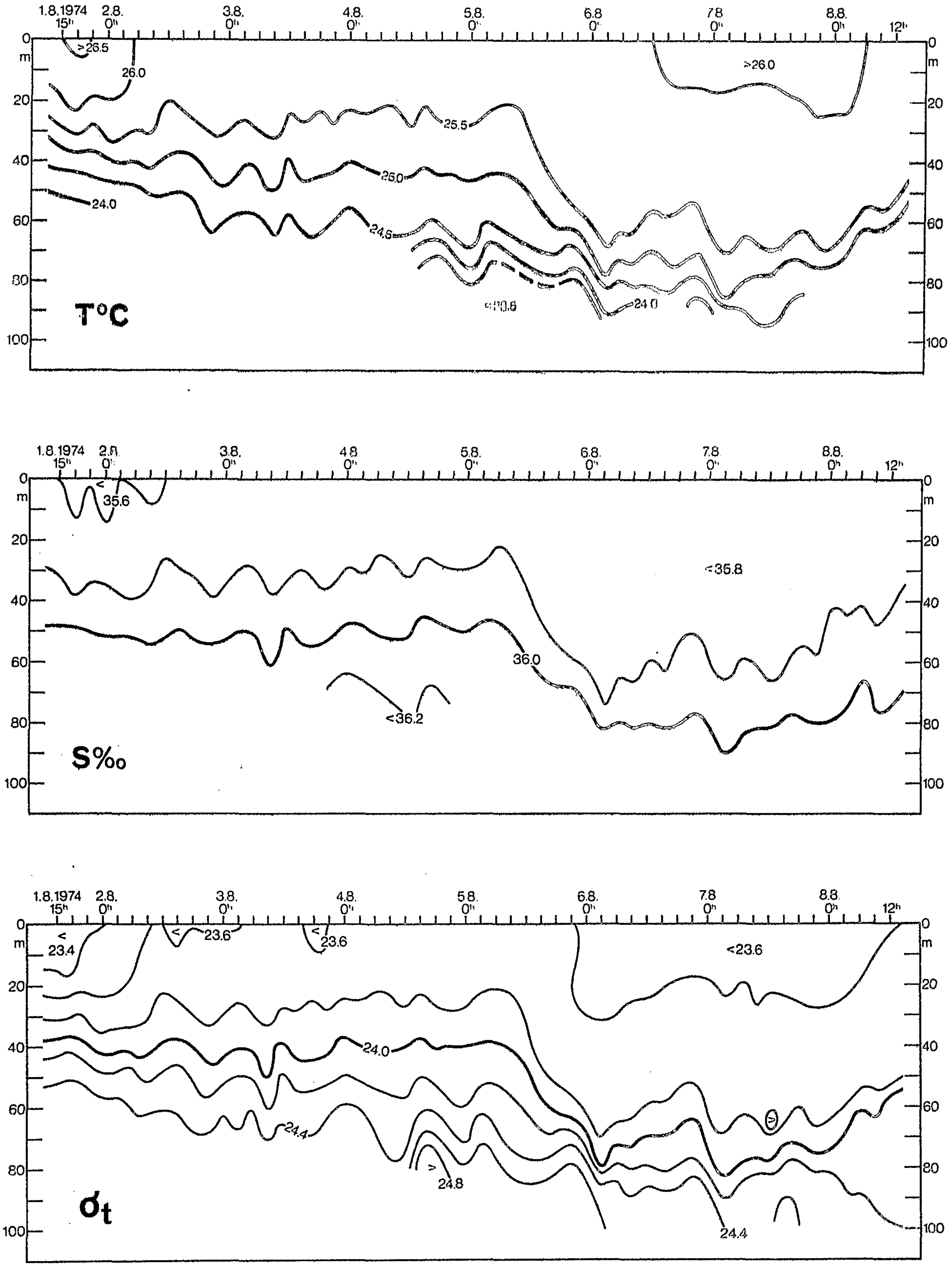


Figure 4

Profiles of temperature (T), salinity (S), relative current's east-component (U) and relative current's north-component (V) obtained at 3-hourly intervals during the drift station (see Figure 1)
Begin: August 1, 1974, 15.00 GMT



<u>Figure 5</u>

Isopleths based on data shown in Figure 4

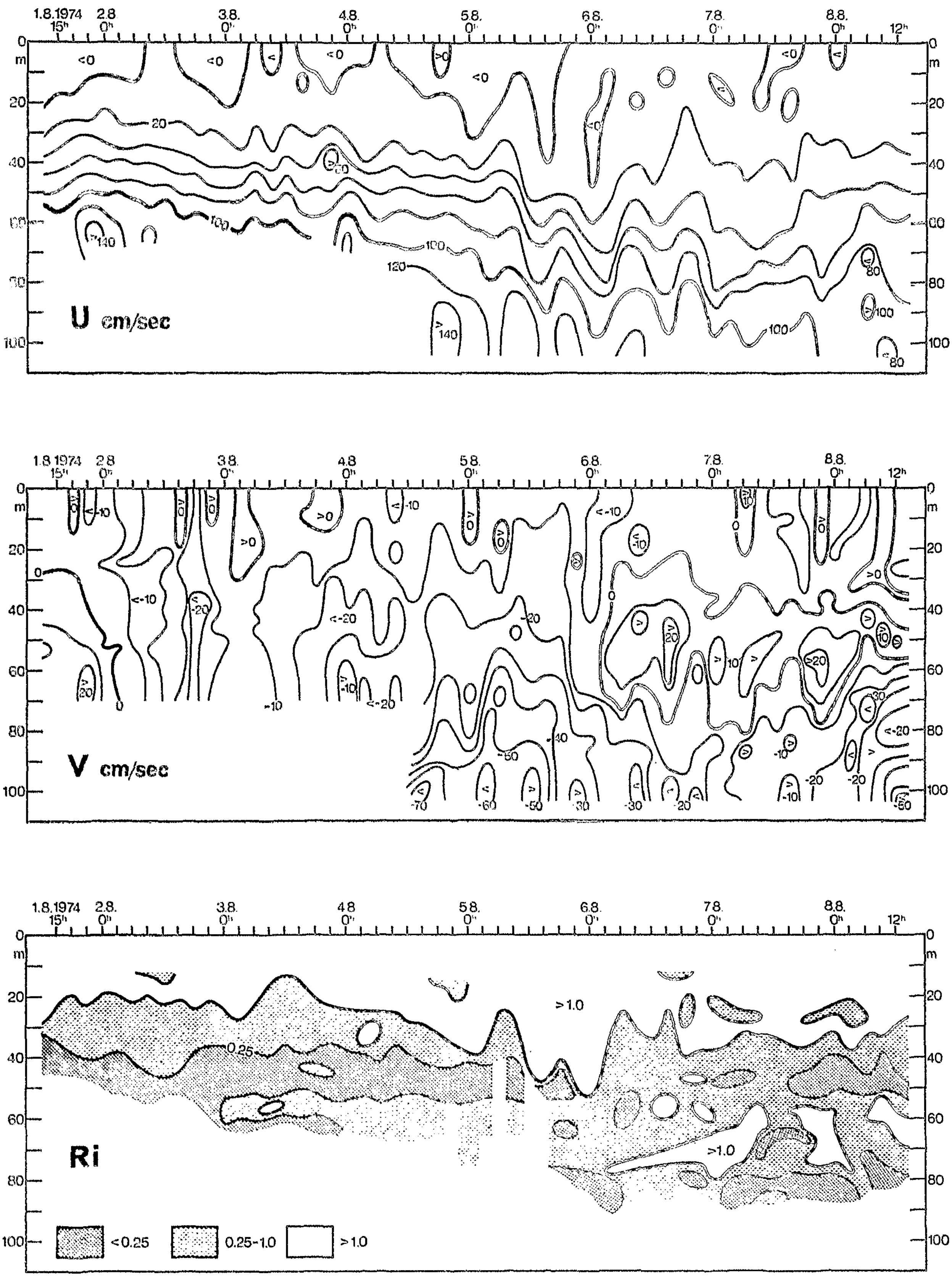


Figure 6

Isopleths based on data shown in Figure 4 and gradient Richardson numbers (Ri)

