FOTEC

PHYSICAL OCEANOGRAPHY

FINAL REPORT

ROSENSTIEL SCHOOL

OF

MARINE AND ATMOSPHERIC SCIENCE

4600 RICKENBACKER CAUSEWAY

MIAMI, FLORIDA 33149

OCTOBER, 1983

FLORIDA INSTITUTE OF OCEANOGRAPHY

830 FIRST STREET SOUTH

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ACKNOWLEDGMENTS

The project described in this report was supported by the Coastal Energy Impact Program (CEIP Grant #82-CE-CW-13-00-05-006), which is administered by the Office of Ocean and Coastal Resource Management, National Oceanic and Atmospheric Administration through the Florida Department of Community Affairs.

INDEX

1) Introduction

This report summarizes the results of surveys of two proposed sites for a Florida Ocean Thermal Energy Conversion (FOTEC) plant near Key West. Both sites are located in the Straits of Florida as seen on the locator map in figure 14 in section 3 on data. OTEC plants extract energy and/or fresh water from the vertical temperature gradient between the warm surface water and the cold water below the thermocline in the ocean. While the source of energy in the form of solar heating of the oceans surface waters is virtually inexhaustible and free of charge, very large heat exchangers and structures are required for acceptable efficiencies of operation. Careful environmental and engineering studies are required to insure long life and low maintenance of these large capital investments. Of particular interest to the design engineers are the thermal resources upon which the plant feeds and the current induced forces the structure must withstand. These issues are both addressed in this report.

Three sources of information are used to focus on the temperature and current structure at these sites. The first source of information is historical data collected on past cruises by various investigators and institutions. These data were collected over larger space and time scales and thus expand our knowledge. Dr. Thomas Lee of the University of Miami (RSMAS) functioned as a consultant to this project to examine the historical data which might be applicable to these sites.

Second, direct measurements made in the course of this contract of temperature and current structure. These data were collected on the R/V Bellows during the period from February 15, 1983 to February 27, 1983.

Capt. Gene Olson and Marine Technician Albert Rodriguez of Florida Institute of Oceanography (FIO) at the University of South Florida were particularly helpful in anchoring the ship in 700-800 meter water depths and careful data acquisition respectively. Marine Technician Mark Graham and Graduate Student Jiann-Gwo Jiing at the University of Miami (RSMAS) both worked effectively preparing the profiler plus acquiring data and analyzing and plotting the data respectively. The final source of information was remotely sensed surface temperature provided by NOAA Miami SFSS. These data give some idea about the context in which the in-situ data were recorded.

Owing to limitations in time and funding, the data and interpretation presented here will not be sufficient for final engineering analysis. However these data will be required for feasibility studies and for the design of a definitive study. Clearly, data gathered during weather windows in a two week period during the winter of one year will not define current and temperature variability in great enough detail. Since none have ventured into the edge of the Gulf Stream to record data at the peak of a winter storm much less a hurricane, we have little direct evidence of current magnitudes and wave induced forces to be expected at the proposed sites under extreme storm conditions. We can however recommend methods of acquiring such data using new radar and acoustic remote sensing techniques which allow the estimation of both wave and current conditions.

2) Background on the Florida Current

The Florida Current is a highly variable, dynamic current system flowing through the Florida Straits from the Yucatan Channel to Cape Hatteras. The mean downstream flow is in approximate geostrophic balance with cross-stream pressure gradients over a large portion of the current structure (Wust, 1924). However, within the cyclonic shear zone ageostrophic conditions can prevail (Brooks and Niiler, 1977). Richardson, Schmitz and Niiler (1969) measured the velocity structure and volume transport of the Florida Current with 7 dropsonde sections between the Florida Keys and Cape Fear (Figs. 1 and 2). Downstream velocities were strongly sheared in the vertical and horizontal with a baroclinic jet located in the western side of the Straits. Volume transport were northward and increased from a minimum of 29.6 x $10^6 m^3 s^{-1}$ off the Florida Keys near Marathon, FL., to a maximum of 53.0 x $10^6 m^3 s^{-1}$ off Cape Fear. The Marathon section (section I of Fig. 2) was located very near the proposed FOTEC sites and will serve as useful data for comparison with site specific measurements. This average downstream velocity section was derived from 9 dropsonde transects between June 13 - July 4, 1966. The averaging tends to smooth out the velocity structure, making the upper layer high speed core of 140 cm s^{-1} broader than what actually occurred on any single transect.

Between May 3 and June 8, 1972 Brooks and Niiler (1975) made 16 dropsonde and CTD transects across the Florida Current along the $81^o 44'$W meridian between Key West and Matanzas, Cuba. This section is located approximately 60 km upstream of the proposed FOTEC sites. Ensemble-averaged profiles of the downstream velocity (u), cross-stream

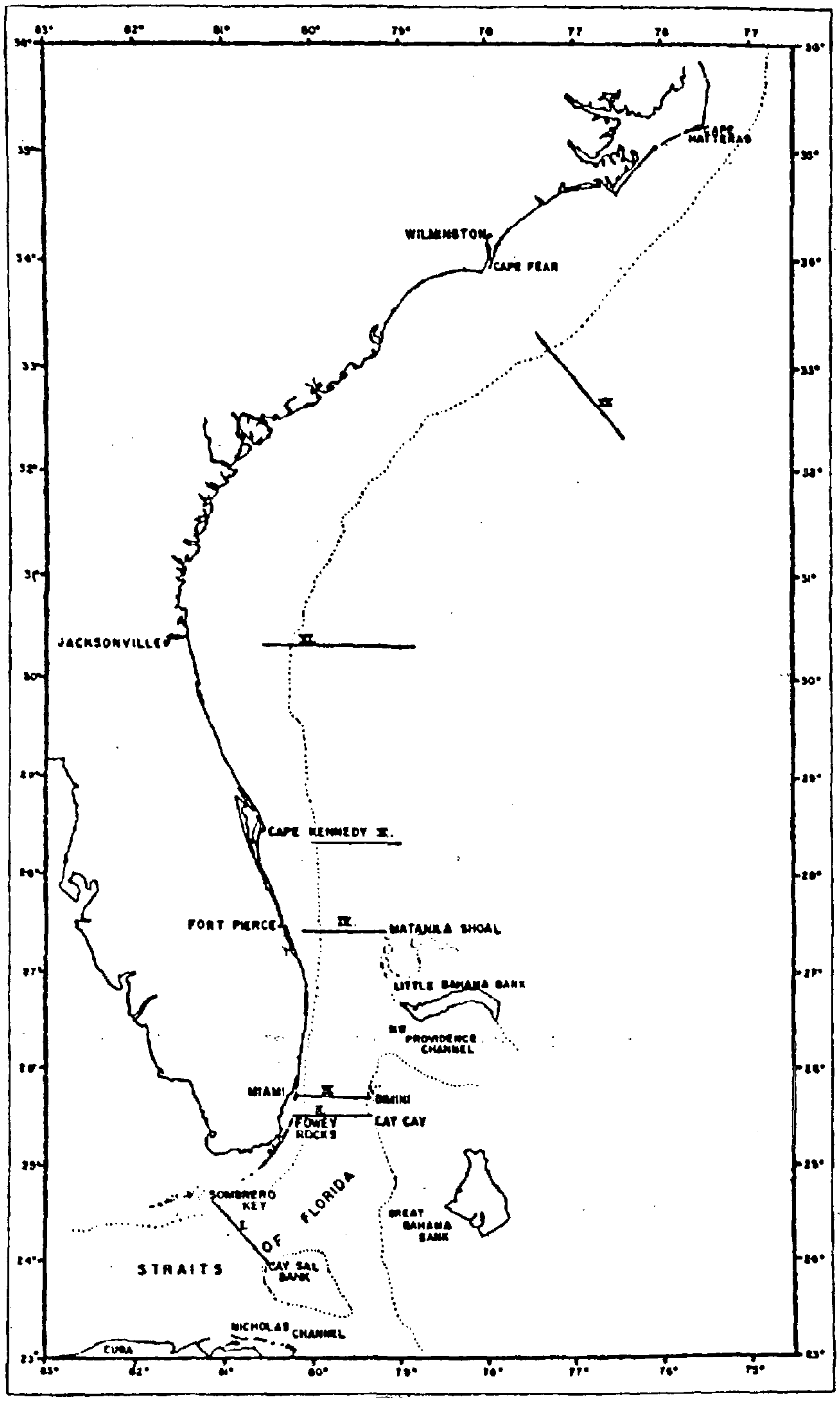


Fig. 1. Florida Current transport sections (from Richardson et al., 1969).

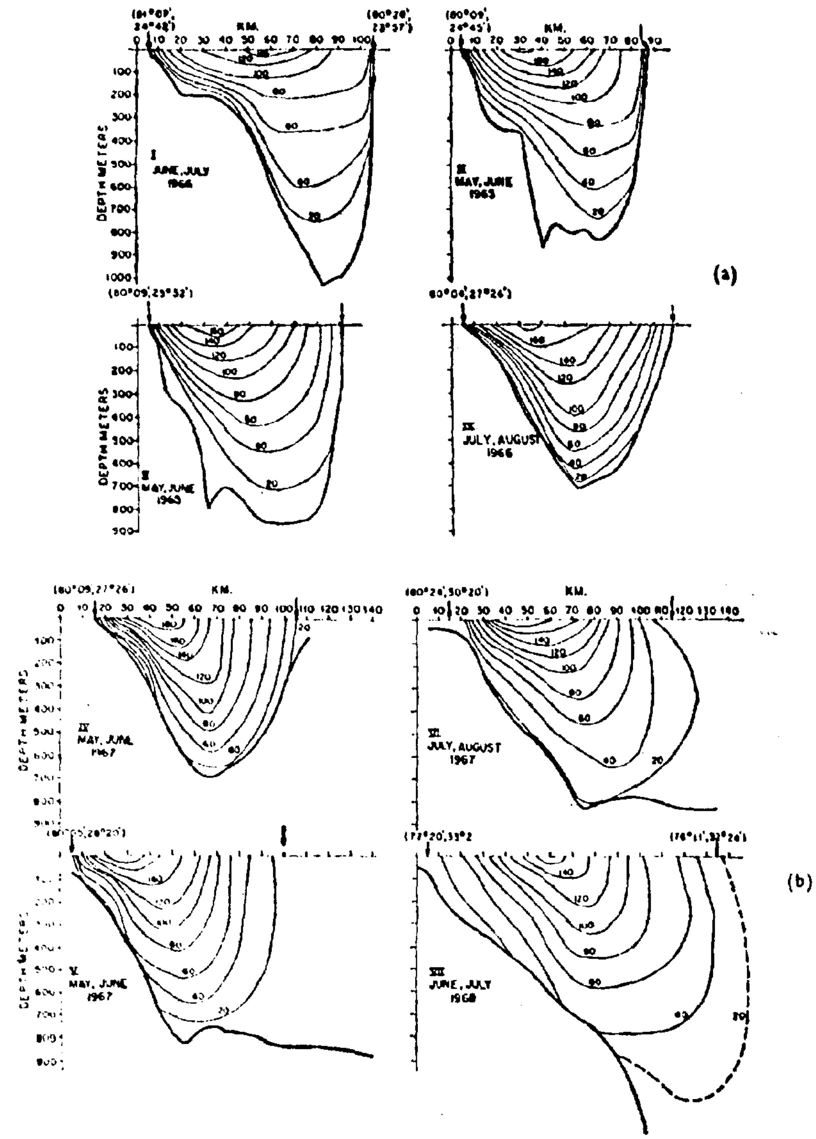


Fig. 2. Downstream velocity structure: isotachs are in cm s^{-1}. The 0 cm s^{-1} isotach not presented could not be drawn with comparable confidence. Arrows at the top of each diagram show the location where the mean surface current is zero. (a) Sections, I, II, III and IVA., (b) Sections IVB, V, VI and VII (from Richardson et al., 1969).

velocity (v), temperature and salinity from Station 9 of these transects, is shown in Fig. 3. Station 9 was located at approximately the same isobaths as the proposed FOTEC sites. These data show the large variability of currents at this site. Current speeds ranged from about 20 to 170 cm s^{-1} in the upper layer during the one month experiment. However, temperature variations were much smaller. Surface temperature ranged from about 25°C to 28°C and near bottom temperatures were nearly constant at about 5°C, giving a vertical temperature difference from the surface to 800 m of 20 to 23°C. The mean downstream velocity field is shown in Fig. 4. The magnitude and pattern of the eastward flow is similar to the Richardson et al., (1969) section at Marathon (Fig. 2, section I). However, off Key West a westward mean flow of 20 cm s^{-1} was observed on the northern side of the straits. This counterflow was found on 13 out of the 16 transects with current speeds reaching 80 cm s^{-1} toward the west. Similar features have been observed all along the western boundary of the Florida Current between Miami and Cape Hatteras and have been described as northward traveling cold cyclonic eddies (Lee, 1975; Lee and Mayer, 1977; Lee, Atkinson and Legeckis, 1981; Lee and Atkinson, 1983). These eddies form in conjunction with offshore meanders of the Florida Current on a weekly time scale and their passage by a prospective FOTEC plant would produce a current reversal and upwelling of cold deeper Florida Current water. Chew (1974) observed an offshore meander of the Florida Current in the vicinity of the proposed FOTEC sites (Fig. 5). Strong upwelling is indicated north of the offshore meander by the uplifted isotherms (Figs. 5 and 6). The domed isotherms and topography of the 15°C surface are

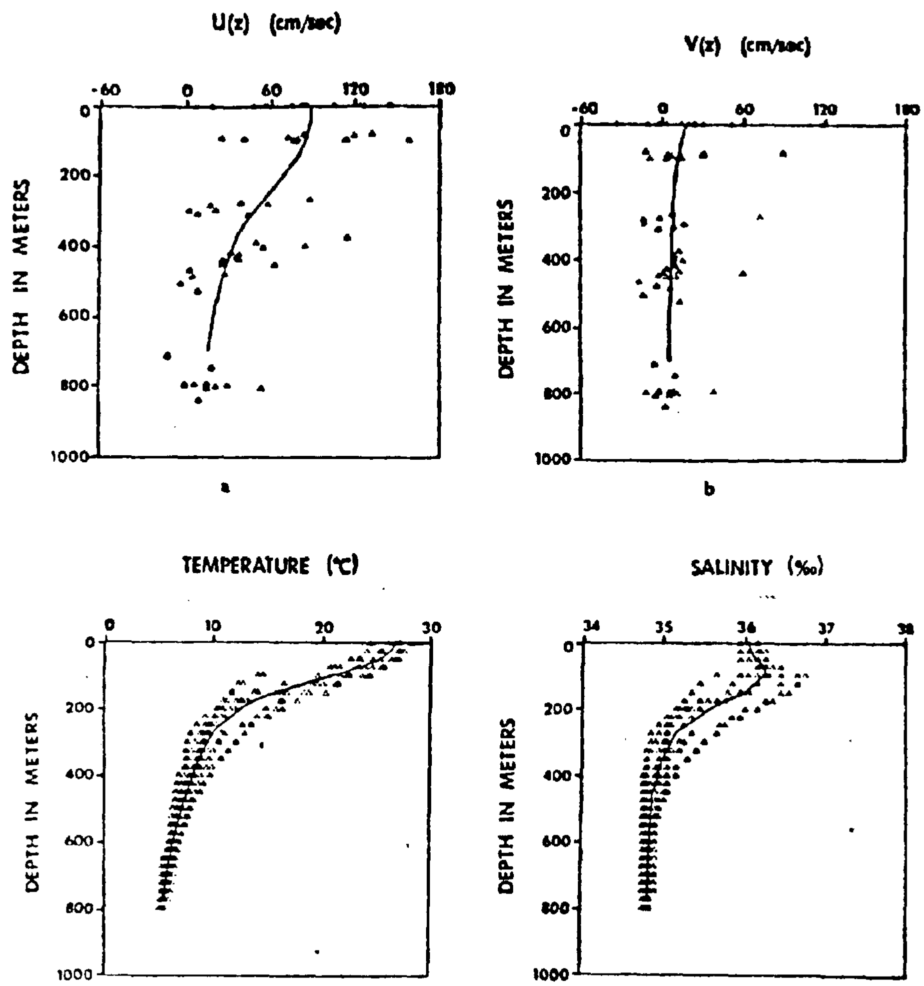


Fig. 3. The data ensemble for Station 9: (a) downstream average velocity, U(z); (b) cross-stream average velocity, V(z); (c) temperature; (d) salinity (from Brooks and Niiler, 1975).

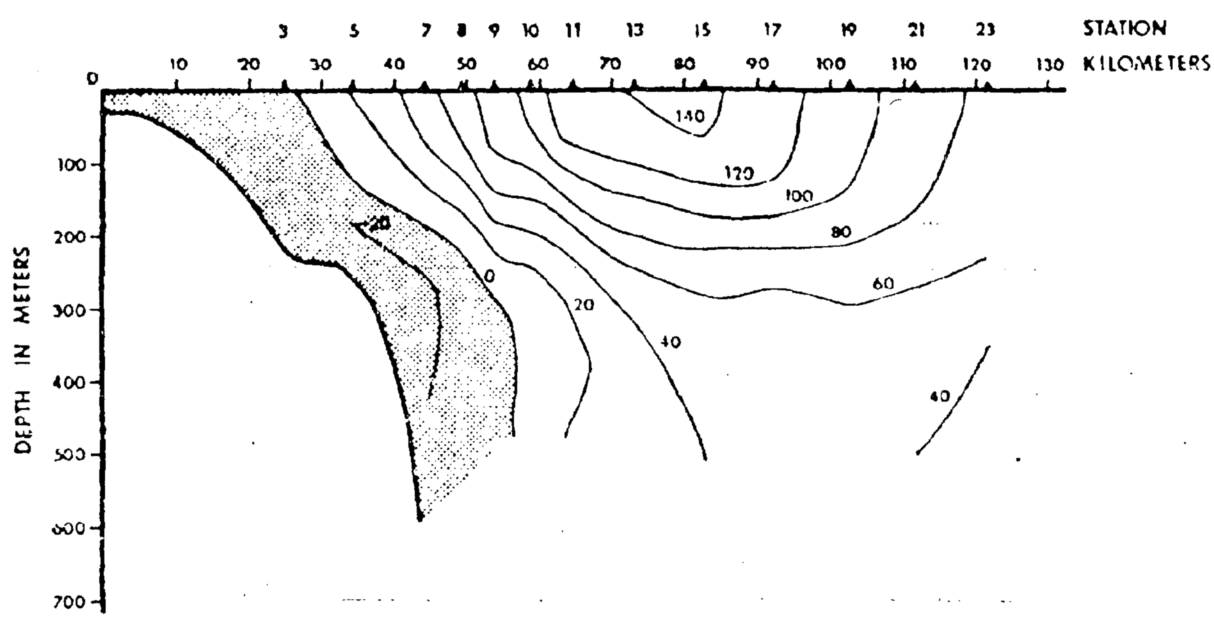


Fig. 4. The ensemble-averaged downstream velocity field (from Brooks and Niiler, 1975).

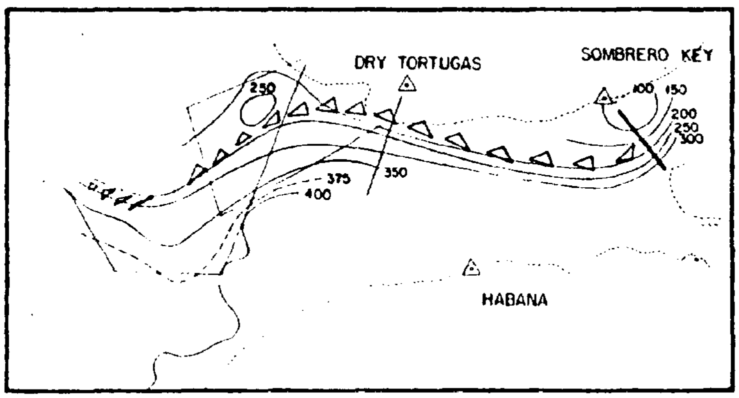


Fig. 5. Depth (m) contour of the 15C surface with drogue tracks superposed, August 1971 (from Chew, 1974).

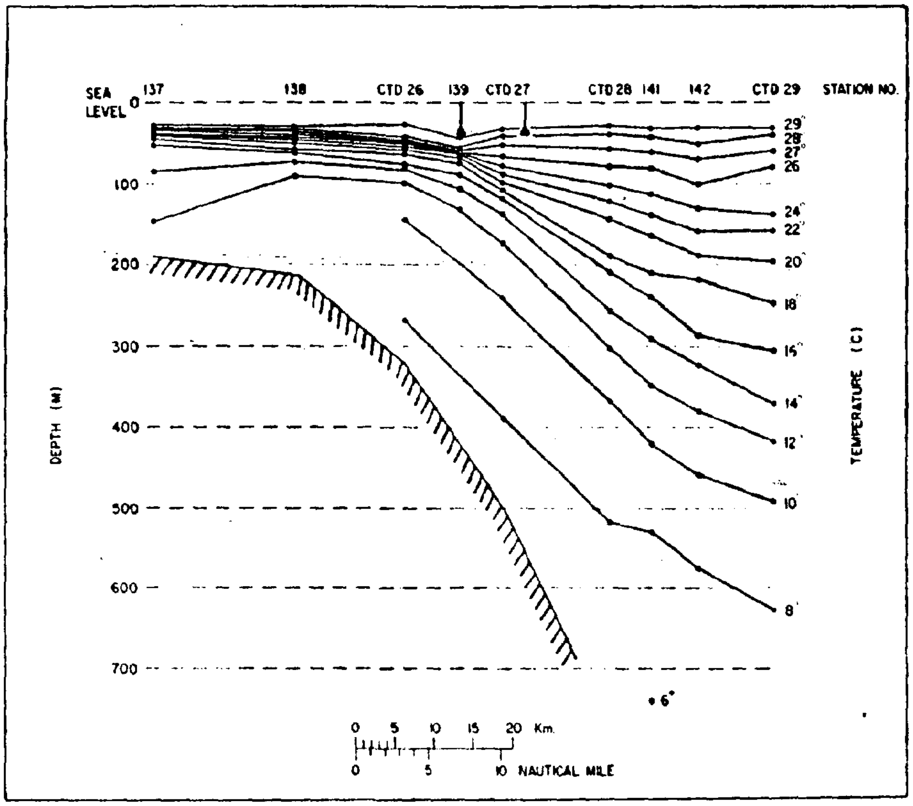


Fig. 6. Vertical distribution of temperature and drogue positions at Sombrero Key section (from Chew, 1974), see Fig. 5.

both indicative of the presence of a cold cyclonic eddy north of the offshore meander.

Niiler and Richardson (1973) have estimated the mean transport off Miami at 32.0 x $10^6 m^3 s^{-1}$ with energetic fluctuations occurring on seasonal, 2-15 day and tidal time scales. Their data were reported as transport time series and shown in Fig. 7. They concluded that there was little energy between the 15 day and seasonal periods. The total fluctuation bound was about 19 x $10^6 m^3 s^{-1}$ with a maximum of 38.2 x $10^6 m^3 s^{-1}$ in summer and a minimum of 19.0 x $10^6 m^3 s^{-1}$ in winter. Seasonal variations were on the order of ± 3 x $10^6 m^3 s^{-1}$ and accounted for about 45% of the observed variability. Fluctuations within the 2-15 day period band also had amplitudes of ± 3 to 4 x $10^6 m^3 s^{-1}$ and appear to produce 40 to 50% of the total variance. Tidal fluctuations occurred with both diurnal and semi-diurnal periods, again with amplitudes of ± 3 to 4 x $10^6 m^3 s^{-1}$ and accounted for 10-20% of the variability (Schmitz and Richardson, 1968; Brooks, 1979).

Low-frequency Variability

(a) Current Profiling Results

Fluctuations of the Florida Current in the 2-15 day period range were observed by Pillsbury (1891) and later by Parr (1937). Schmitz and Richardson (1968) reported east-west meanders of the Florida Current occurring on a one-week scale with amplitudes of about 5 km. Düing (1975) analyzed 2 weeks of current profiles sampled from 4 ships anchored off Miami and noted a barotropic current meander with a 4 to 6 day time scale (Fig. 8). Comparison of the ship measured transport data

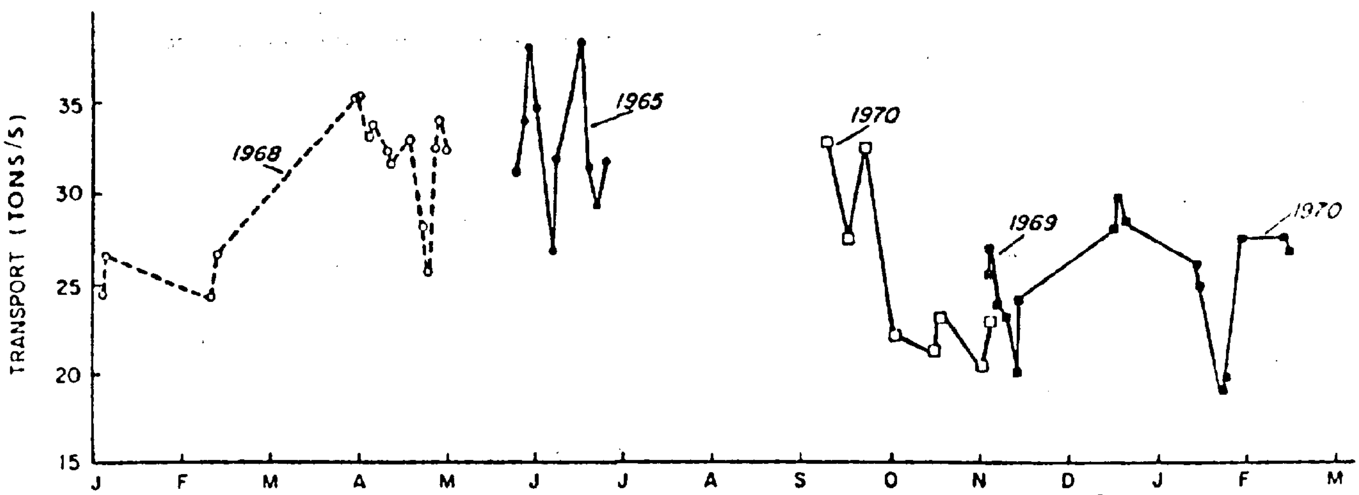


Fig. 7. Florida Current transports of Niiler and Richardson, 1973, replotted (Molonari, personal communication).

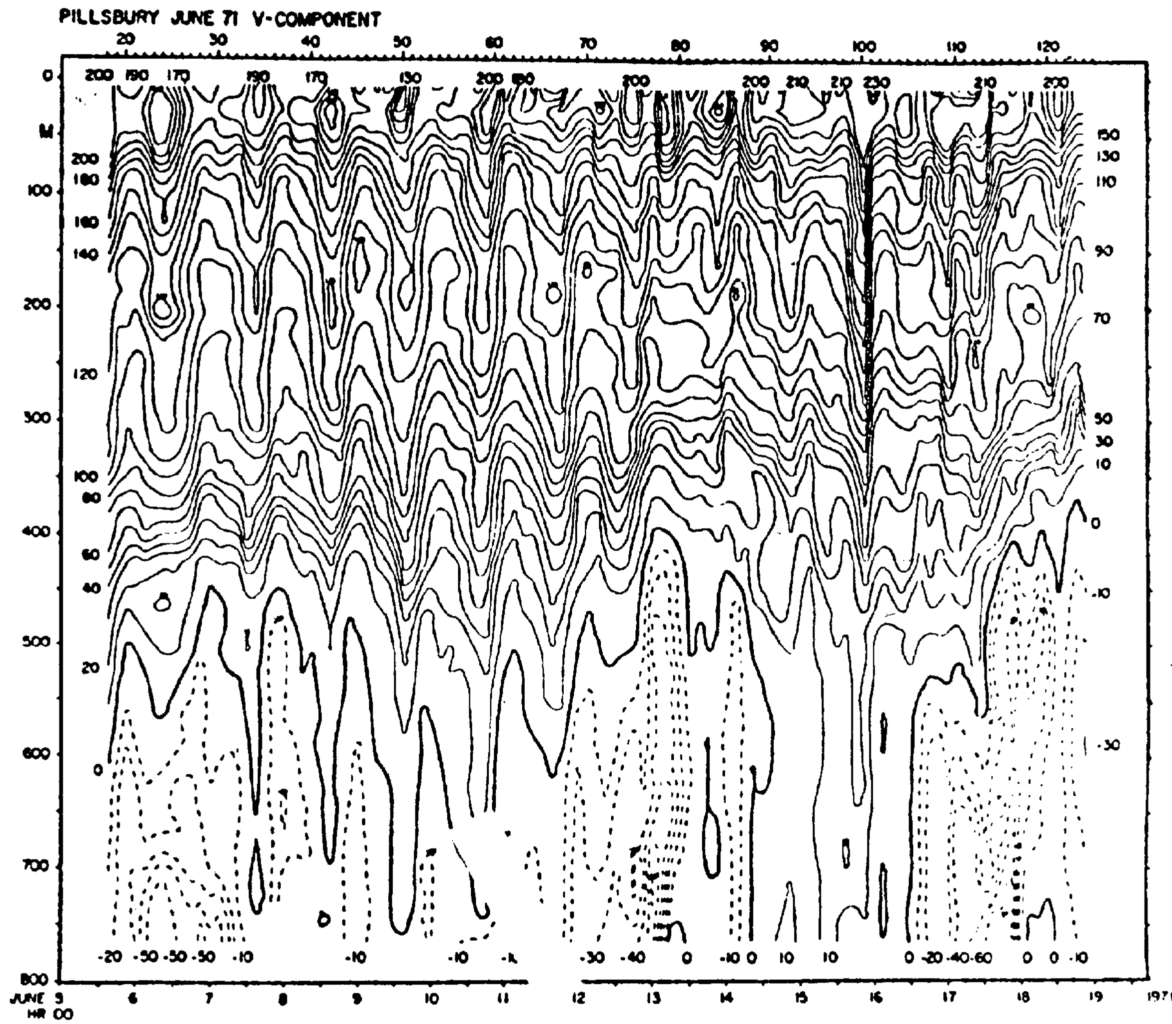


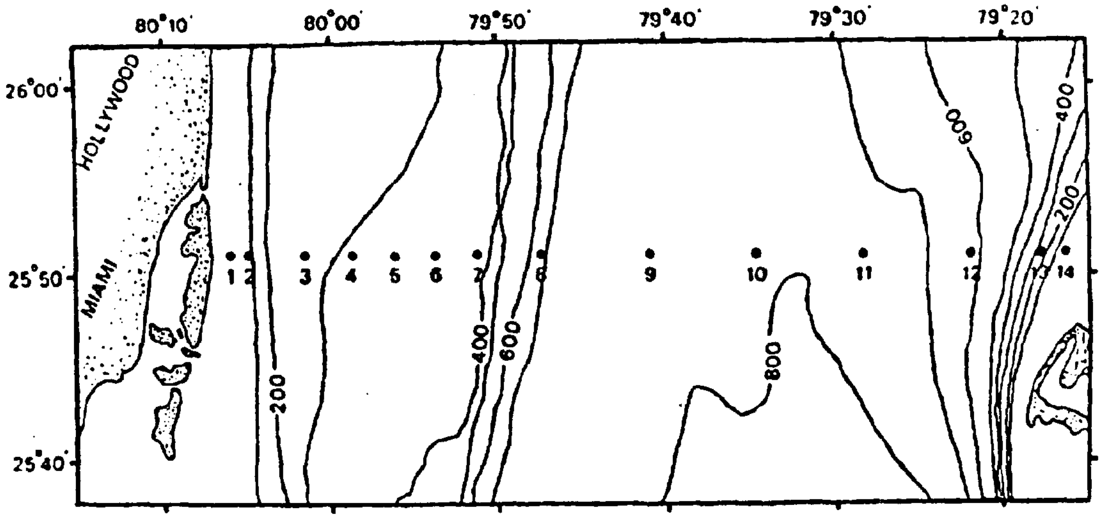
Fig. 8 Isotach contours of north-south component (cm s^{-1}) from Project SYNOPS 71. Solid lines denote northward flow, dashed lines southward flow. Top Scale shows profile numbers from current profiling for 2 weeks through the core of the Floirda Current (from Kielmann and Duing, 1974).

with transport estimated from the electrical potential on a submarine cable off Jupiter, FL., indicated that the several day "meander" was produced by a wave traveling to the north at 47 cm s^{-1} and wave length of 200 km. Düing described 2 cases for meanders: deep southward flow appeared to occur over the Miami Terrace during an offshore meander (current axis displaced to the east) and deep northward flow occurred over the Terrace during an onshore meander stage (axis displaced to the west). In general it appeared that flow variations on the cyclonic shear side of the axis were about 180° out of phase with the anticyclonic side.

More recently Brooks (1979) found similar results from detailed dropsonde transects of the Florida Current off Miami over an 83 day period in the summer of 1974 (Fig. 9). Transport fluctuations with periods of 2-14 days were highly coherent and in phase at stations in the cyclonic shear region as were stations in the anticyclonic region, but the two regions were about 180° out of phase. Brooks also found fluctuations in the total transport that were visually coherent and in phase with the variations on the anticyclonic side. During the experiment the current axis meandered a total distance of approximately 24 km. An offshore (onshore) meander was associated with a transport increase (decrease) on the eastern side of the current, a transport decrease (increase) on the western side and an increase (decrease) of total transport.