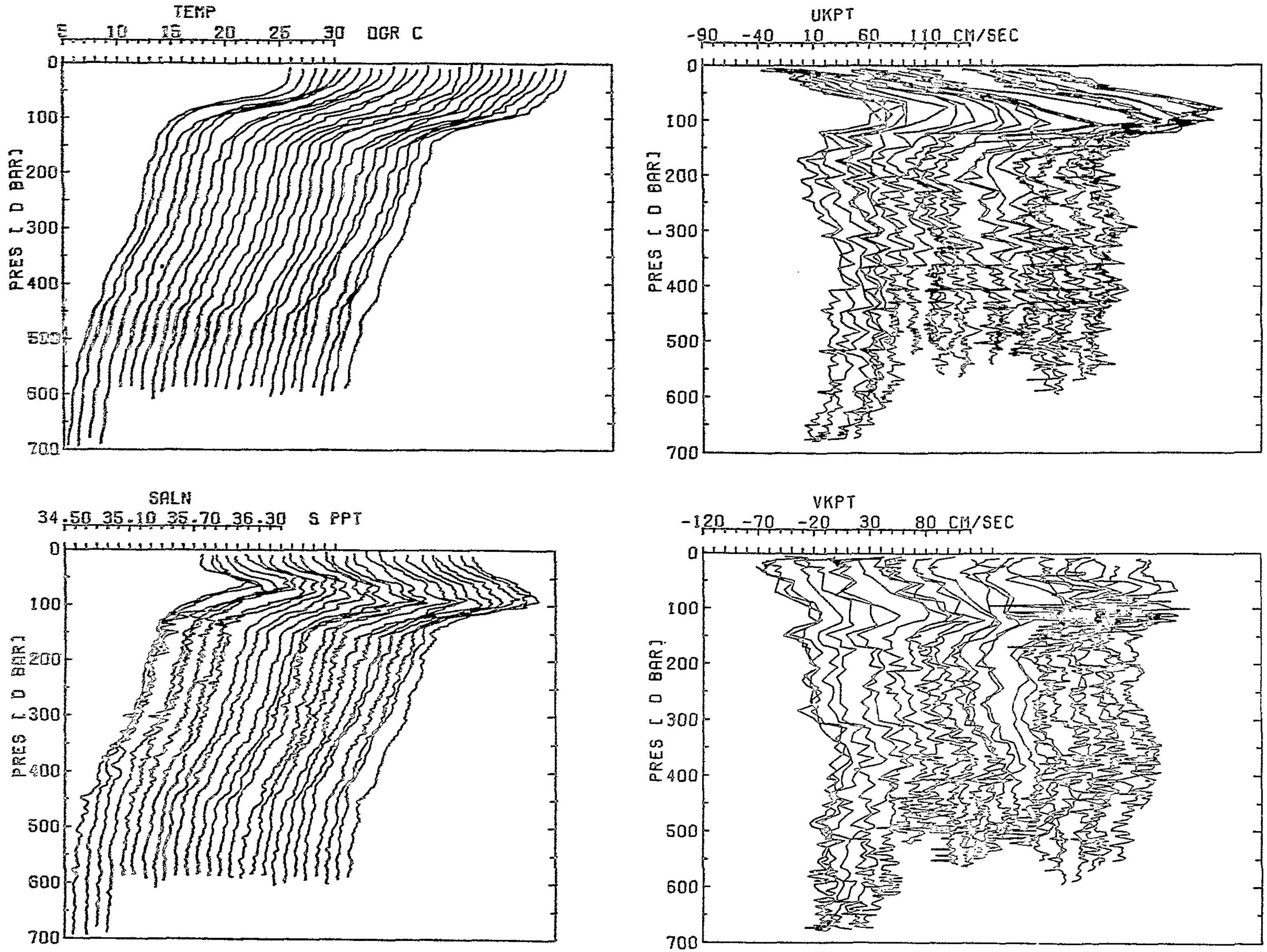
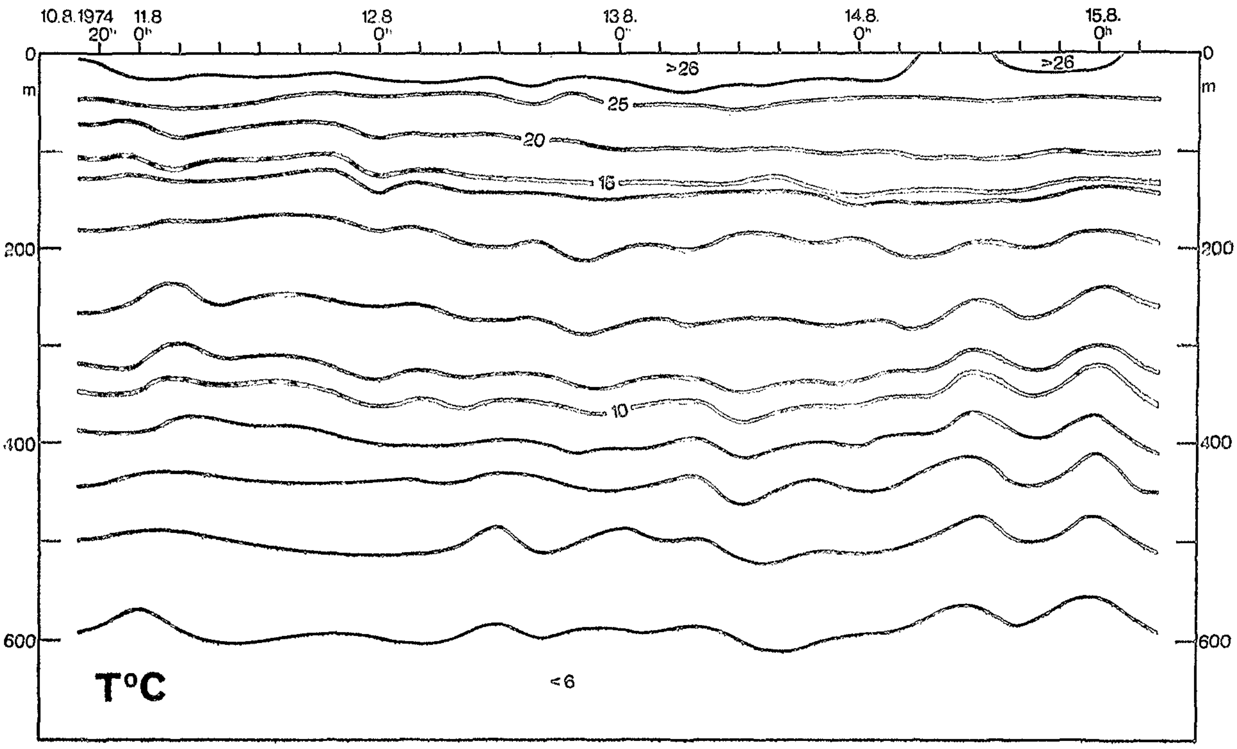
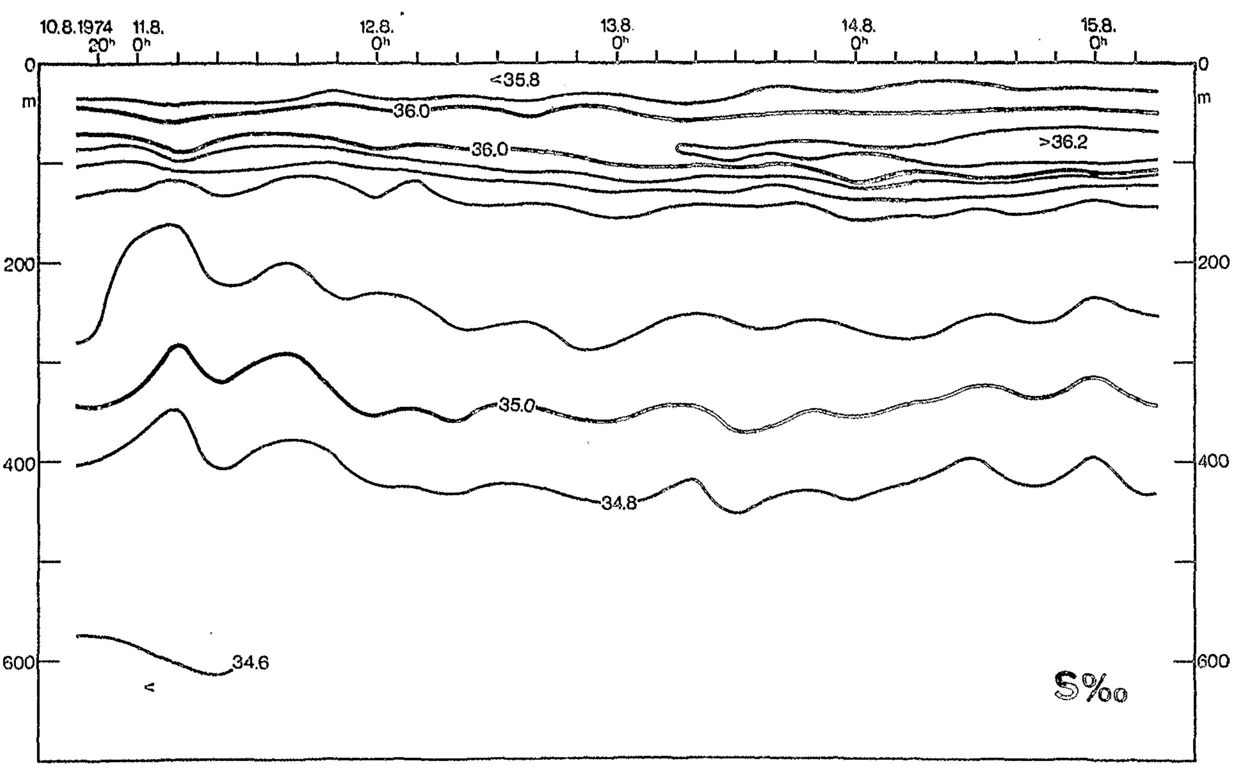


Figure 7

Profiles of temperature (T), salinity (S), absolute current's east-component (U) and absolute current's north-component (V) obtained at 4-hourly intervals during the permanent station at **GATE-position** M2 (see Figure 1)
Begin: August 10, 1974, 20.00 GMT





<u>Figure 8</u>

Isopleths based on data shown in Figure 7

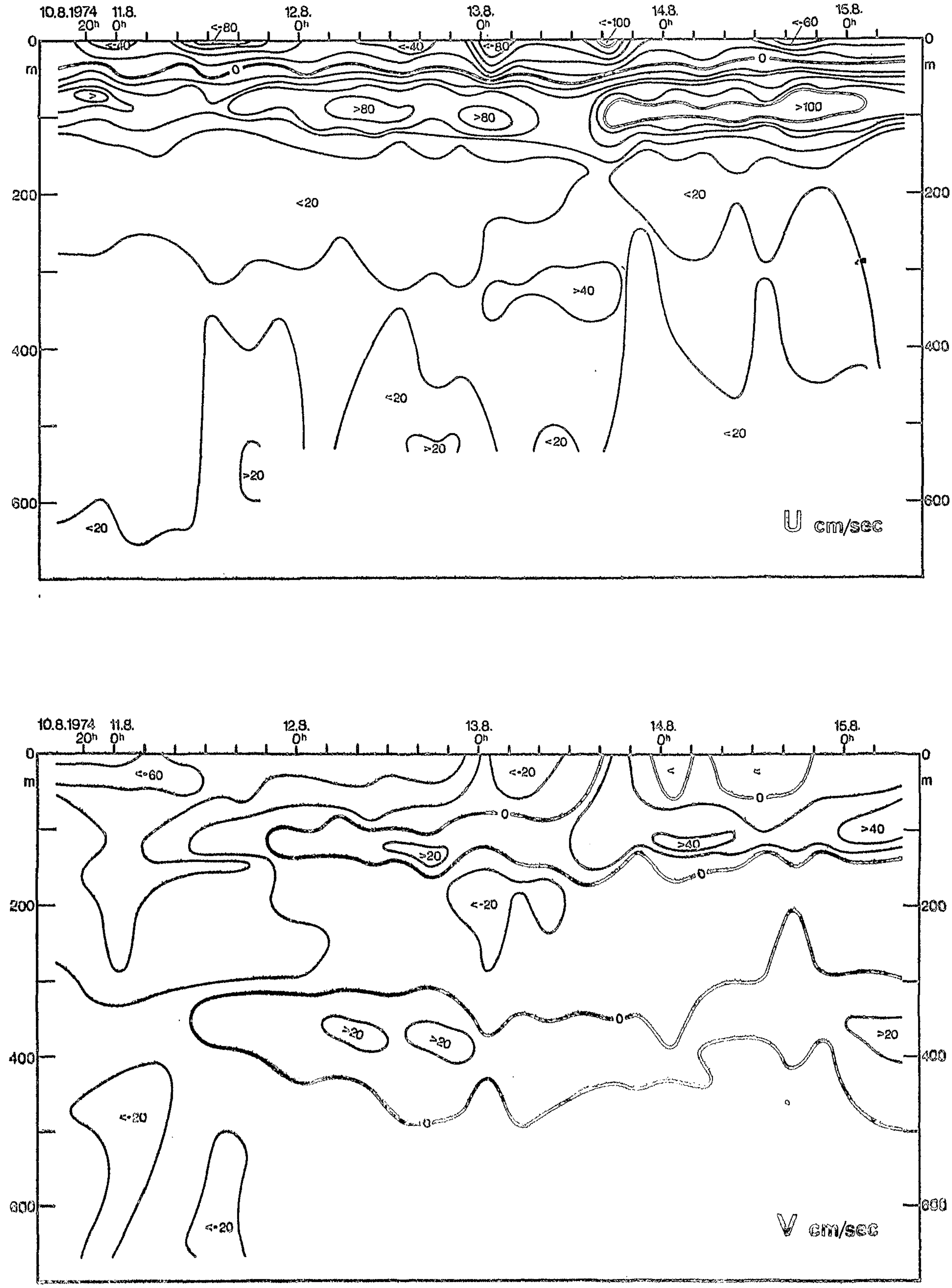


Figure 9

Isopleths based on data shown in Figure 7

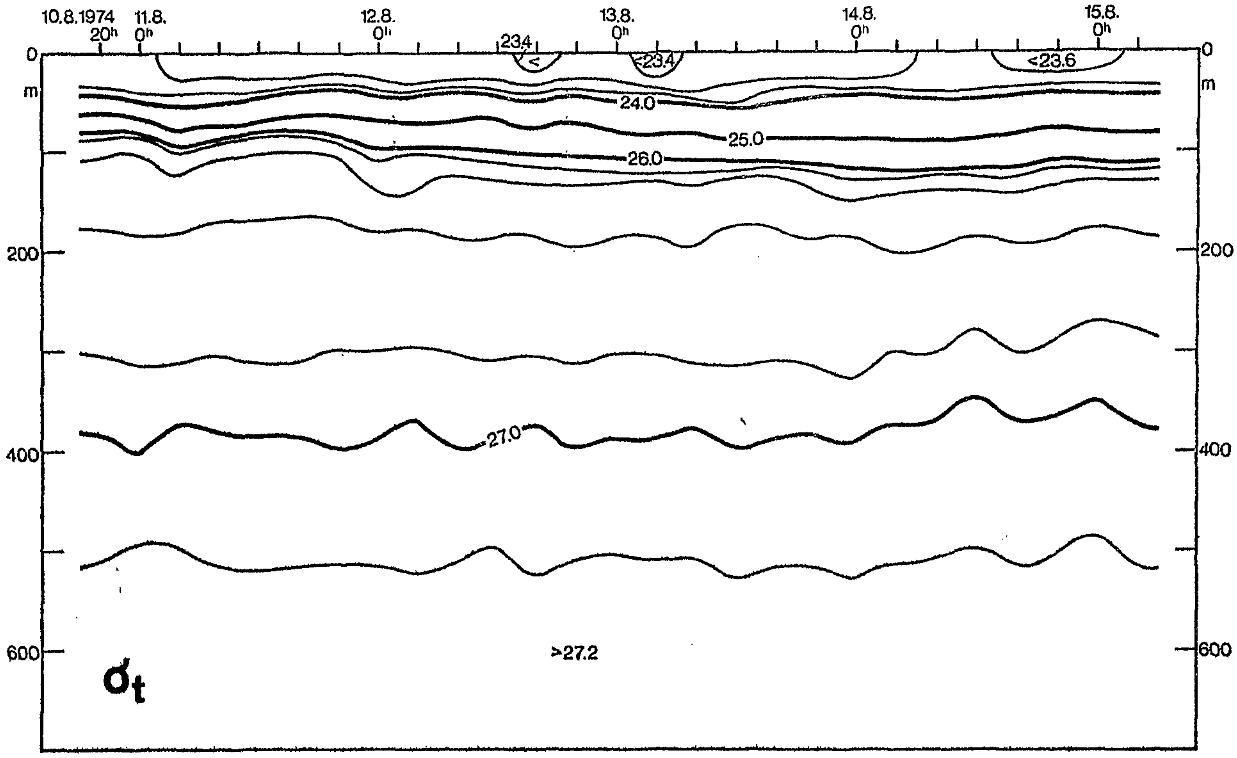


Figure 10
Isopleths based on data shown in figure 7

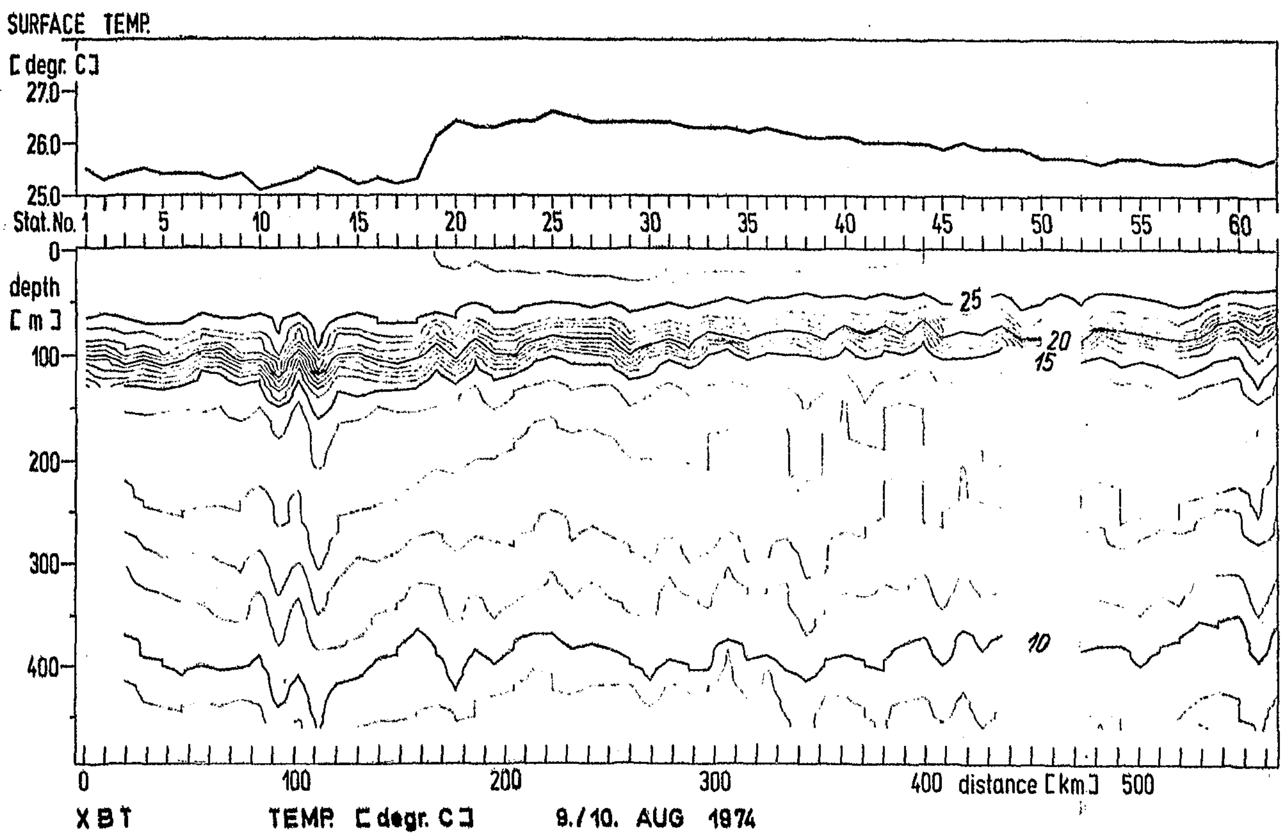


Figure 11
XBT-temperature section along the equator (see Fig. 1)

7. Results of measurements from moored systems

The following pages give statistics and graphs on data which were obtained on moorings 102 (M1), 103 (M2) and 104 (M3). Unfortunately only mooring 103 gave a 100 % data return, in mooring 104 the battery of the upper current meter was faulty and the lower part of mooring 102 was lost during recovery because of improper operation of the acoustic release system.

Remarks on individual parameters

a) U, V, T as time series: All time series plots are based on hourly mean values. They are presented as deviations from the overall mean, which is indicated on the left of the zero-line in each case.

b) U, V combined for progressive vector diagrams: The plots are based on hourly mean values

c) U, V, T as isopleths: Computer-contoured by using linear interpolation between hourly mean values

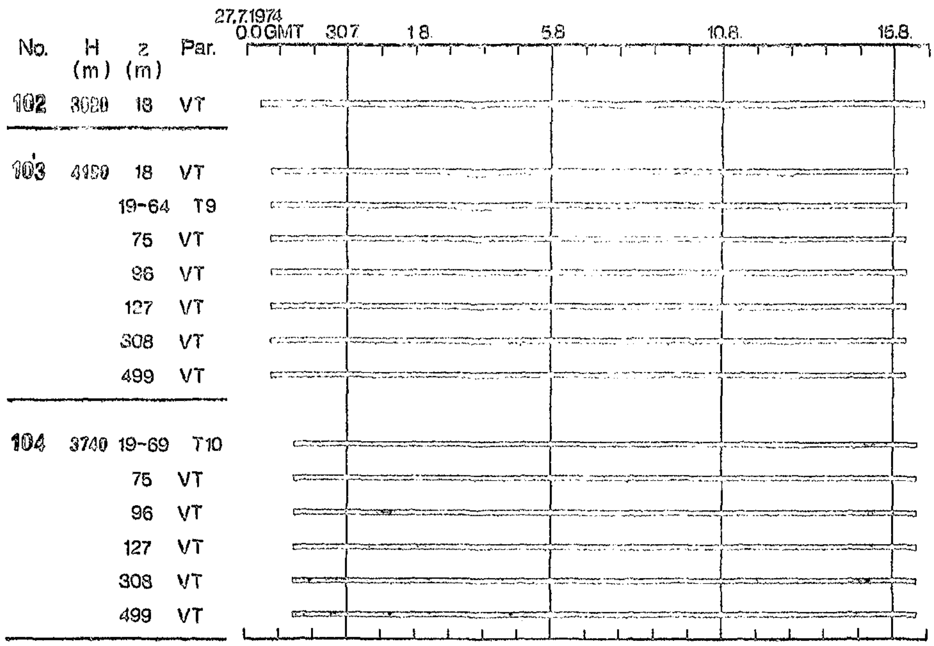


Figure 12

Operating time of moored instruments
H = bottom depth, z = instrument depth
V = velocity record, T = temperature record
Tn = n records from thermistor cable

MOORING NO.: 102 (M1), BOTTOM DEPTH: 3620 m

POSITION: $\phi = 00^{0}25,0'$ N $\lambda = 29^{0}04,0'$ W

START: 27.07.1974, 10.00 GMT STOP: 15.03.1974, 21.00 GMT Δt = 5 min

REMARKS: LOWER PART OF MOORING LOST DURING RECOVERY

DEPTH (m)	PAR.	MEAN	VARIANCE	STD DEV.	SKEWN.	KURT.	MIN	MAX	VECTOR MEAN	DIR MEAN	INSTR.