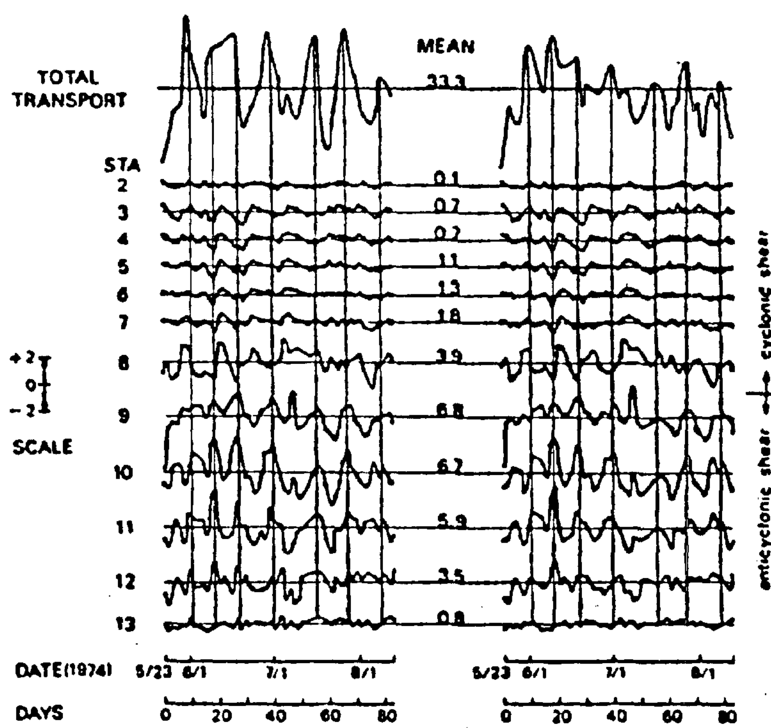
(b) Moored Current Meter Stations

Current records from an array of near bottom current meters (Fig. 10) spanning the Florida Straits at the same location and time as the



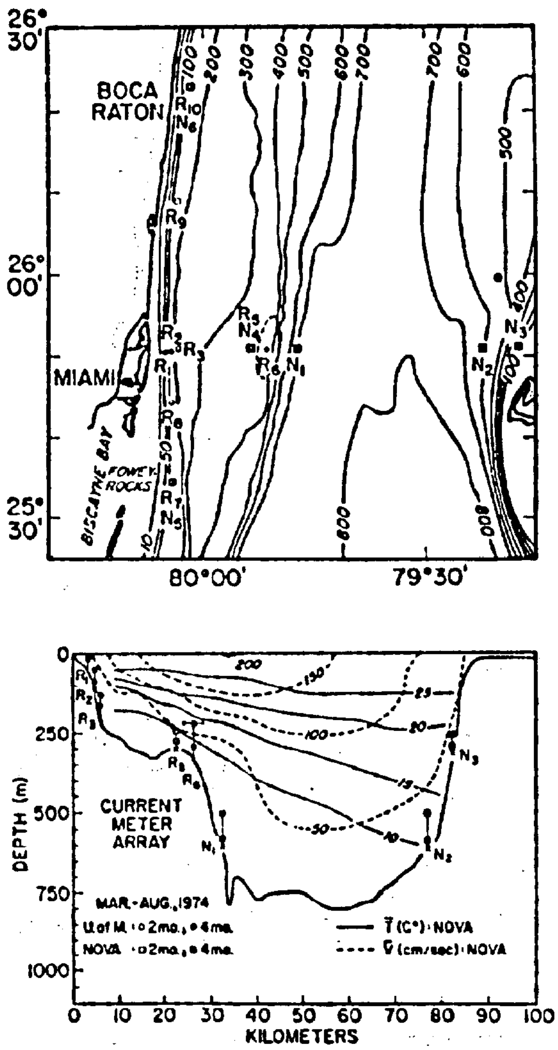
Topography of the experimental section. Isobaths in meters.

b)



. Transport versus time. The top curves represent total transport through the section. The remaining curves represent transport at the individual stations. The left-hand column represents time series of measured values of transport. The right-hand column represents the series after tides are removed. Transport is in units of $10^6\ m^3\ s^{-1}$. Event markers are at days 10, 18, 26, 39, 55, 66 and 78.

Fig. 9. Transport fluctuations from dropsonde sections across the Florida Current. a) Station locations; b) Detided transports (from Brooks, 1979).



a) Plan view of the Florida Straits with mooring sites.

b) Cross-stream mooring array with vertical section of the mean flow and mean temperature distribution based on observations from March to August, 1974, made by Nova University.

Fig. 10. Some previous mooring positions in the Florida Straits (from Duing et al., 1977).

Brooks dropsonde measurements showed energetic fluctuations of the downstream component with well-defined spectral peaks at periods of 9 to 12 days that were coherent across the entire Florida Straits (Düing, Mooers and Lee, 1977). The downstream coherence scale of these fluctuations was estimated at 55 km from a current meter array along the continental slope (Lee, Brooks and Düing, 1977).

Current spectra from the Florida Straits generally show a decrease of energy toward the very low frequencies (Düing et al., 1977) which appears to be typical of continental shelves (Niiler, 1976) and in contrast to spectra from the deep ocean (e.g., from side D; Thompson, 1971). The most energetic motions in the Florida Current appear to occur with periods of 8 to 12 days, with smaller but still significant fluctuations occurring at periods of 4 to 5 and 2 to 3 days (Düing et al., 1977; Mooers and Brooks, 1977; Brooks, 1979).

(c) Interpretation of Low-frequency Fluctuations

In the open ocean subinertial motions are largely governed by planetary Rossby wave. Along continental margins and in Straits topographic Rossby waves or continental shelf waves (CSW's) can occur which have a higher-frequency cut-off than do open ocean Rossby waves. Brooks (1975) investigated stable barotropic CSW's in the Florida Straits using a realistic bottom profile with a baroclinic, horizontally sheared steady current. The lowest mode wave properties appeared to agree with observations reasonably well, i.e., periods of 10-12 days, wave length of 200 km and southward propagation of 20 cm s^{-1}. Schott and Düing (1976) found that a barotropic CSW with similar wave properties produced the best fit to current observations from an along-axis array of lower layer moorings. Approximately 70% of the observed variance could be attributed to the barotropic mode. Similar results were found by Mooers and Brooks (1977) and Düing (1975). Continental shelf wave theory predicts a 180° cross-stream phase difference between currents on the shallow Miami Terrace and the deep region of the Florida Straits, which was observed by Düing et al., (1977) and Brooks (1979). In the presence of the horizontally sheared Florida Current northward propagating CSW's are also possible (Brooks, 1975; Niiler and Mysak, 1971). The most probably generating mechanism for CSW's is usually attributed to Ekman suction due to wind stress curl over the Straits (Brooks, 1975; Schott and Düing, 1976; Düing et al., 1977). Significant coherence was found by Düing et al., (1977) between the downstream flow and wind stress curl in the 10 to 13 day period band, with the curl being nearly in quadrature with the downstream current.

Niiler and Mysak (1971) found that unstable barotropic waves could exist in the Florida Current in the vicinity of the Blake Plateau. These waves propagated northward at a period of about 10 days and wave lengths of 150 to 200 km. Schott and Düing (1976) reported that rescaling the Niiler and Mysak dispersion relation for topography and current conditions in the Florida Straits indicated only stable waves with lengths of 100 km for the 10 day period.

(d) Observations of Eddies

On the western side of the Florida Straits, Lee (1975) and Lee and Mayer (1977) have observed cyclonic, cold-core eddies embedded in the Florida Current front. The eddies occur during periods of offshore meanders and have horizontal dimensions equivalent to the meander (10's of kms). They propagate to the north at the same phase speed as the meander (30 to 70 cm s^{-1}) and appear to grow as the meander develops. They occur on the average of about 1 per week and have life spans of about 1 to 3 weeks. Satellite I.R. images (Legickis, 1975; Stumpf and Rao, 1975) suggest that the eddies evolve from growing Florida Current meanders. Similar eddies have been observed along the Loop Current cyclonic front in the Gulf of Mexico (Maul, 1977) and north of the Florida Straits (Lee et al., 1981; Lee and Atkinson, 1983). Evidence for the occurrence of these features in the vicinity of the proposed FOTEC plant is given in Figs. 4, 5 and 6.

(e) Speculation Concerning Generation of the Low-frequency Fluctuations

If the apparent meteorological influences are more than coincidental, then the Florida Current may be viewed as one large system where disturbances generated by the winds in the band of 2 to 15 day period can propagate either north or south along the Straits because of the sheared current. Wave speeds in the upper layer range from 30 to 70 cm s^{-1} to the north and wave lengths are 100 to 200 km. The most energetic waves occur in the 8 to 12 day period band. Downstream velocities seem to be coherent in the lower layer across the entire Florida Straits in this period band and downstream coherence scales are about 50 to 100 km. Offshore meanders are associated with the formation of cyclonic, cold-core frontal eddies, deep flow reversals, decreased transports on the cyclonic side of the current, increased transport on the anticyclonic side, and increased total transport. Onshore meanders are accompanied by increased northward transport in the cyclonic zone, decreased transport in the anticyclonic zone and decreased total transport. Growing meanders of this type appear to derive their energy from the potential energy of the mean Florida Current then convert the energy back to the mean state through transfer of perturbation kinetic energy, with no substantial net energy conversion on the cross-sectional average. This internal energy readjustment appears to be more active within the cyclonic shear zone and could be connected to a baroclinic instability process. Fluctuations of this type have a significant impact on fluxes of mass, heat and momentum through the Florida Straits and to the adjacent water masses.

Tidal Variability

Current and transport fluctuations in the tidal/inertial period band account for approximately 10 to 20% of the observed total variability (Schmitz and Richardson, 1968; Kielman and Düing, 1974; Mooers and Brooks, 1977; Brooks, 1979). Both diurnal (K_1, O_1) and semi-diurnal (M_2, S_2) periods occur and produce transport fluctuations with amplitudes of ± 3 to $4 \times 10^6 m^3 s^{-1}$. Smith, Zetler and Broida (1969) and Zetler and Hansen (1970) hypothesized that since tidal sea level variations in the Florida Straits were primarily semi-diurnal then the observed diurnal component of the flow is produced by a standing wave with a node near Miami. Amplitudes of the K_1 and O_1 components of downstream currents or transport were found to be greater than or equal to the M_2 component (Schmitz and Richardson, 1968; Smith et al., 1969; Kielman and Düing, 1974; Brooks, 1979). Energy spectra of downstream (v) and cross-stream (u) velocity components from the lower layer over the Miami Terrace clearly show larger variance for the diurnal fluctuations (Fig. 11, from Kielman and Düing, 1974). The O_1 constituent was largest for the v component and K_1 was greatest u tidal constituent. The downstream component accounted for about 25% of the total variance and 6% for the cross-stream component. The harmonic constants (amplitude and phase for K_1, O_1, M_2 and S_2 computed from surface current speed records (Smith et al., 1969) were found to agree well with those computed for lower layer currents by Kielman and Düing, indicating a strong barotropic structure to the tides. Spectra of the "detailed" velocity components, i.e., after subtracting the tidal components determined by harmonic analysis (Fig. 11) show a considerable reduction (by almost an order of magnitude) in the downstream component both at diurnal-inertial and semi-diurnal periods. Brooks (1979) used a Munk/Cartwright technique to remove the tidal signal from station transport data and found little effect. However, the small changes at each station accumulated to produce a large effect on the total transport through the section. Brooks reported that the semi-diurnal and diurnal tides accounted for about 20% of the total variance. The diurnal component produced most of the tidal variance over the Miami Terrace and near the Bahama Bank and the semi-diurnal component had a larger effect in the interior of the Current. The phase of the diurnal component was relatively constant between Miami and the Bahamas, again indicating a standing wave with a node near Miami.

Mooers and Brooks (1977) analyzed thermistor arrays and tide gauge records from sides of the Florida Current. They found appreciable diurnal and semi-diurnal internal tidal energy that was as large as the

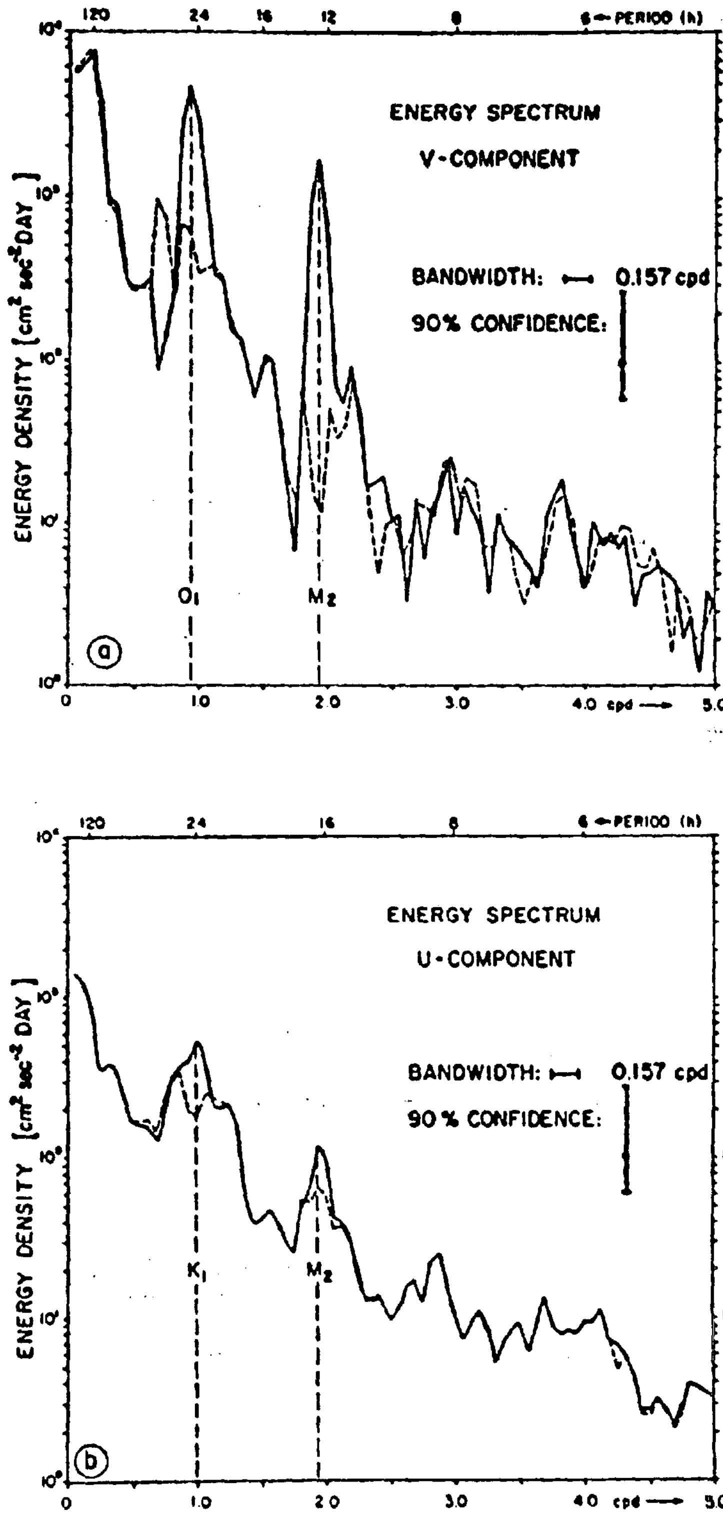


Fig. 11. High-frequency spectra of north-south and east-west components (solid lines) and spectra of residuals after removal of tidal oscillations K_1, O_1, M_2, S_2 (dashed lines) (from Fig. 7, Kielmann and Duing, 1974).

surface tides. The diurnal internal tide was dominant. Near-inertial motions were apparent at depths at the effective inertial frequency which varied as a function of horizontal shear (20 hours near Miami and 35 hours near Bimini). They found that low-frequency fluctuations can modulate all near-inertial motions including diurnal and semi-diurnal internal tides causing time-varying amplitudes. The modulation time scale was monthly and longer for the diurnal internal tides and fortnightly and longer for the semi-diurnal internal tides. Mooers and Brooks also found that the cross-channel phase of the diurnal and semi-diurnal internal tides indicated that internal seiches could exist in the Florida Straits at these periods.

Loop Current

Circulation in the eastern Gulf of Mexico is dominated by the Loop Current, the portion of the Gulf Stream which connects the Yucatan Current to the Florida Current (Cochrane, 1972; Nowlin and Hubertz, 1972). Its water originates in the North Atlantic Equatorial Zone and is transported to the area via the Caribbean Sea and the Straits of Yucatan. After penetrating the Gulf, the current pattern arcs anticyclonically (clockwise) to the east and southeast, forming a current "Loop" which subsequently exits through the Florida Straits. The western and eastern boundaries of the Loop are fixed by topography of the basin (eastern Gulf)(Cochrane, 1972).

In the Loop, interior flow is also anticyclonic. The flow pattern is elongated along an axis parallel to the shelf regions on either side and centered over the deep basin (Cochrane, 1972). Some portion of the southern Loop flow may exit back through the Straits of Yucatan rather than the Florida Straits (Nowlin, 1971). This portion varies, depending upon the degree of arc in the Loop pattern, or as a lower layer return flow (Maul, 1977).

The Loop Current influences flow to a depth of greater than 1000 m (Nowlin, 1971). As would be expected, current velocities decrease with increasing depth from a maximum of about 100 cm s^{-1} at the surface.

Numerous estimates of transport in the Loop Current have been made using various techniques. An average value of 30 x $10^6 m^3 s^{-1}$ has been determined by Nowlin and Hubertz (1972), Nowlin and McLellan (1969), Schmitz and Richardson (1968), and Morrison and Nowlin (1977), although their reference levels are not necessarily directly analogous. Values for inflow and outflow of 22.3 and 21.4 x $10^6 m^3 s^{-1}$ were determined by Molinari and Yager (1977) and Brooks and Niiler (1975), respectively.

Studies of the Loop Current have shown that it is a highly variable, complex system. A comparison of the extent of the northward intrusion of the Loop as observed by different investigators indicates that the spatial extremes of 1) direct flow from the Yucatan Straits to the Florida Straits and 2) intrusion of the Loop as far north as 28.5^{o} are both relatively common.

Leipper (1967, 1970) proposed an annual cycle of growth and decay of the Loop Current, beginning with the formation of a small Loop near Cuba in January-February and subsequent growth into the Gulf through August. He termed the sequence the "spring intrusion". The decay phase follows with a general weakening of the Loop and splitting of the flow, either in detached eddies, current rings, or extension to the west.

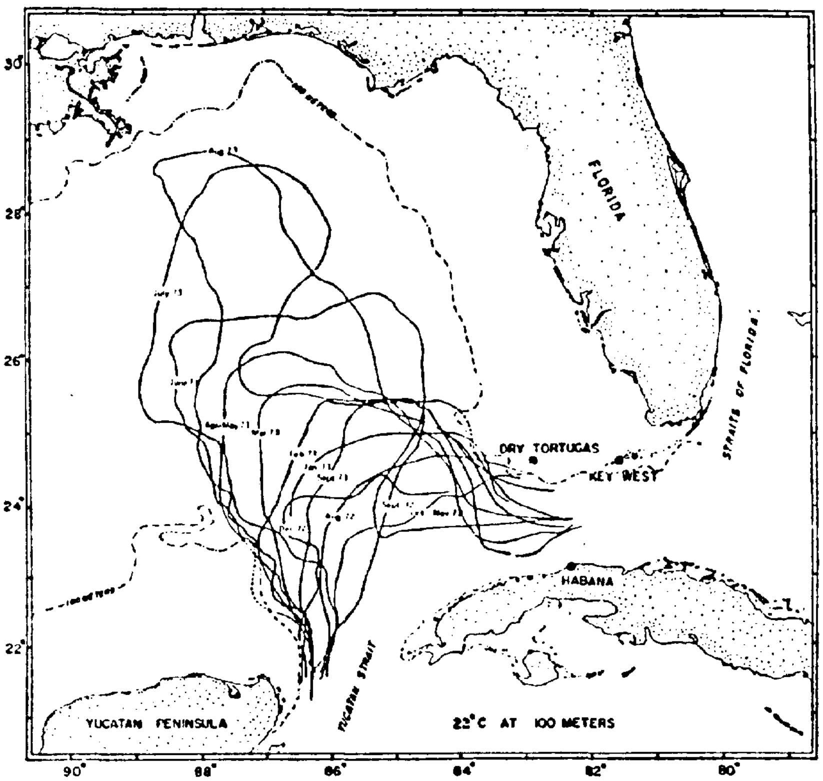


Fig. 12. Compilation of pathlines of the 22°C isotherm at 100 m depth from August, 1972 through September, 1973. Where the indicator isotherm intersected the bottom topography, a dashed line is used to estimate its position from the other thermal data. Where the cruise started in 1 month and ended in another, both months are indicated. 100 m isobath is indicated by a dash-dot line and represents very closely the shelf break and escarpment zone (from Maul, 1977).

Maul (1977) studied the annual cycle of the Loop Current between August, 1972 and September, 1973, and concluded that, although the pattern is cyclic, year-to-year variability is significant and that the "intrusion" (Leipper, 1970) is not necessarily a spring phenomenon. Fig. 12 shows the path lines of the 22^{o}C isotherm determined in his work. They demonstrate a maximum intrusion to 28^{o}45'N in August, 1973 and a minimum to 24^{o}15'N in December, 1972. As the Loop penetrated deeper into the Gulf, it also moved further to the west (Maul, 1977).

Growth of the Loop in the Gulf is believed to result from an excess of inflow through the Yucatan Straits over outflow through Florida Straits (Leipper, 1967; Maul, 1977). Maul (1977) calculated that a net flow increase of 4 x $10^{6} m^{3} s^{-1}$ was required to induce growth. The flow increase through the Yucatan area may be associated with seasonal increase in transport of the Florida Current.

The detachment of large, anticyclonic eddies from the Loop Current is well documented (Nowlin, Hubertz and Reid, 1968; Leipper, 1970; Leipper, Cochrane and Hewitt, 1972; Morrison and Nowlin, 1977; Cochrane, 1972). These features exhibit a range of surface current speeds up to a maximum comparable to that observed within the main Loop Current (about 100 cm s^{-1}). The formation of these eddies is believed to occur on an average of once per year, normally following the intrusion of the Loop north into the Gulf. Hurlburt and Thompson (1982) used numerical model experiments to show that the quasi-annual eddy shedding period could be

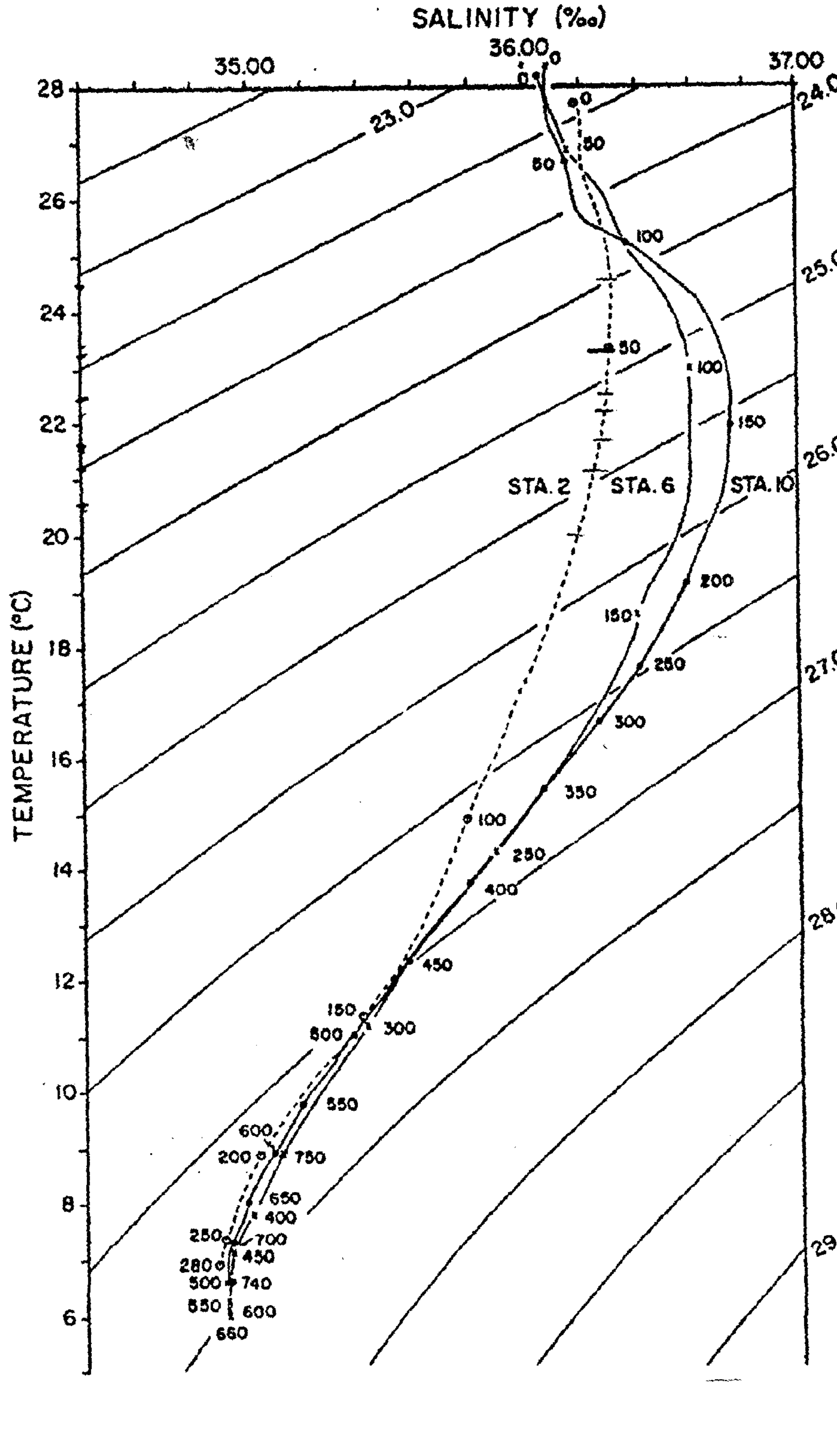


Fig. 13. T-S curve, stations 2, 6 and 10 (from Stubbs, 1971).

of interior Florida is classified as wet subtropical because the impact of the warm Florida Current is less significant. The mean annual air temperature near the Straits is 23.9°C, with July-August the hottest months (average high of 29.2°C) and December-January the coldest (average low of 15.8°C).

An upper air trough centered over south Florida gives rise to a rainy season during the months of June and September. The wet season abates somewhat in July and August because the trough moves west out over the Gulf of Mexico during that period. It returns by September. The entire rainy season may span May through November. January and February are the driest months. Average annual rainfall is approximately 160 cm.

South Florida lies at the northern end of the trade wind belt (easterlies) throughout most of the year. Resultant summer winds are commonly out of the southeast. In the winter, the easterly trades are interrupted by the transient occurrence of cold fronts on time scales of about one week (Fernandez-Partagas and Mooers, 1976). During a cold front, winds cycle in a clockwise direction and intensify to 10 m s^{-1} or more. Diurnal variations of the trade winds are common, especially in summer; winds often become light and variable at nightfall.

Hurricanes

Tropical cyclones occasionally affect the Florida Straits region. Similar to Pacific typhoons, Atlantic hurricanes occur seasonally, generally between June and November. Most hurricanes originate as a tropical disturbance in the equatorial Atlantic, attaining hurricane strength in the Atlantic Caribbean or Gulf of Mexico.

South Florida coasts are affected by hurricanes more often than any other equal-sized area of the United States (see Gentry, 1974). Based on data for the past 100 years, the probability that hurricanes with winds greater than 119 kph will hit the Miami-Ft. Lauderdale coastline is 15% per year; the probability of a great hurricane (>201 kph) is 7% per year. September and October are the most active months, 62% of all hurricanes occurring then. The south Florida area has averaged about one hurricane every two years for the period since 1885.

Hurricane winds are capable of producing extremely large waves. As an example, a 15.24 m, 10 second period wave was recorded at $27^{\circ}01'$N, $79^{\circ}51'$W (off Hollywood, FL.) in 317 m of water during Hurricane Betsey in 1965.

3) Current and Temperature Profile Data

A total of 28 profiles of temperature, current speed and direction were recorded during three anchor stations I, II and III which each last approximately 24 hours(see locator map Fig. 14). From the historical data (see section 2) it is well known that considerable current variability exists at the diurnal and semidiurnal tidal periods. By recording over a 24 hour period we can estimate the slowly varying mean current profile and its standard deviation. The times of each profile and wind data are shown in figure 15.

Current profiles were recorded using a FB-II profiling hull with an Aanderaa current meter as described by Düing and Johnson (1972). The R/V Bellows was first anchored at each proposed OTEC site in 700 to 800 meters of water respectively using a scope of about 2 to 1 with a large Danforth type anchor, 100 feet of 3/4" chain and 1/2 trawl wire deployed over a bow roller. Once Loran C fixes showed a steady position, the hydro wire was lowered over the "A frame" on the starboard side with a 500 pound weight to minimize wire angle. This weight was then lowered to within 10 to 30 meters of the bottom. Finally the profiler was attached to the wire by means of its roller and permitted to free fall down the hydro wire until it encountered the bottom stop. Ballasting and horizontal trim of the profiler was checked in a tank at RSMAS and monitored using the Precision Depth Recorder (PDR). When the PDR trace confirmed that the profiler had arrived at the bottom, the hydro wire was winched in until the profiler was once again at the surface. A line secured the profiler at the surface while the weight was lowered to the bottom ready for the next profile to begin. Figure 16 from Düing and

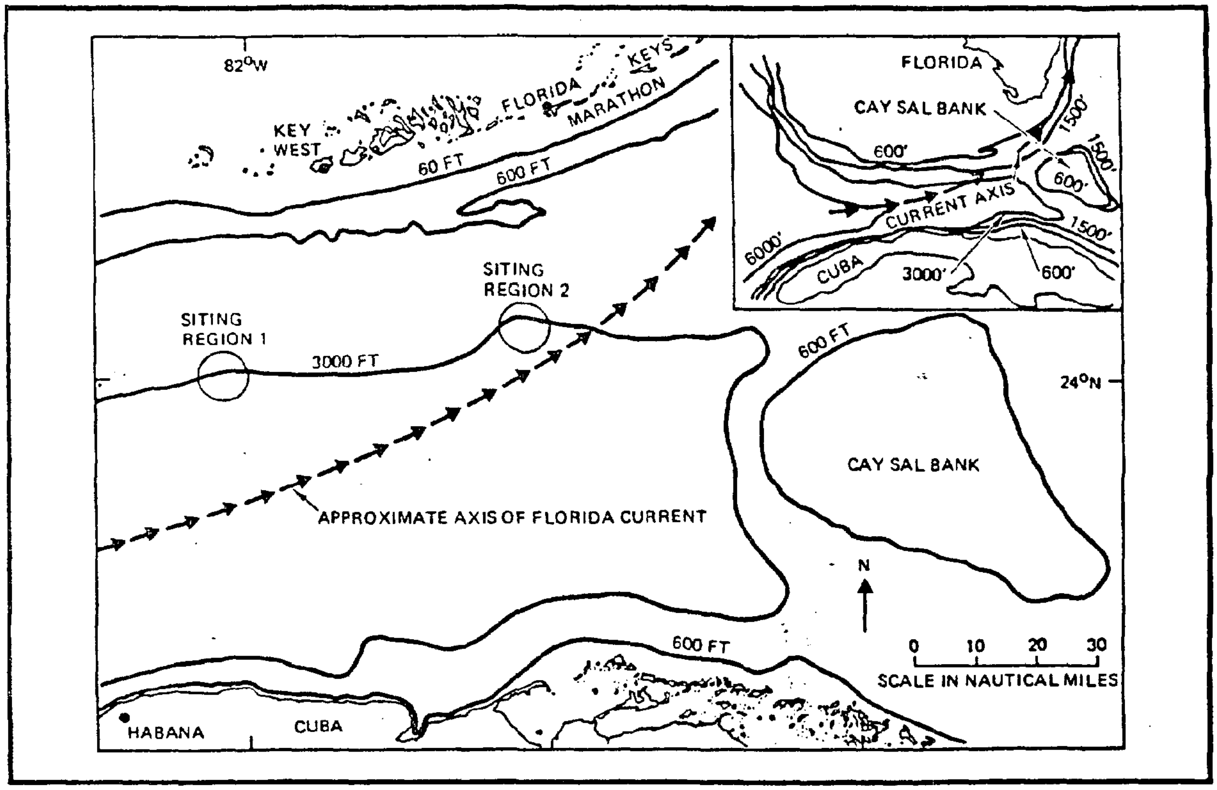


Figure 14: Locator map showing prospective FOTEC sites. Stations I and III were made at site 1 while Station II was made at site 1.

STATION NO.	PROFILE NO.	DATE---TIME	WIND SPEED	WIND DIRECTION
			(KNOTS)	(DEGREES M)
I	1	2/19/83 16:10	0 TO 3	VARIABLE
I	2	2/19/83 18:30	2 TO 3	180
I	3	2/19/83 21:33	0	---
I	4	2/20/83 00:35	8 TO 10	25
I	5	2/20/83 03:00	12	125
I	6	2/20/83 05:16	10 TO 12	112
I	7	2/20/83 07:52	10 TO 12	90
I	8	2/20/83 10:19	5 TO 8	50
I	9	2/20/83 12:48	5 TO 8	90
IN PORT	STRONG WINDS			
II	10	2/23/83 05:45	6 TO 8	290
II	11	2/23/83 20:00	6 TO 8	340
II	12	2/23/83 22:15	4 TO 6	330
II	13	2/24/83 01:20	5 TO 8	320
II	14	2/24/83 02:47	4 TO 6	300
II	15	2/24/83 05:10	3 TO 5	250
II	16	2/24/83 07:15	4 TO 6	270
II	17	2/24/83 09:37	10 TO 12	251
II	18	2/24/83 12:15	10 TO 15	264
II	19	2/24/83 14:43	6 TO 8	272
II	20	2/24/83 17:07	4 TO 6	247
MOVE TO NEXT	STATION			
III	21	2/25/83 06:54	10 TO 15	320
III	22	2/25/83 09:32	12 TO 15	310
III	23	2/25/83 12:08	10 TO 15	340
III	24	2/25/83 15:45	8 TO 10	340
III	25	2/25/83 18:22	12 TO 15	350
III	26	2/25/83 21:06	15	5
III	27	2/25/83 23:30	15 TO 17	5
III	28	2/26/83 01:45	15	50

2. INSTRUMENT AND METHODS

Principle. Figure 1 shows the principle of the profiling method. The profiler (Fig. 2) consists of a self-contained Aanderaa current meter (AANDERAA, 1964; DAHL, 1969) attached to a cylindrical hull. The density of the instrument package is slightly greater than that of the surrounding water. The Savonius rotor extends out from the bottom side of the cylindrical hull when it is in its horizontal working position. The entire package is attached by a roller to a taut wire suspended beneath the anchored ship and allowed to descend slowly through the entire water column.