18	U	-54.00	392.10	19.80	-0.89	3.72	-121.5	-10.1	54.2	265.6	AVT
	V	-4.20	778.20	27.90	-0.30	2.27	- 70.5	67.6			
	T	26.46	0.33	0.58	0.01	1.48	25.6	27.3			

Table 1

Detailed statistics on data from moored instruments

Explanation: U = east component of current
V = north component of current
T = temperature
VECTOR MEAN = speed of mean flow
DIR MEAN = direction of mean flow in geographical orientation
AVT = Aanderaa recording current meter
AT = Aanderaa recording thermistor cable

MOORING NO.: 103 (M2), BOTTOM DEPTH: 4190 m

POSITION: $\phi = 00^{0}01,0'$ S $\lambda = 28^{0}52,0'$ W

START: 27.07.1974, 18.00 GMT STOP: 15.08.1974, 09.00 GMT Δt = 5 min (AVT)
10 min (AT)

DEPTH (m)	PAR.	MEAN	VARIANCE	STD DEV.	SKEWN.	KURT.	MIN	MAX	VECTOR MEAN	DIR MEAN	INSTR.
18	U	-59.50	609.30	24.68	-0.56	2.37	-122.6	-0.1	60.0	262.4	AVT
	V	-7.90	873.80	29.56	-0.21	2.23	-71.3	51.2			
	T	26.31	0.29	0.53	0.45	0.45	25.5	27.4			
19	T	26.05	0.31	0.56	0.54	2.19	25.2	27.4			AT
29	T	25.80	0.24	0.49	0.75	2.44	25.1	27.0			AT
34	T	25.65	0.19	0.43	1.00	3.01	25.0	26.8			AT
39	T	25.59	0.11	0.33	1.07	3.59	24.9	26.6			AT
44	T	25.34	0.11	0.34	0.32	3.94	23.9	26.3			AT
49	T	25.13	0.14	0.37	-0.67	3.07	23.9	26.0			AT
54	T	24.83	0.21	0.46	-0.60	2.48	23.5	25.8			AT
59	T	24.52	0.36	0.60	-0.46	2.70	22.1	25.6			AT
64	T	23.40	1.33	1.15	-0.65	3.09	19.6	25.2			AT
75	U	53.90	414.70	20.36	0.43	2.75	12.6	115.7	55.0	78.5	AVT
	V	10.90	711.40	26.67	0.08	2.02	-40.7	71.0			
	T	21.84	28.85	1.70	-0.25	2.25	17.6	24.9			
96	U	68.20	290.30	17.04	0.35	2.61	35.3	112.6	68.9	81.7	AVT
	V	10.00	595.30	24.40	-0.36	2.39	-49.3	61.3			
	T	18.25	2.69	1.64	0.23	2.48	15.1	22.2			
127	U	26.30	72.80	8.54	0.75	3.56	5.4	56.4	30.9	58.3	AVT
	V	16.20	246.00	15.68	0.11	1.97	-23.2	49.7			
	T	14.92	0.60	0.78	0.47	2.55	13.6	17.1			
308	U	26.10	10.70	3.28	-0.97	7.69	7.0	35.3	26.2	86.2	AVT
	V	1.70	87.90	9.38	0.12	2.90	-25.2	27.5			
	T	10.96	0.11	0.34	0.17	2.78	10.0	11.7			
499	U	22.90	10.00	3.17	-0.62	3.85	11.2	31.2	23.0	94.7	AVT
	V	-1.90	75.90	8.71	-0.56	3.29	-26.6	20.3			
	T	6.85	0.04	0.21	0.76	3.34	6.4	7.6			

Table 1 continued

MOORING NO.: 104 (M3), BOTTOM DEPTH: 3740 m

POSITION: $\phi = 00^{0}49,5'$ S $\lambda = 29^{0}06,0'$ W

START: 28.07.1974, 10.30 GMT STOP: 15.08.1974, 13.30 GMT Δt = 5 min (AVT)
10 min (AT)

REMARKS: UPPER CURRENT METER HAD BATTERY FAILURE

DEPTH (m)	PAR.	MEAN	VARIANCE	STD DEV.	SKEWN.	KURT.	MIN	MAX	VECTOR MEAN	DIR MEAN	INSTR.
19	T	25.26	0.05	0.22	-0.05	1.97	24.9	25.7			AT
24	T	25.20	0.05	0.22	-0.02	2.02	24.8	25.7			AT
29	T	25.19	0.05	0.23	-0.07	2.16	24.8	25.6			AT
34	T	25.17	0.07	0.26	0.33	2.16	25.8	26.7			AT
39	T	25.06	0.06	0.24	0.17	2.20	24.5	25.6			AT
44	T	24.86	0.07	0.24	-0.07	2.46	24.2	25.4			AT
49	T	24.83	0.07	0.26	-0.39	2.47	24.2	25.4			AT
59	T	24.51	0.20	0.44	-0.94	3.61	22.7	25.2			AT
64	T	24.25	0.49	0.70	-1.52	6.10	20.9	25.1			AT
69	T	23.65	1.31	1.14	-1.66	6.05	18.1	24.9			AT
75	U	33.80	1382.00	37.17	0.32	1.96	-25.3	111.0			AT
	V	20.00	573.80	23.95	-0.33	2.40	-27.0	69.3	39.3	59.4	AVT
	T	22.92	4.12	2.03	-1.09	3.43	16.2	25.4			
96	U	35.60	831.10	28.83	0.01	2.17	-19.2	100.5	38.9	66.4	AVT
	V	15.60	505.60	22.49	-0.27	2.72	-32.8	70.3			
	T	17.77	4.92	2.23	0.77	3.18	14.2	24.2			
127	U	6.10	279.70	16.73	0.13	2.48	-23.3	48.1	10.1	36.8	AVT
	V	8.10	289.30	17.01	-0.16	2.21	-23.6	48.0			
	T	14.45	0.91	0.91	1.88	5.90	13.6	17.9			
308	U	9.00	80.20	8.96	-0.68	2.89	-18.4	24.8	14.8	37.1	AVT
	V	11.80	95.00	9.75	-1.12	4.12	-20.1	40.2			
	T	10.60	0.99	0.31	0.72	3.34	9.9	11.6			
499	U	3.10	0.10	0.36	-0.19	3.00	1.9	4.0	3.1	88.5	AVT
	V	0.10	0.60	0.75	0.02	2.32	- 1.7	2.0			
	T	6.77	0.05	0.23	0.40	2.50	6.2	7.4			

Table 1 continued

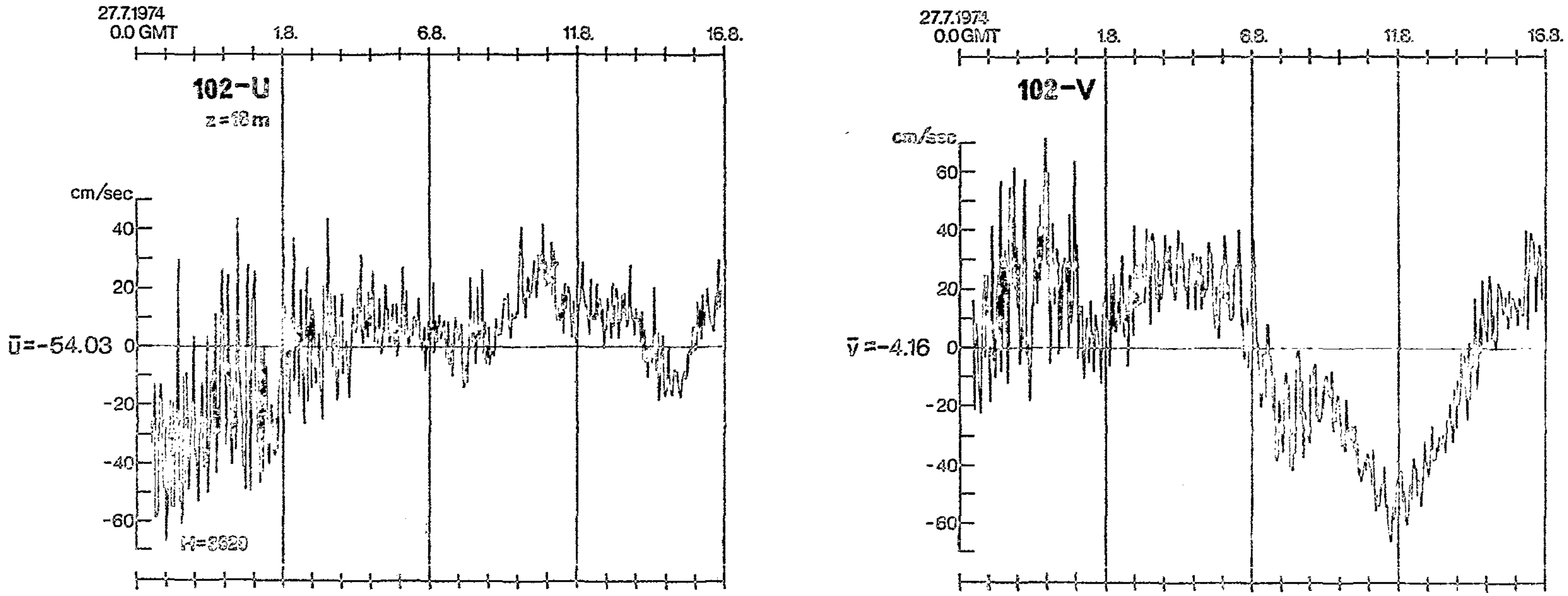


Figure 13

Deviation of east-(U) and north-(V) component of current from their mean value at position 102 (see Figure 1)
H = bottom depth, z = instrument depth, $\bar{u}$, $\bar{v}$ = mean values of U, V