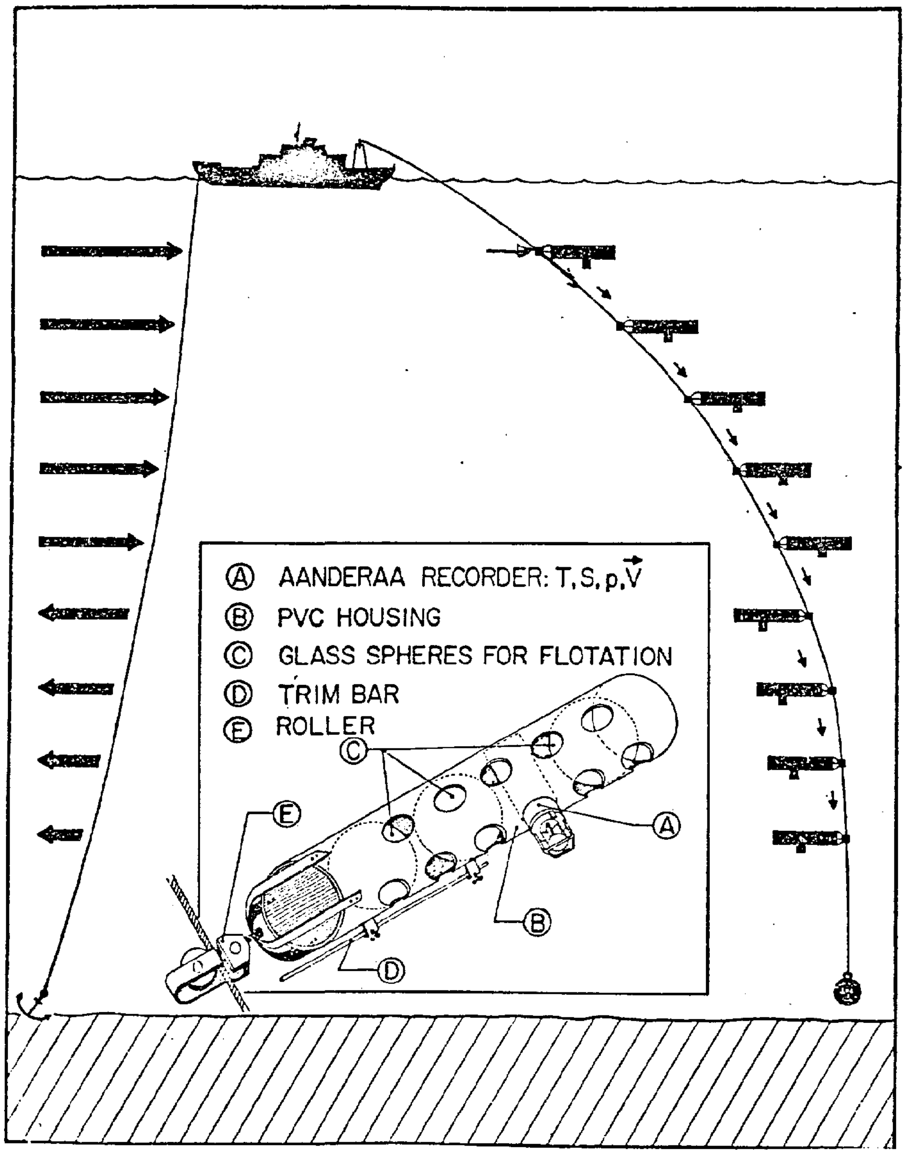


Fig. 1. Principle of current profiling method used in the Florida Current.

Figure 16: Principle of current profiling method used in the Florida Current (from Duing and Johnson, 1972).

a) Mean Current Profiles

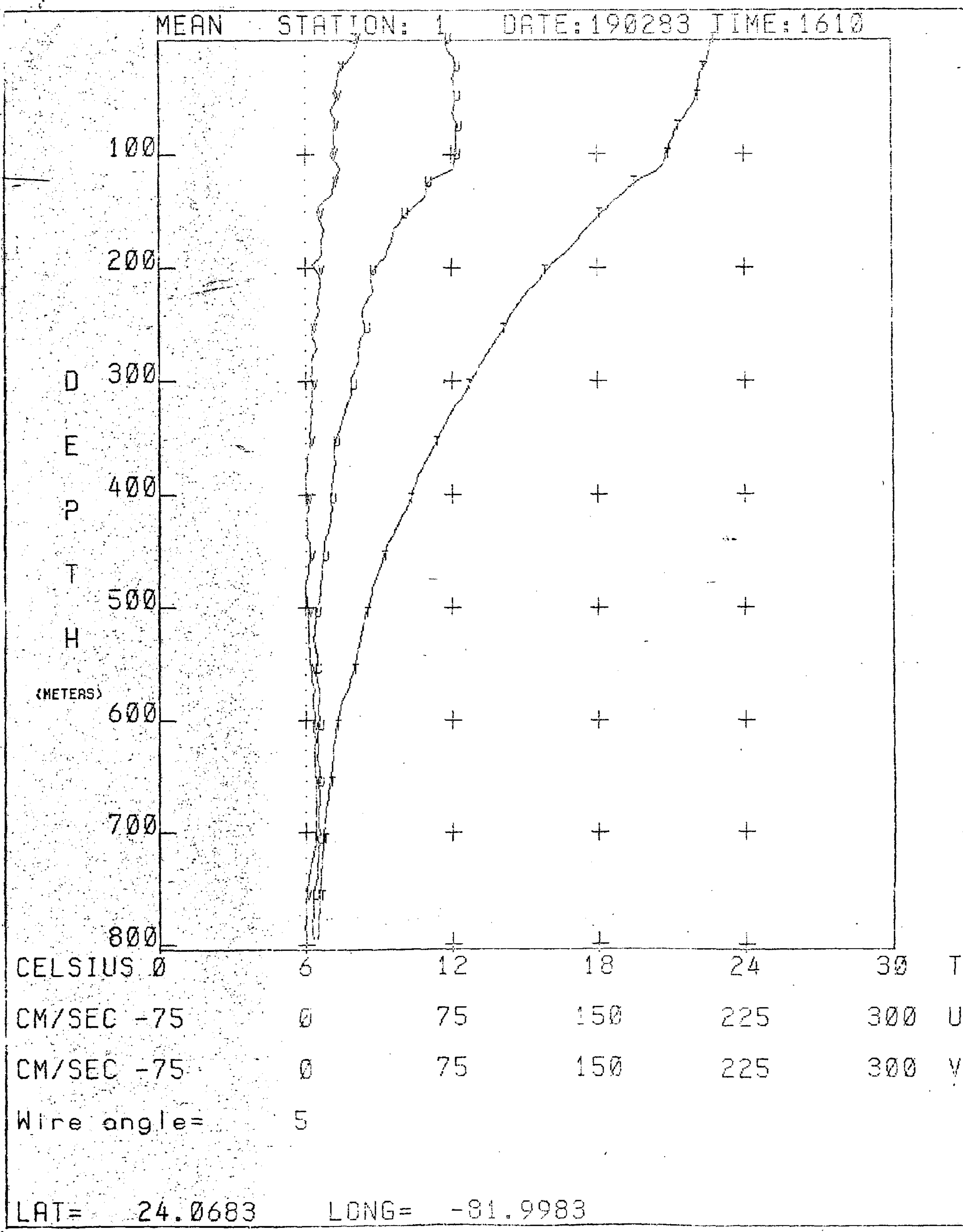
The mean current profiles for the three anchor stations as seen in figures I-M, II-M, III-M are remarkably similar to each other in the upper 100 meters. Here velocities were about 75 cm per sec toward the East with a Northerly component of 10-15 cm s^{-1}. At 100 meters there was a distinct break in the velocity which coincided with a break in the temperature profile from a relic mixed layer structure with modest stratification to the top of a strong thermocline. Below 100 meters both velocity components decreased toward smaller velocities being about a half of the surface amplitude at 200 meters with a more gradual decrease toward $\pm$ 5 cm s^{-1} near the bottom.

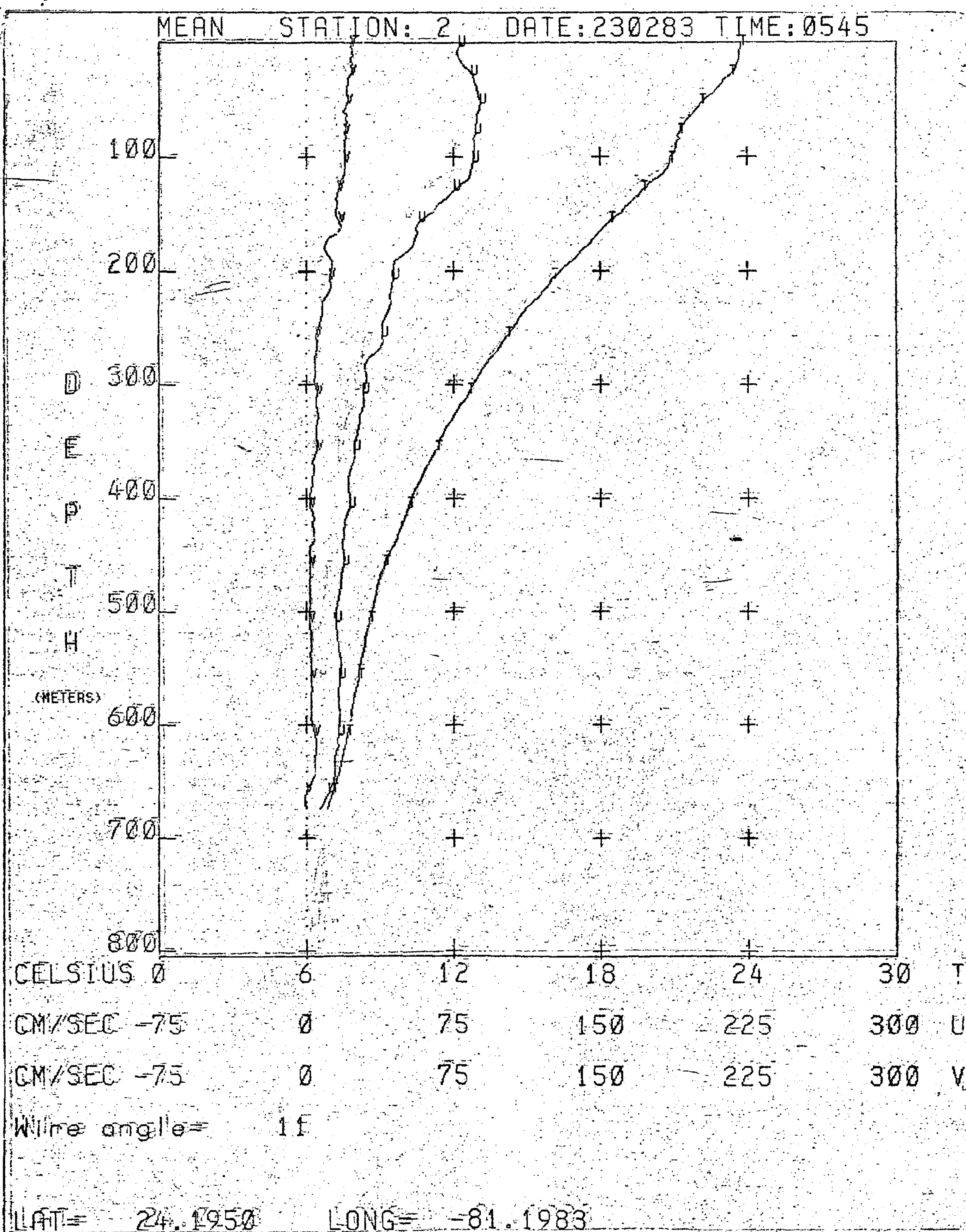
b) Standard Deviations from the Mean Velocity Profiles

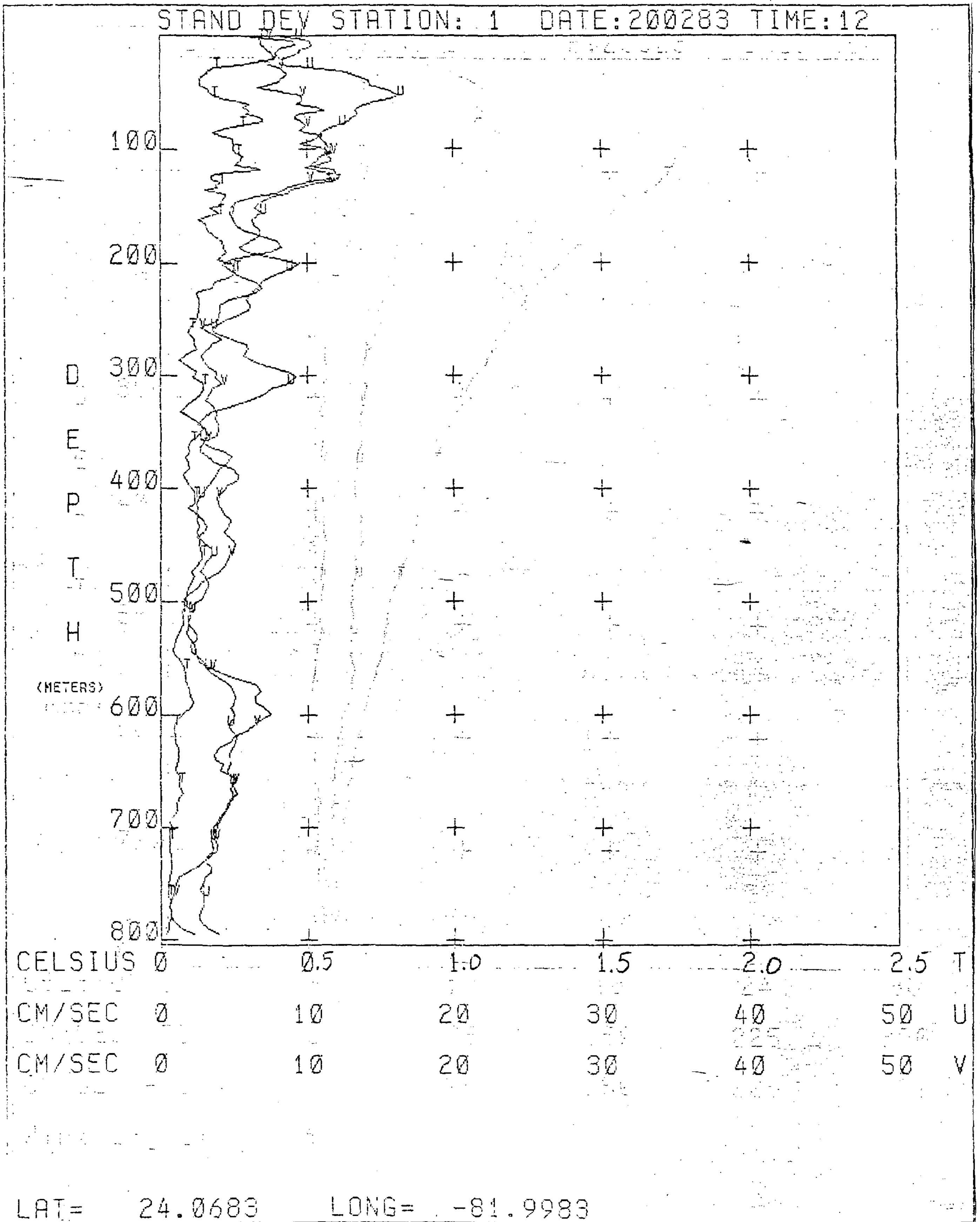
The standard deviations of the individual profiles from the one day average profiles as seen in figures I-SD, II-SD, III-SD show their largest values near the surface. Typical values near the surface are 15 cm s^{-1} while values below 200 meters are order 5 cm s^{-1}. The extreme value occurred at Station 2 at the surface of about 40 cm s^{-1} as a reversal of the velocity deviation near the end of the record with peak velocities over 150 cm s^{-1}. These strong short lived velocities may represent a transient response of the surface layers to westerly wind forcing.