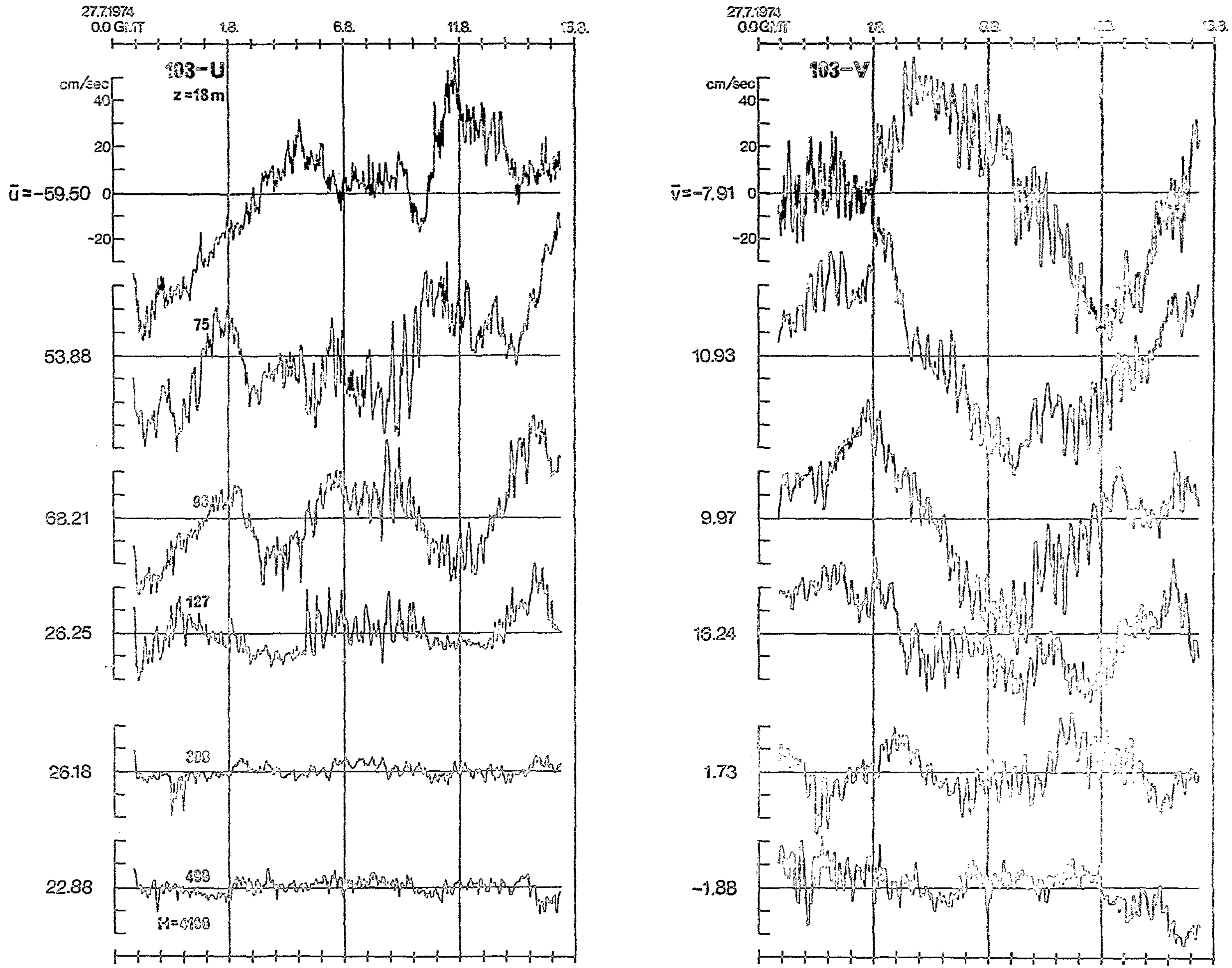


Figure 14

Deviation of current components at position 103 (see Figs. 1, 13)

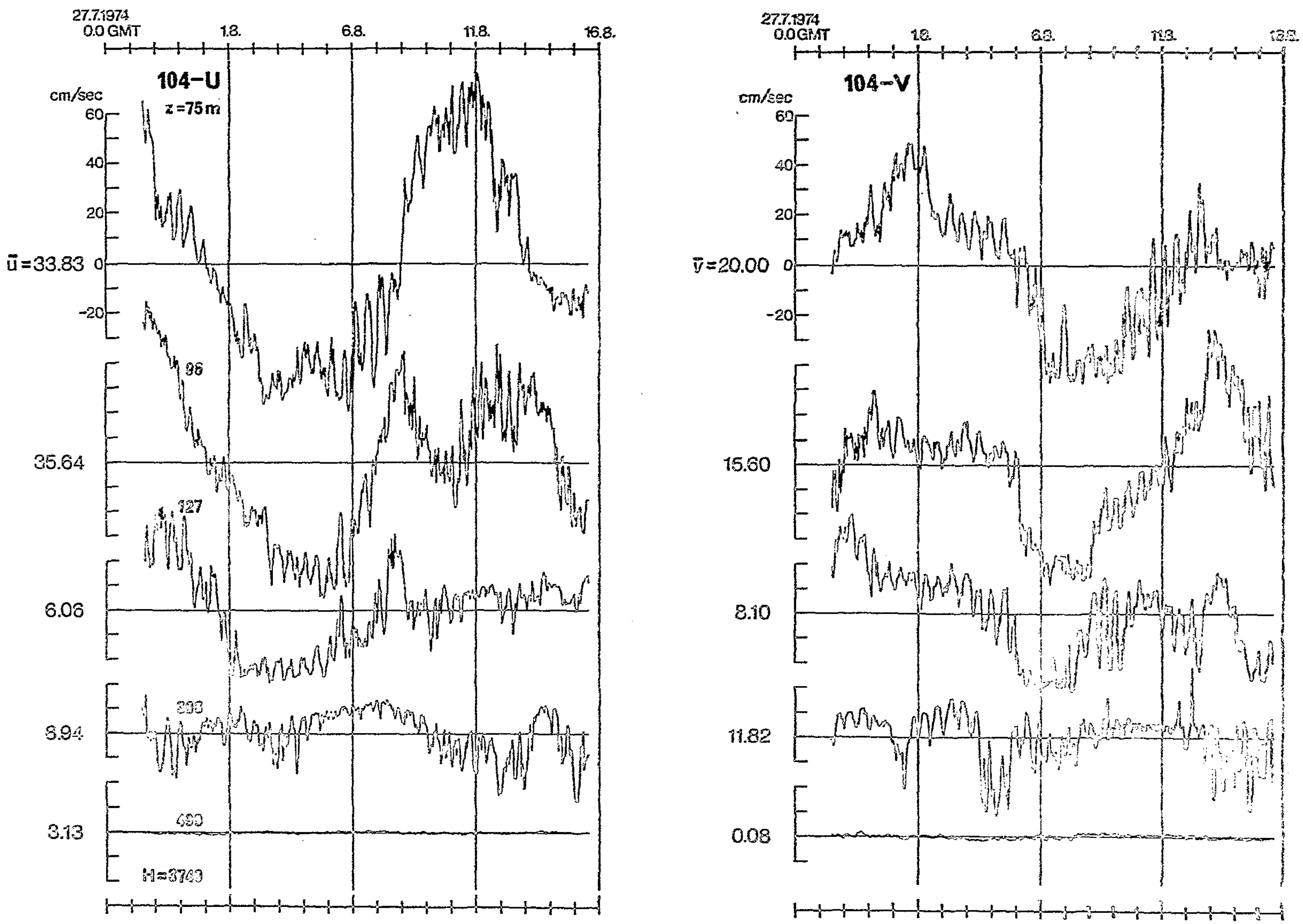


Figure 15

Deviation of current components at position 104 (see Figs. 1, 13)