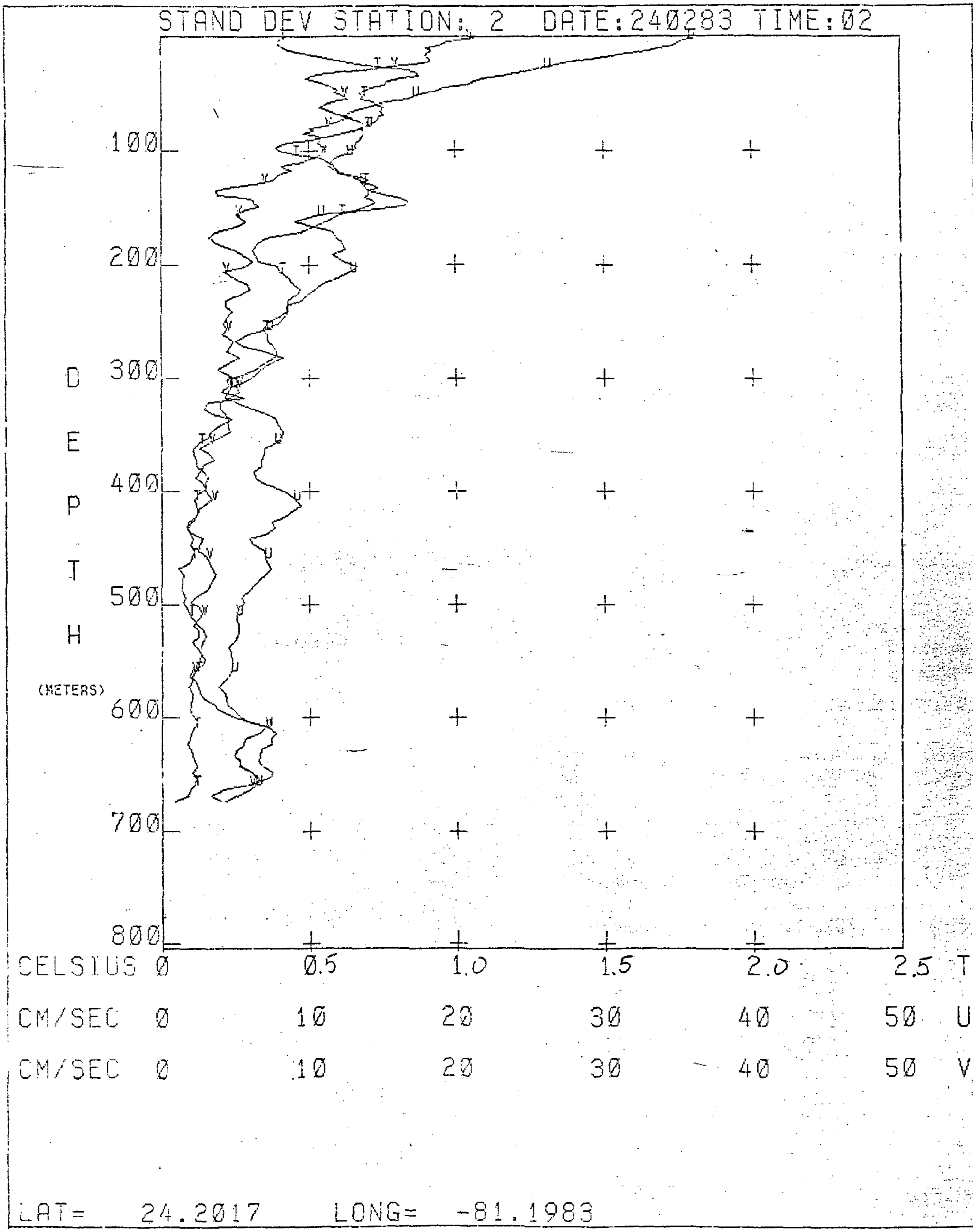
c) Mean Temperature Profiles

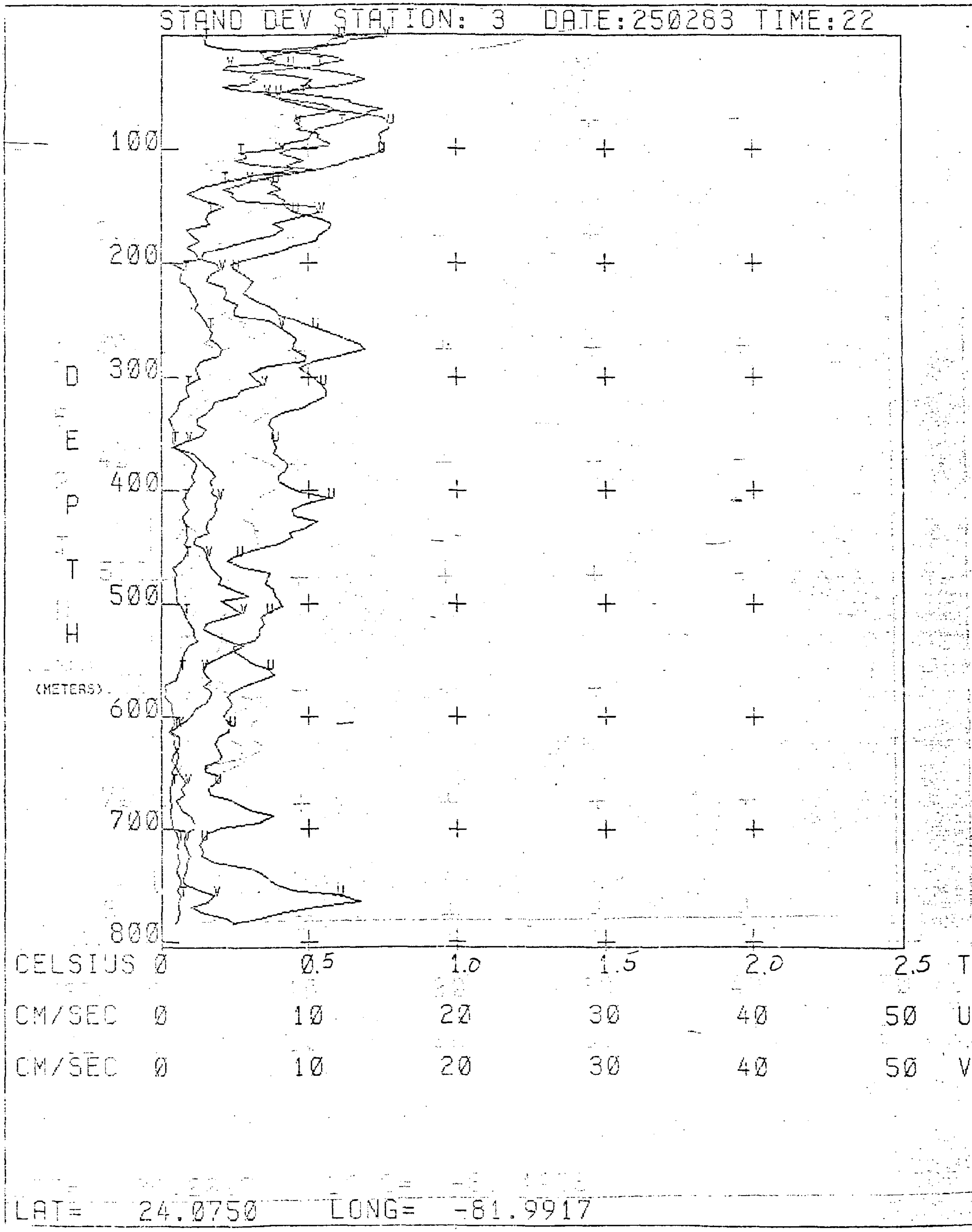
Mean temperature profiles are also seen in Fig. I-M, II-M, and III-M. Near bottom temperatures stayed in a narrow range near 7°C while near surface temperatures varied in a range of 23 $\pm$1°C. Most of the near surface temperatures were nearer 24°C so that a mean temperature


MEAN STATION: 1 DATE:190283 TIME:1610
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 5
LAT= 24.0683 LONG= -81.9983


MEAN STATION: 2 DATE:230283 TIME:0545
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 11
LAT= 24.1950 LONG= -81.1983


STAND DEV STATION: 1 DATE:200283 TIME:12
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 0.5 1.0 1.5 2.0 2.5 T
CM/SEC 0 10 20 30 40 50 U
CM/SEC 0 10 20 30 40 50 V
LAT= 24.0683 LONG= -81.9983


STAND DEV STATION: 2 DATE:240283 TIME:02
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 0.5 1.0 1.5 2.0 2.5 T
CM/SEC 0 10 20 30 40 50 U
CM/SEC 0 10 20 30 40 50 V
LAT= 24.2017 LONG= -81.1983

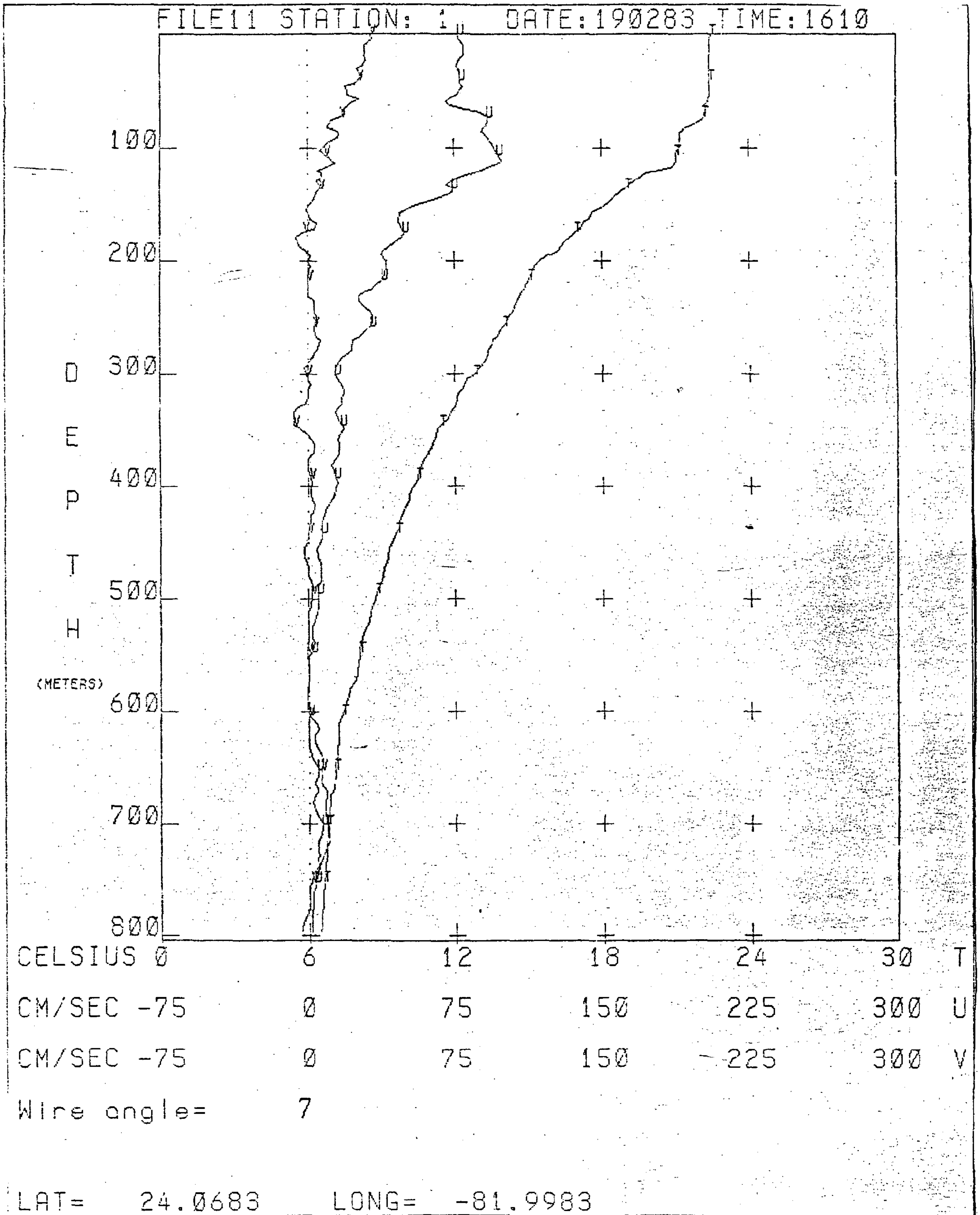


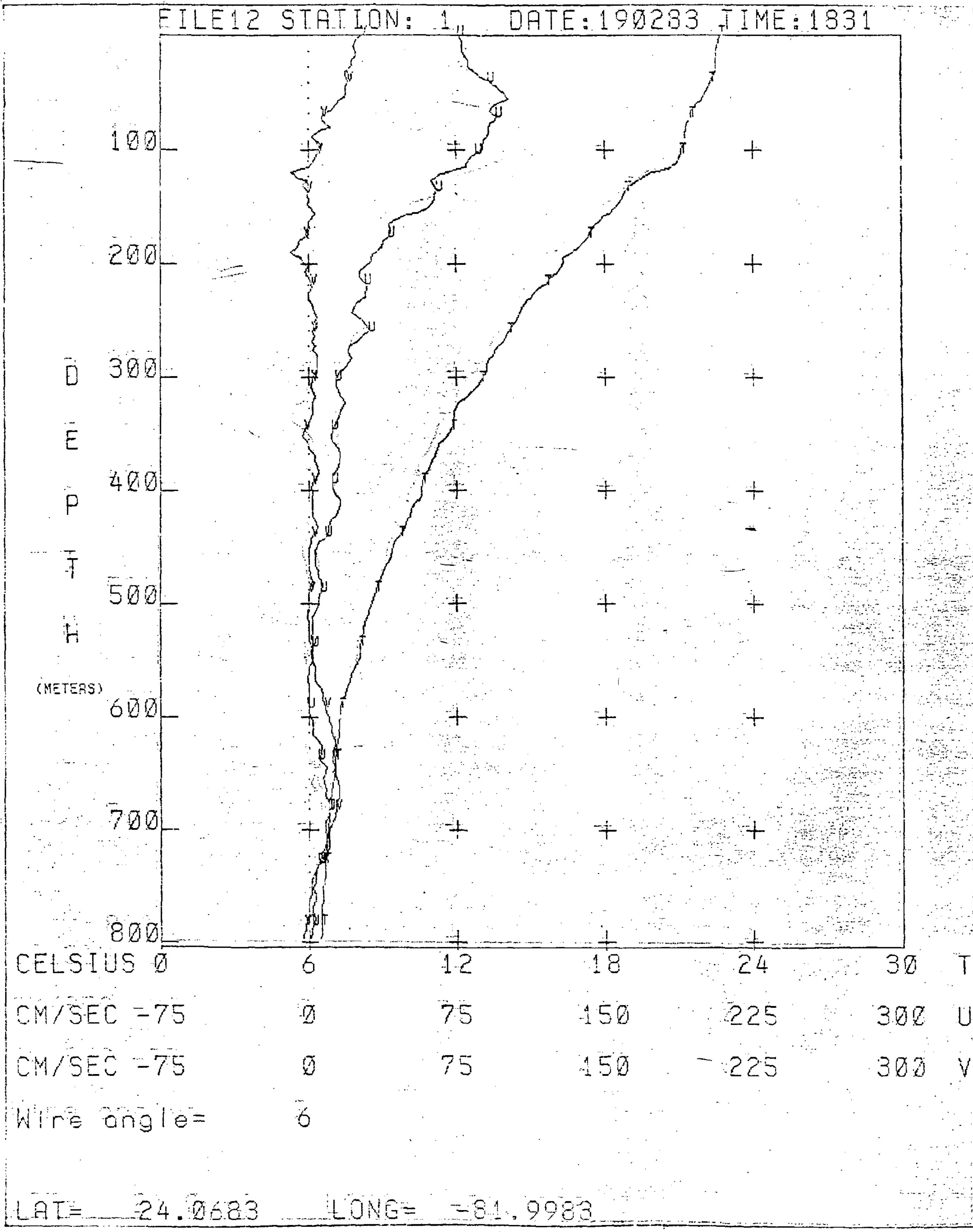
STAND DEV STATION: 3 DATE:250283 TIME:22
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 0.5 1.0 1.5 2.0 2.5 T
CM/SEC 0 10 20 30 40 50 U
CM/SEC 0 10 20 30 40 50 V
LAT= 24.0750 LONG= -81.9917

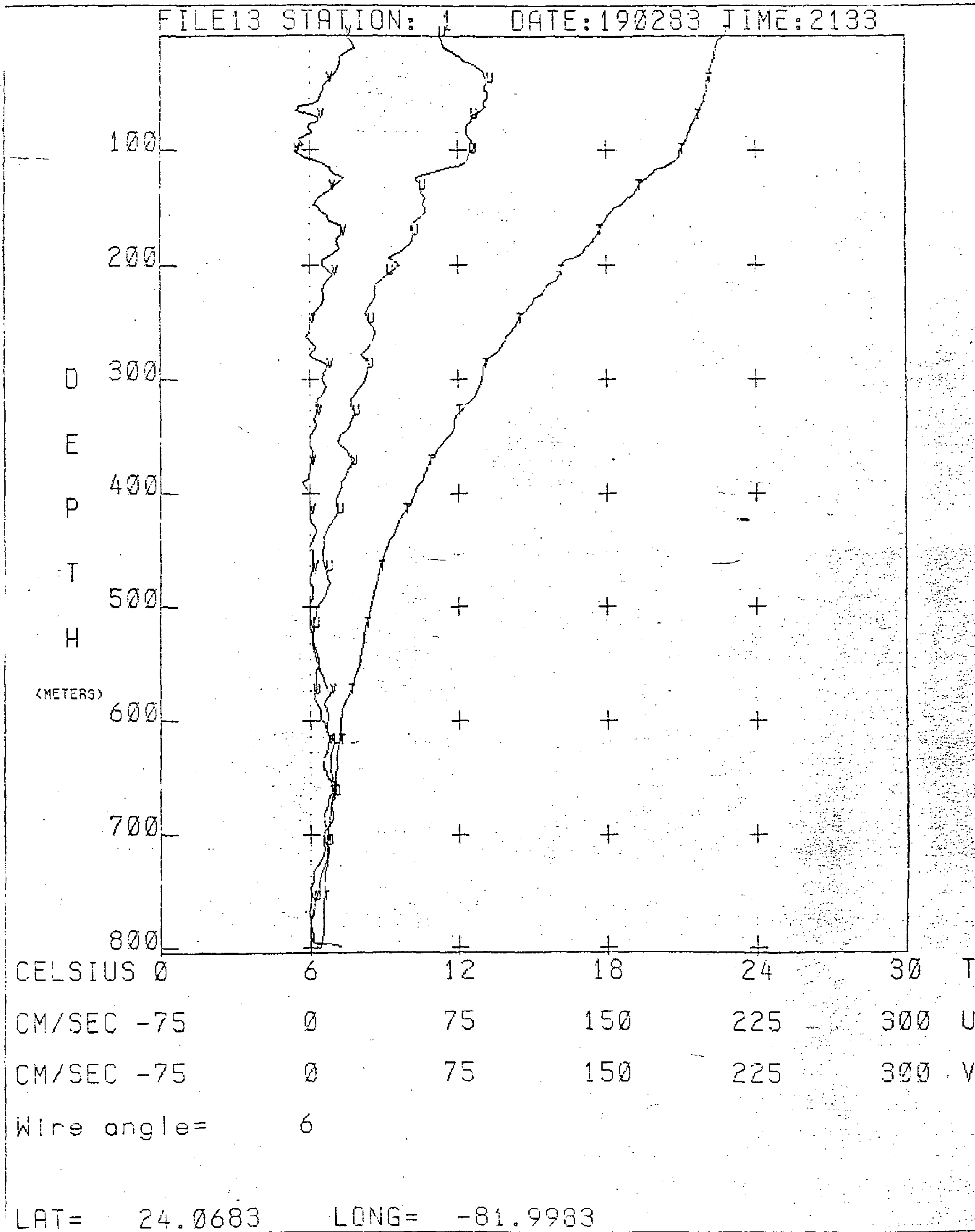
difference on all three anchor stations was near 17°C. February is usually near the minimum temperature for the year so this should represent a worst case. In the upper 100 meters there is some evidence of step structure in the mean temperature profiles while below this depth a smooth monitonically decreasing temperature is seen. Although in winter there may be a local subsurface temperature maximum stabilized by correspondingly higher tropical salinities. Individual profiles show numerous local inversions of this type on the 10-50 meter vertical scale. However, no such inversions were observed in the mean profiler.

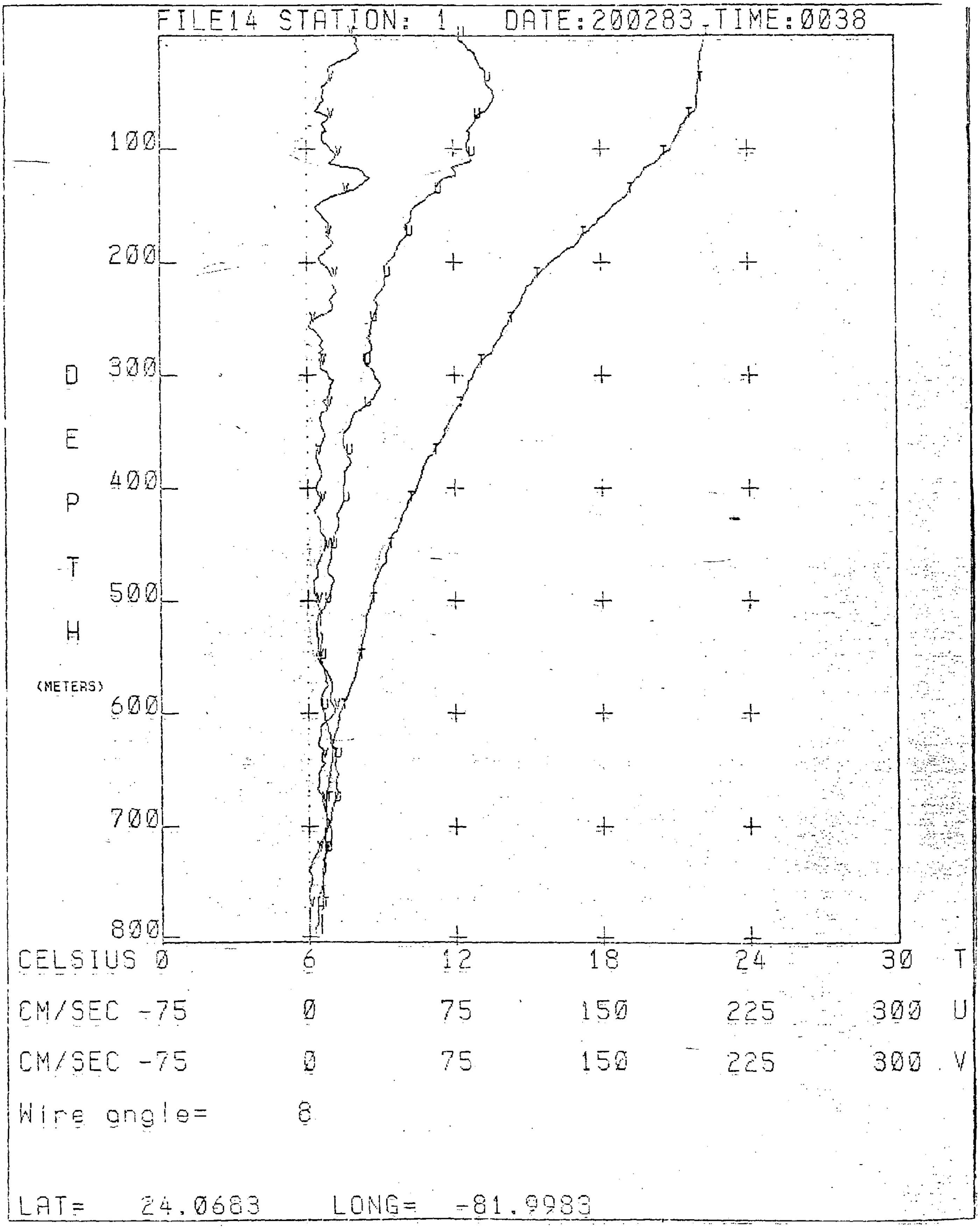
3.4) Standard Deviations about the Mean Temperature Profiles

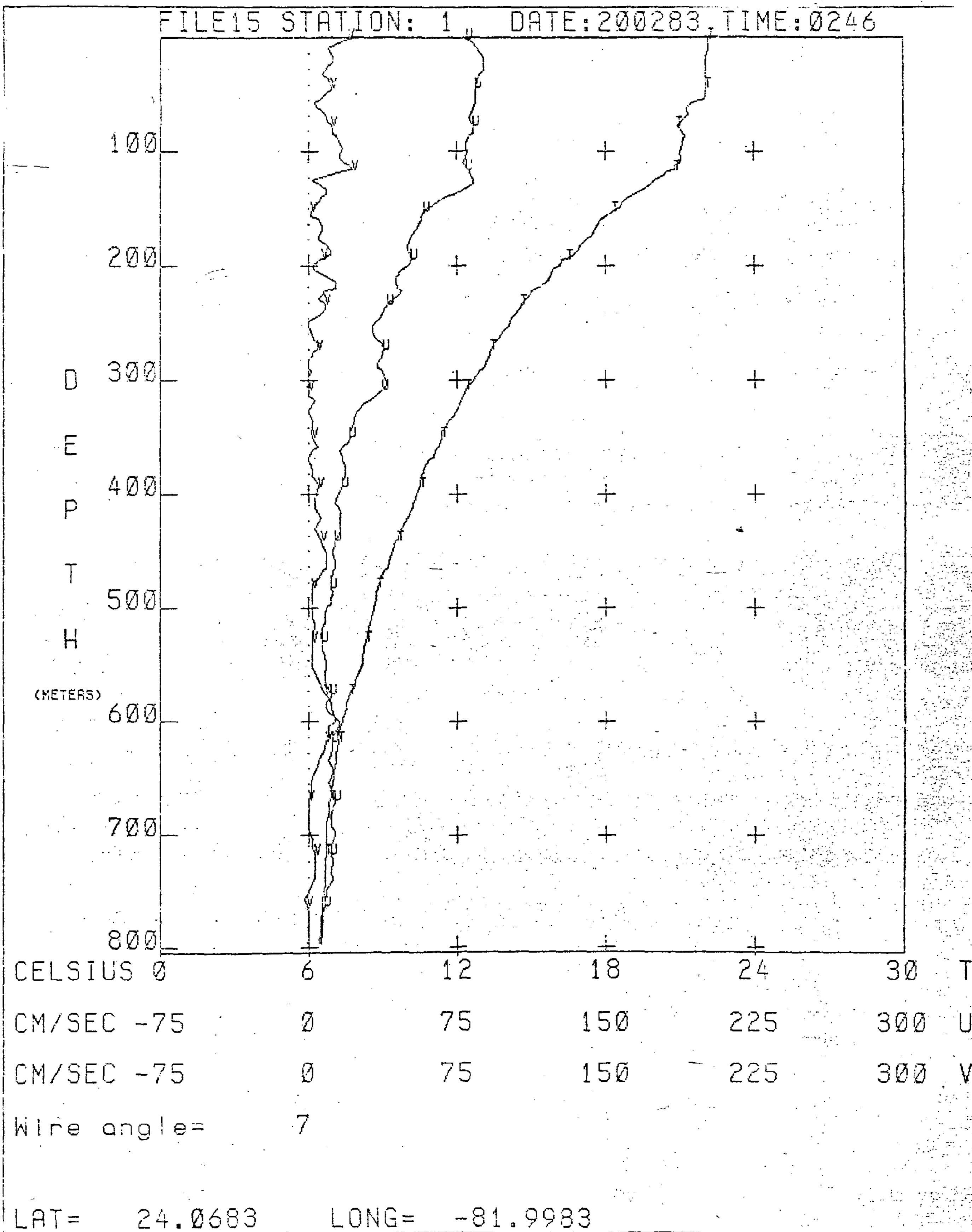
As expected the largest standard deviations from the mean temperature profiles occurred where the vertical temperature gradient was largest. For the lower portions of the profile the standard deviations were less than a tenth of a degree C. However, near the surface typical values increased to .5°C with extreme values of 1.5°C.

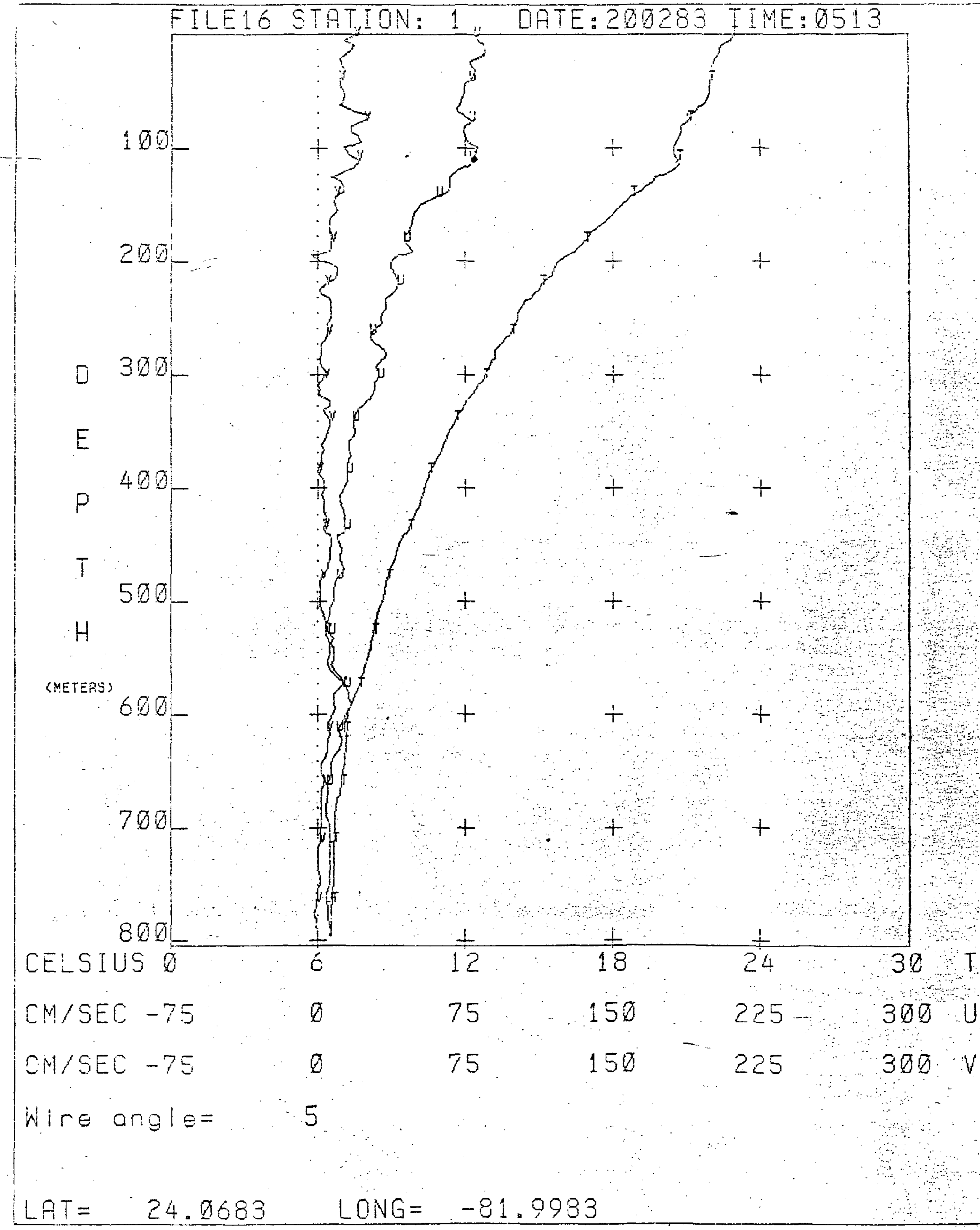

FILE11 STATION: 1 DATE:190283 TIME:1610
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.0683 LONG= -81.9983

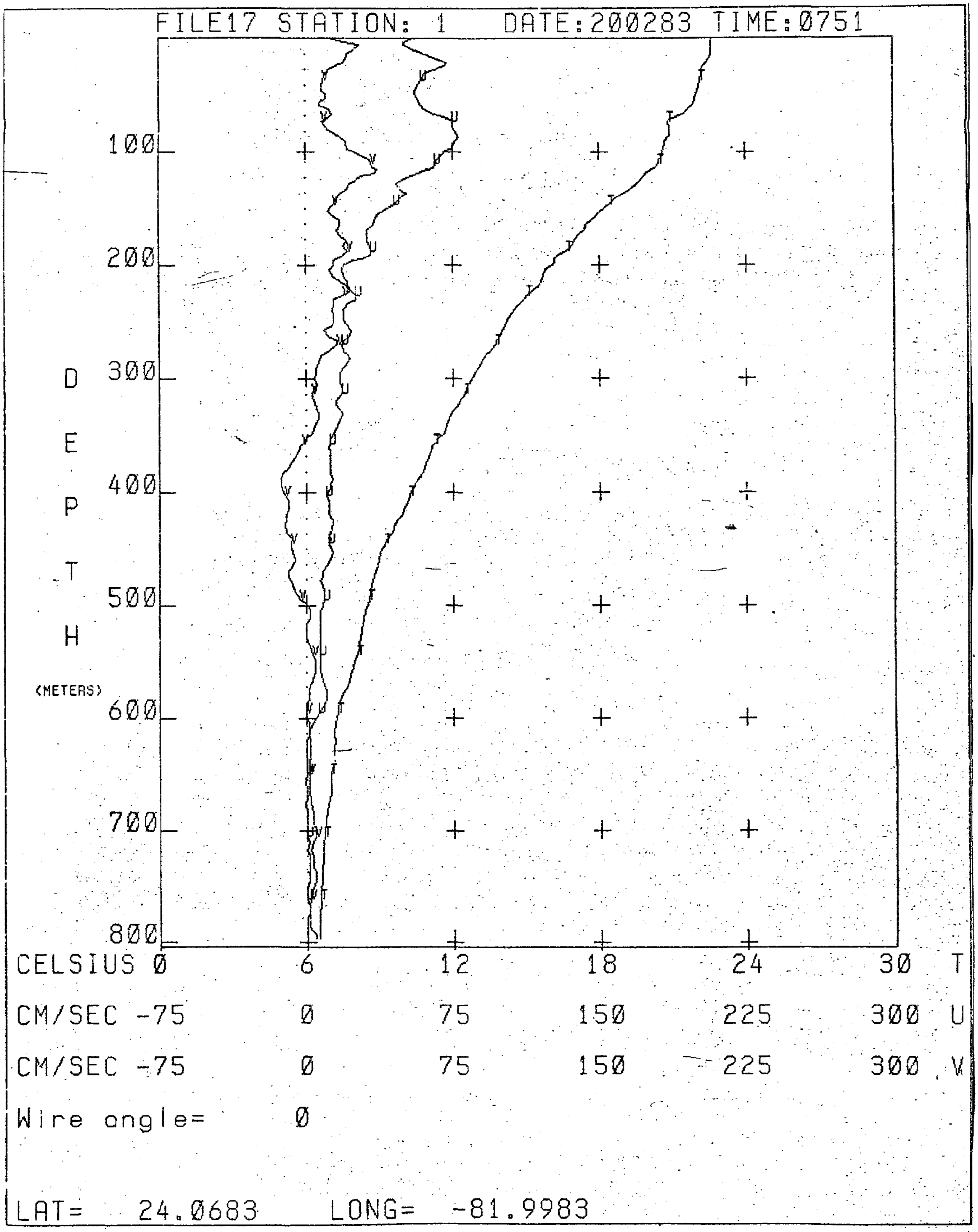

FILE12 STATION: 1 DATE:190283 TIME:1831
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS Ø 6 12 18 24 3Ø T
CM/SEC -75 Ø 75 150 225 3ØØ U
CM/SEC -75 Ø 75 150 225 3ØØ V
Wire angle= 6
LAT= 24.Ø683 LONG= -81.9983