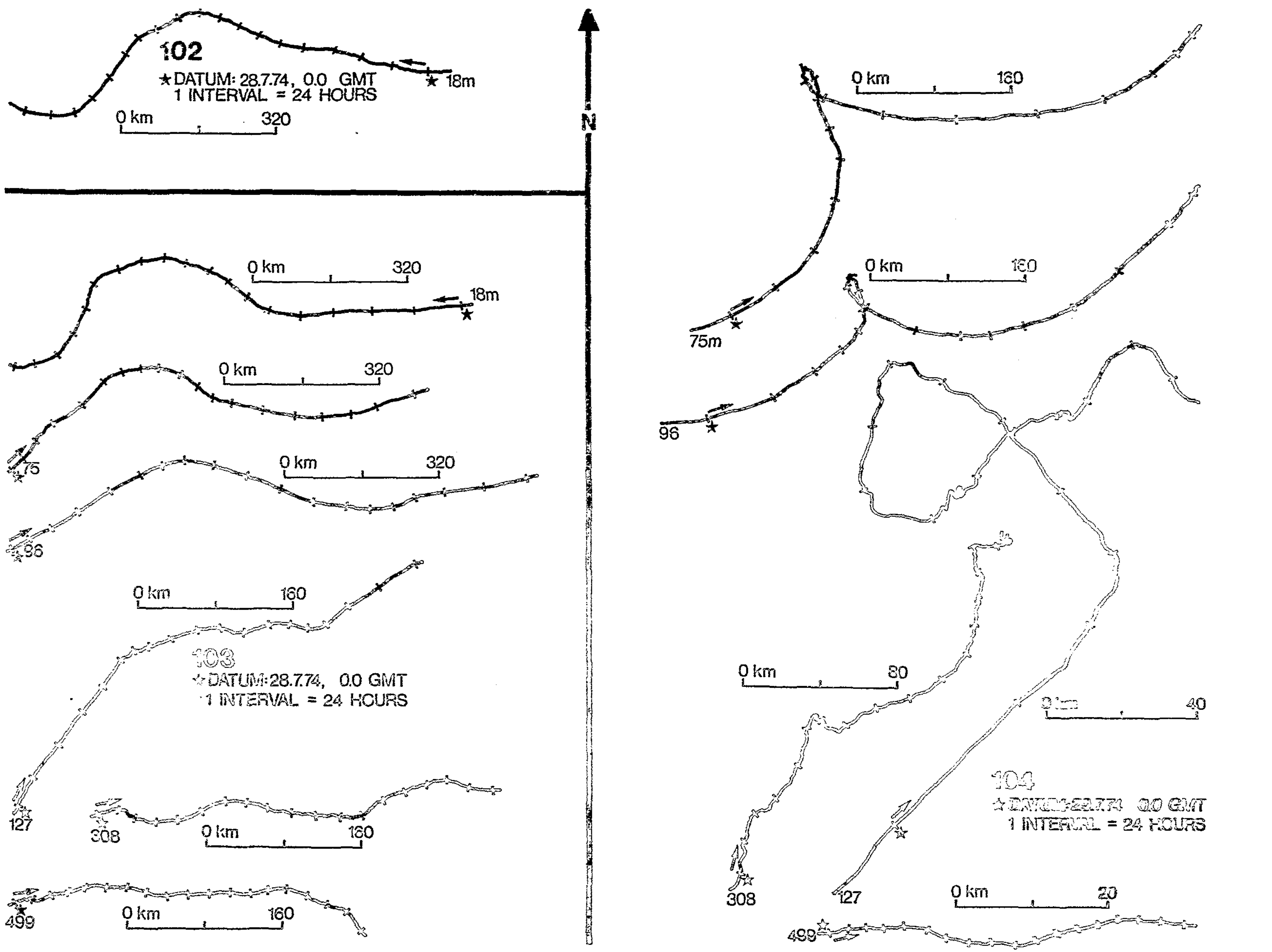


Figure 16

Progressive vector diagrams for positions 102, 103 and 104

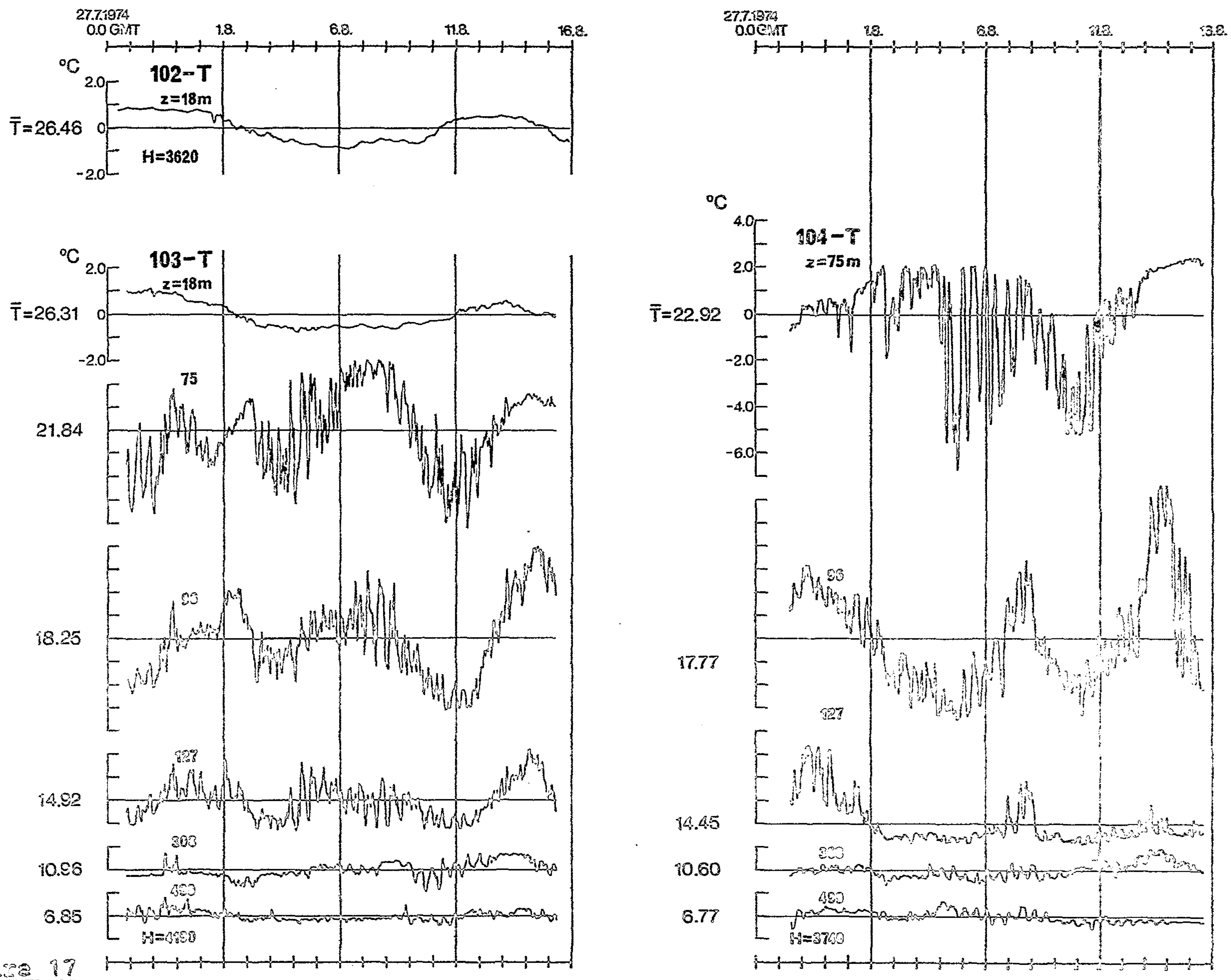


Figure 17

Deviation of temperature (T) from their mean values at positions 102, 103 and 104 (see Fig. 1)
H = bottom depth, z = instrument depth, $\bar{T}$ = mean value of T

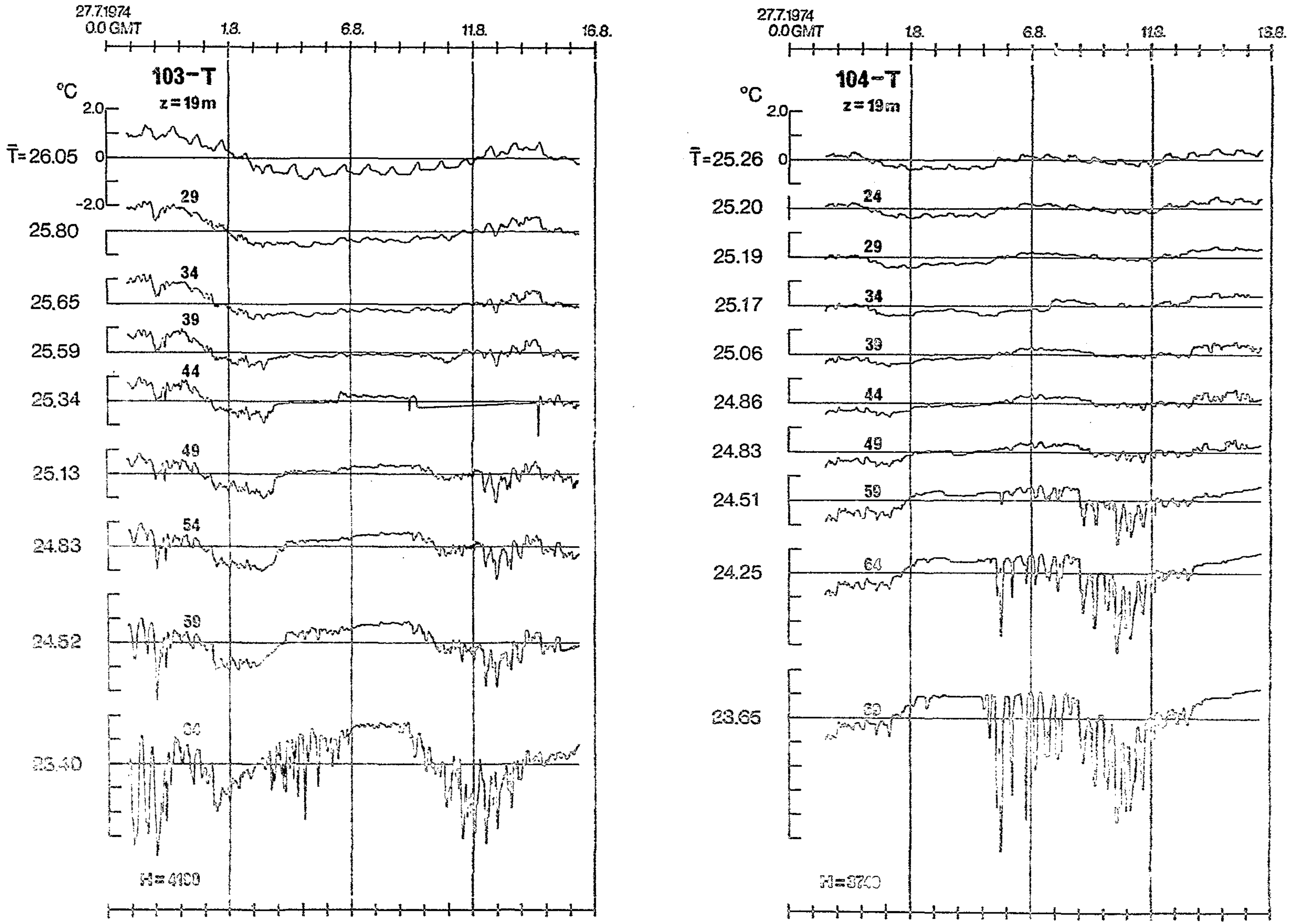


Figure 18

Deviation of temperatures at positions 103 and 104 as recorded by thermistor cables (see Figs. 1, 17)

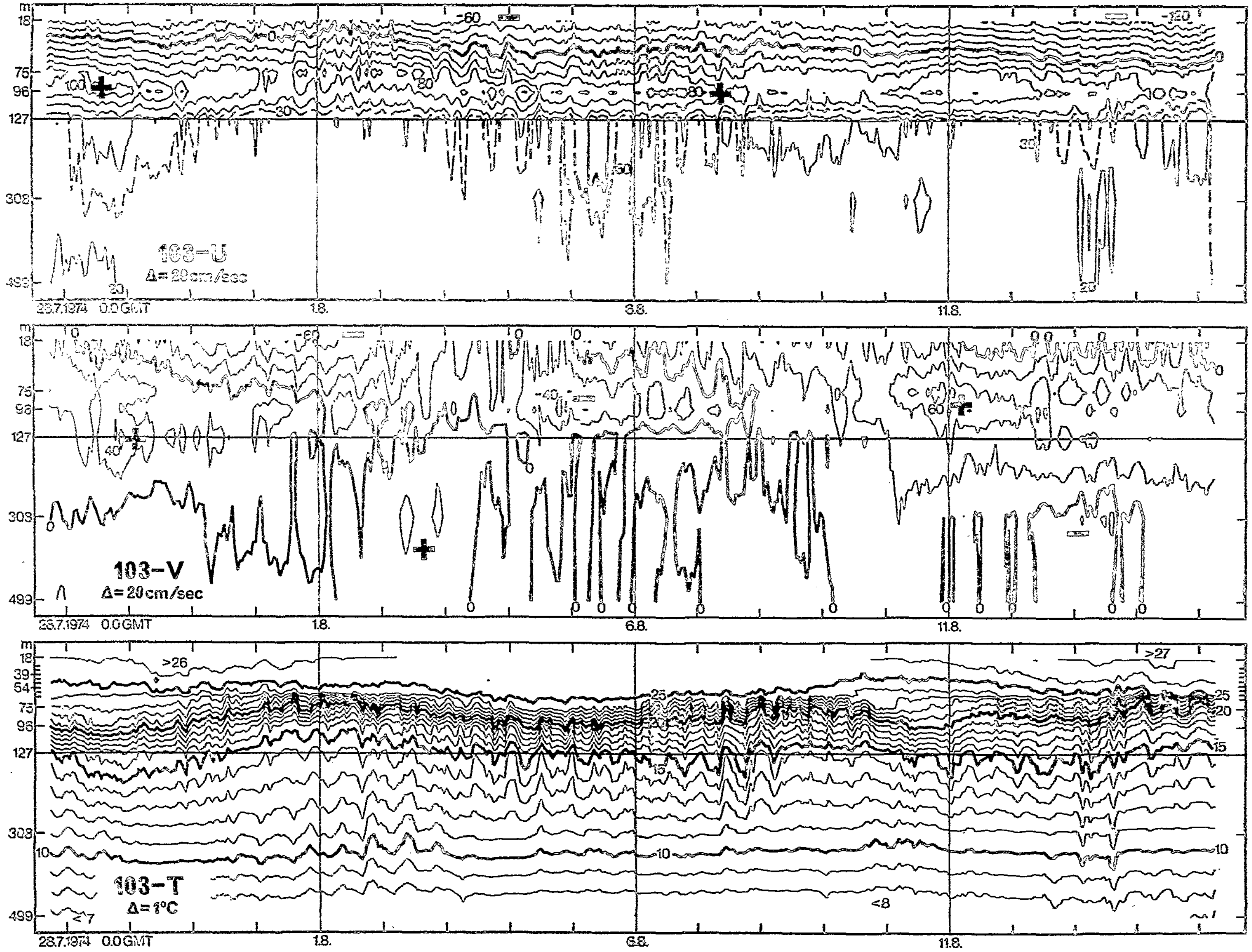
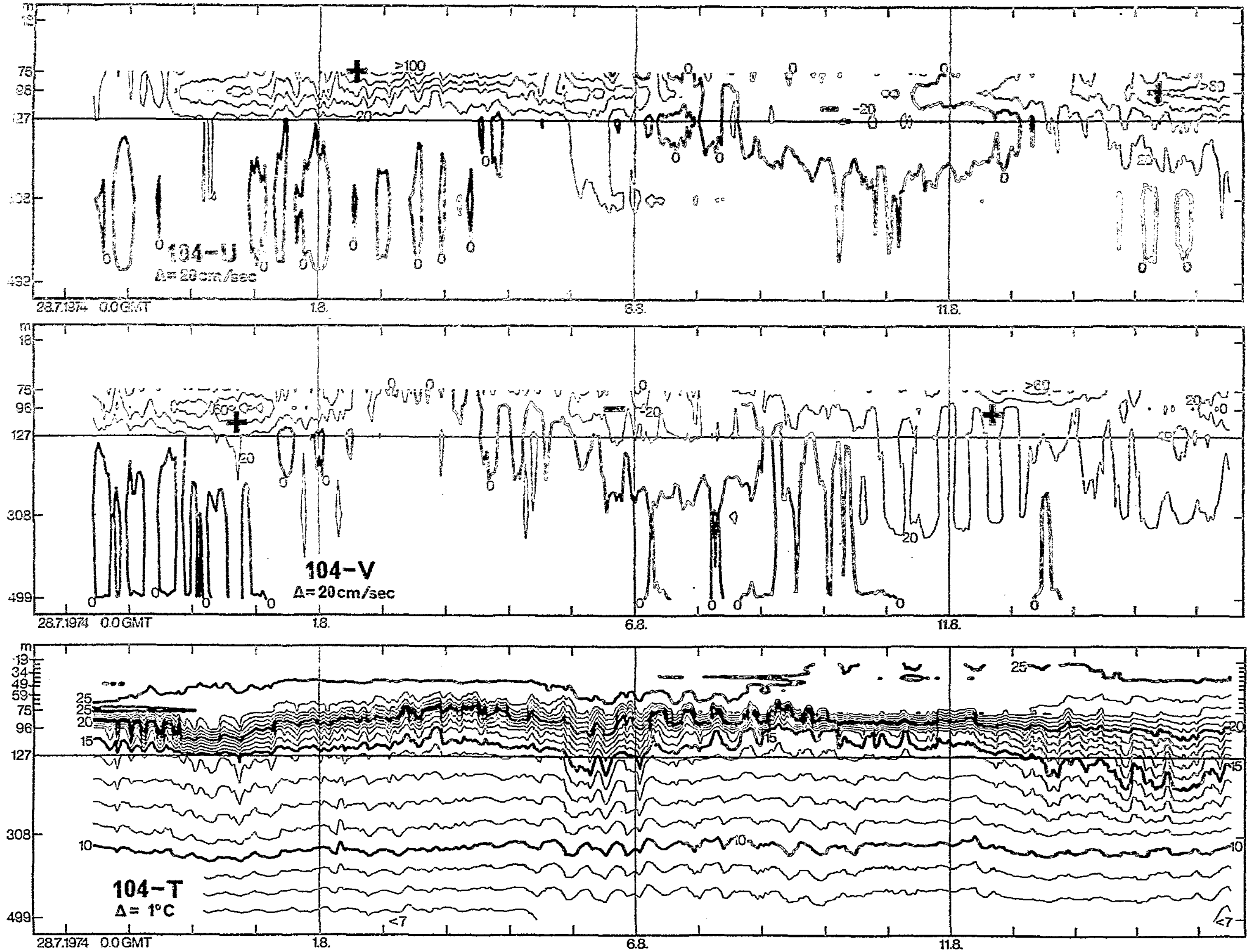


Figure 19

Isopleths of current components and temperature from moored instruments at position 103 (see Fig. 1)



<u>Figure 20</u>

Isopleths of current components and temperature from moored instruments at position 104 (see Fig. 1)