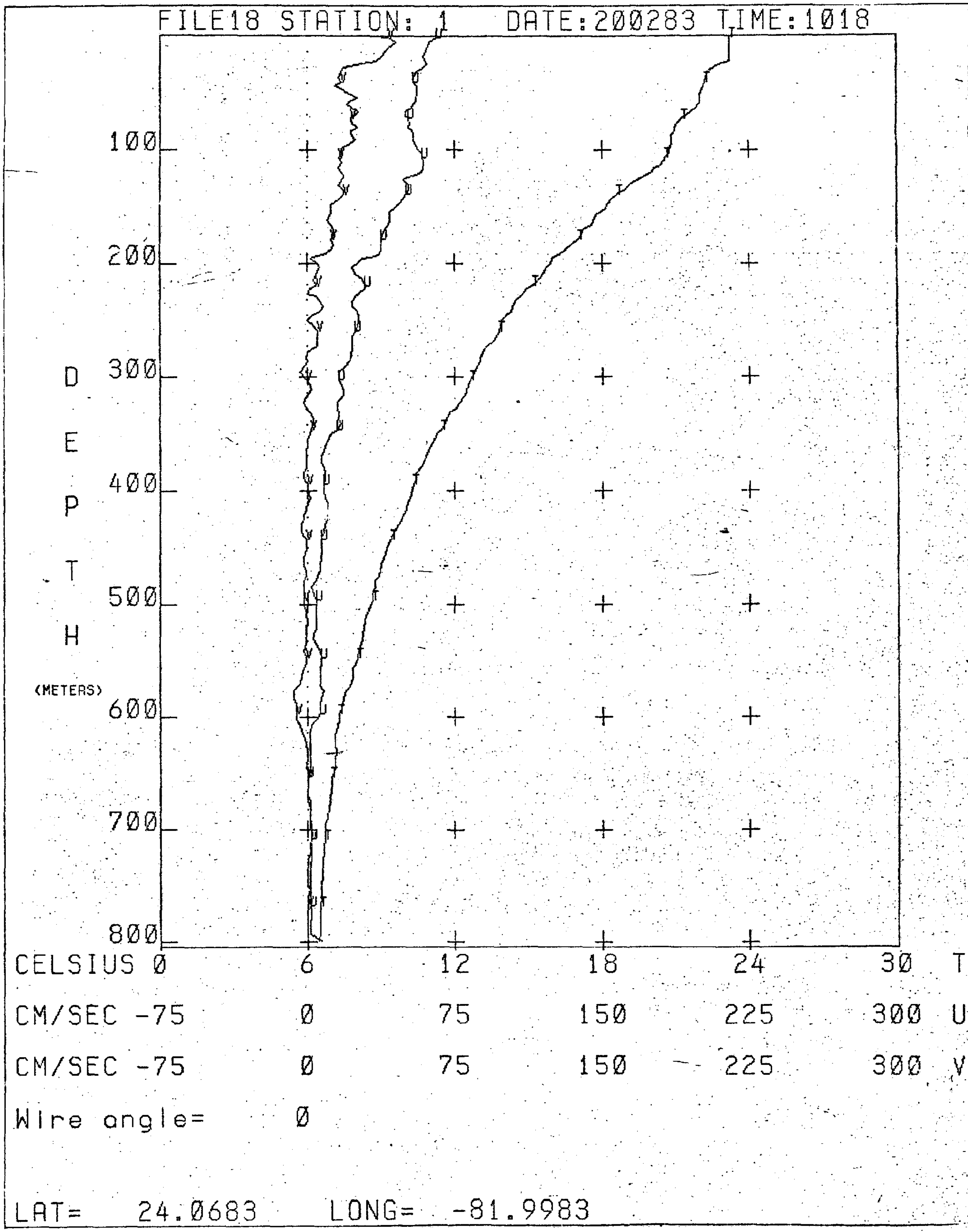

FILE13 STATION: 1 DATE:190283 TIME:2133
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 6
LAT= 24.0683 LONG= -81.9983

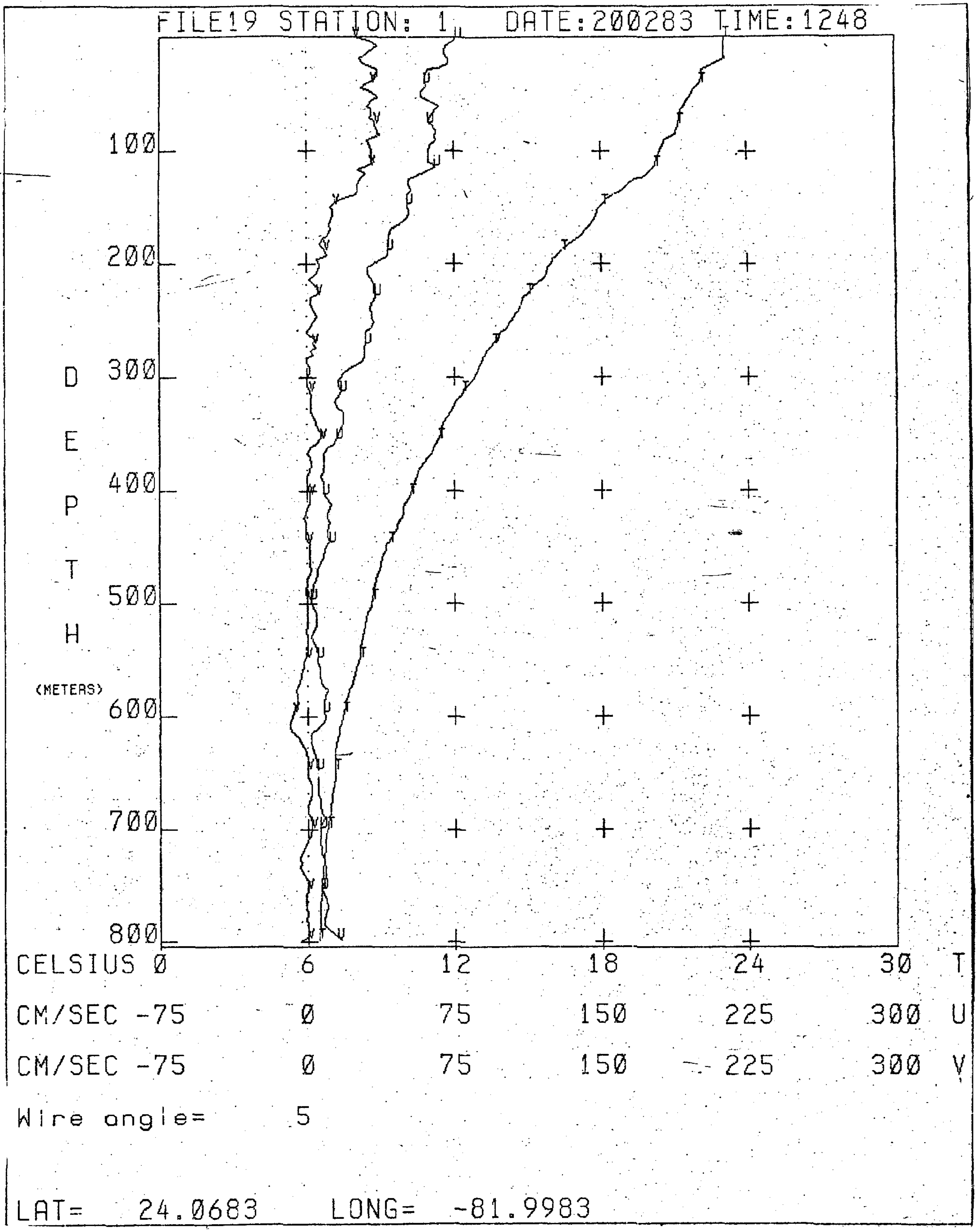

FILE14 STATION: 1 DATE:200283 TIME:0038
DEPTH
(METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 8
LAT= 24.0683 LONG= -81.9983

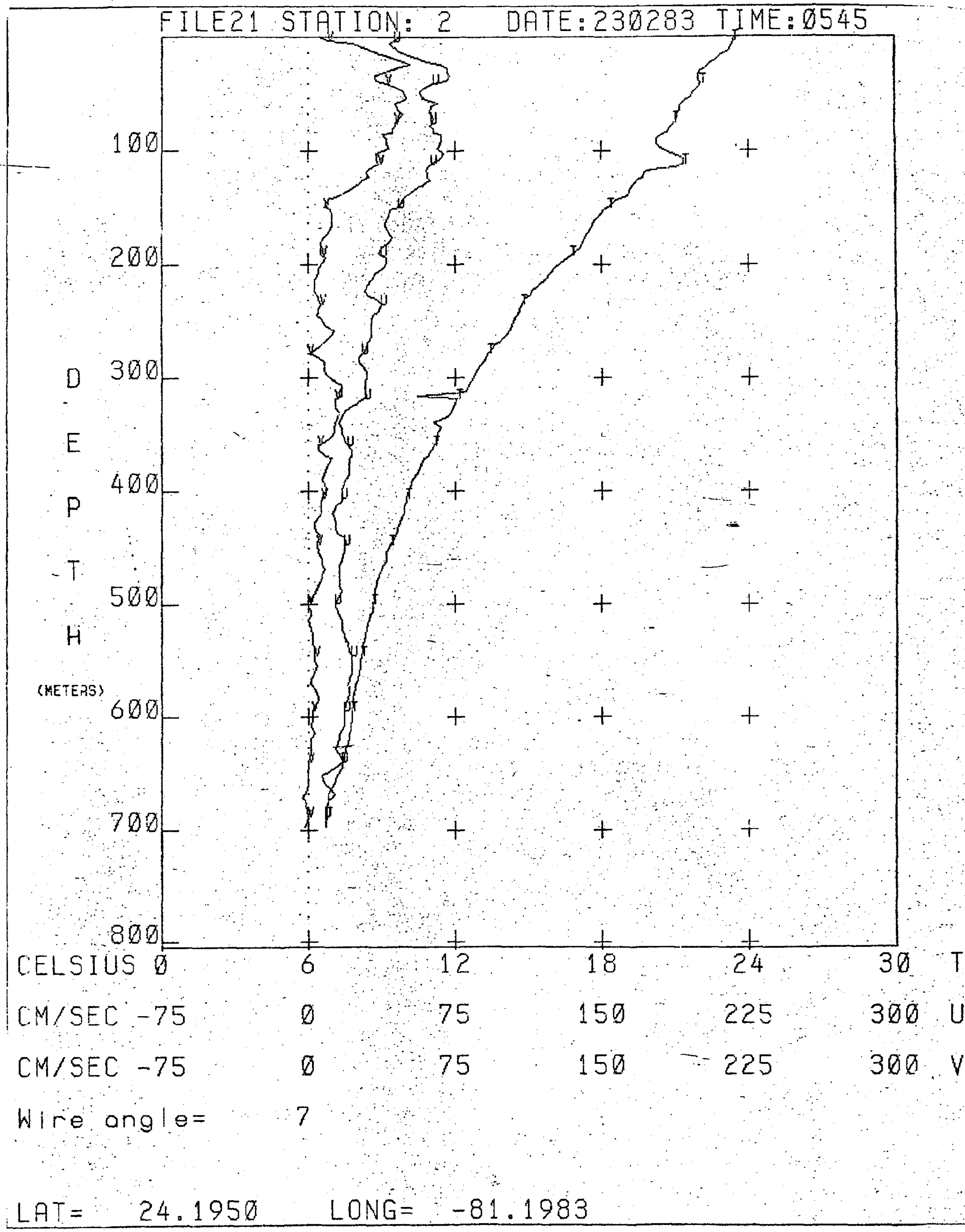

FILE15 STATION: 1 DATE:200283 TIME:0246
DEPTH
(METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.0683 LONG= -81.9983


FILE16 STATION: 1 DATE:200283 TIME:0513
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 5
LAT= 24.0683 LONG= -81.9983


FILE17 STATION: 1 DATE:200283 TIME:0751
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS Ø 6 12 18 24 3Ø T
CM/SEC -75 Ø 75 15Ø 225 3ØØ U
CM/SEC -75 Ø 75 15Ø 225 3ØØ V
Wire angle= Ø
LAT= 24.Ø683 LONG= -81.9983


FILE18 STATION: 1 DATE:200283 TIME:1018
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS Ø 6 12 18 24 30 T
CM/SEC -75 Ø 75 150 225 300 U
CM/SEC -75 Ø 75 150 225 300 V
Wire angle= Ø
LAT= 24.Ø683 LONG= -81.9983


FILE19 STATION: 1 DATE:200283 TIME:1248
D E P T H (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 5
LAT= 24.0683 LONG= -81.9983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DEPTH (METERS)
100
200
300
400
500
600
700
800
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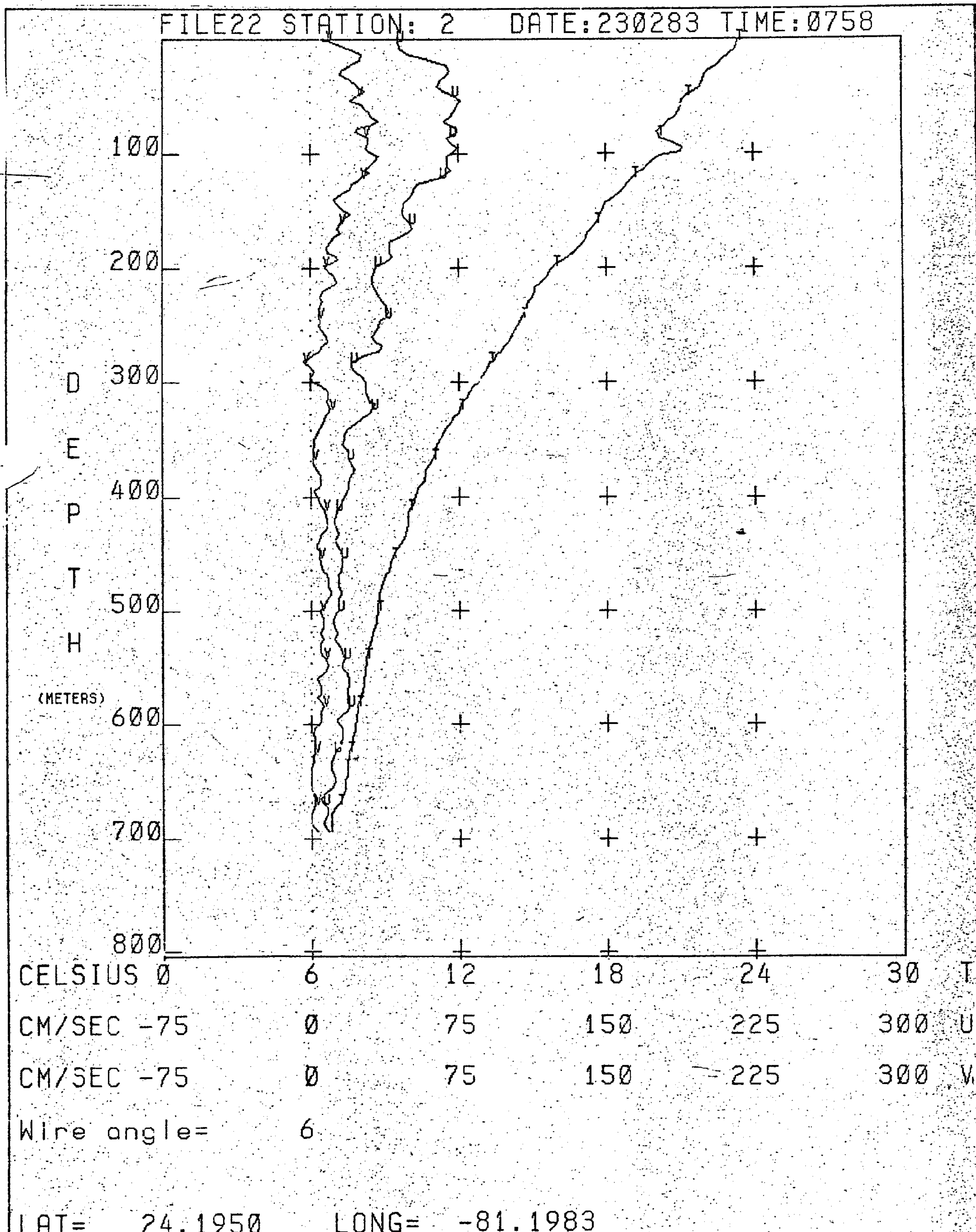
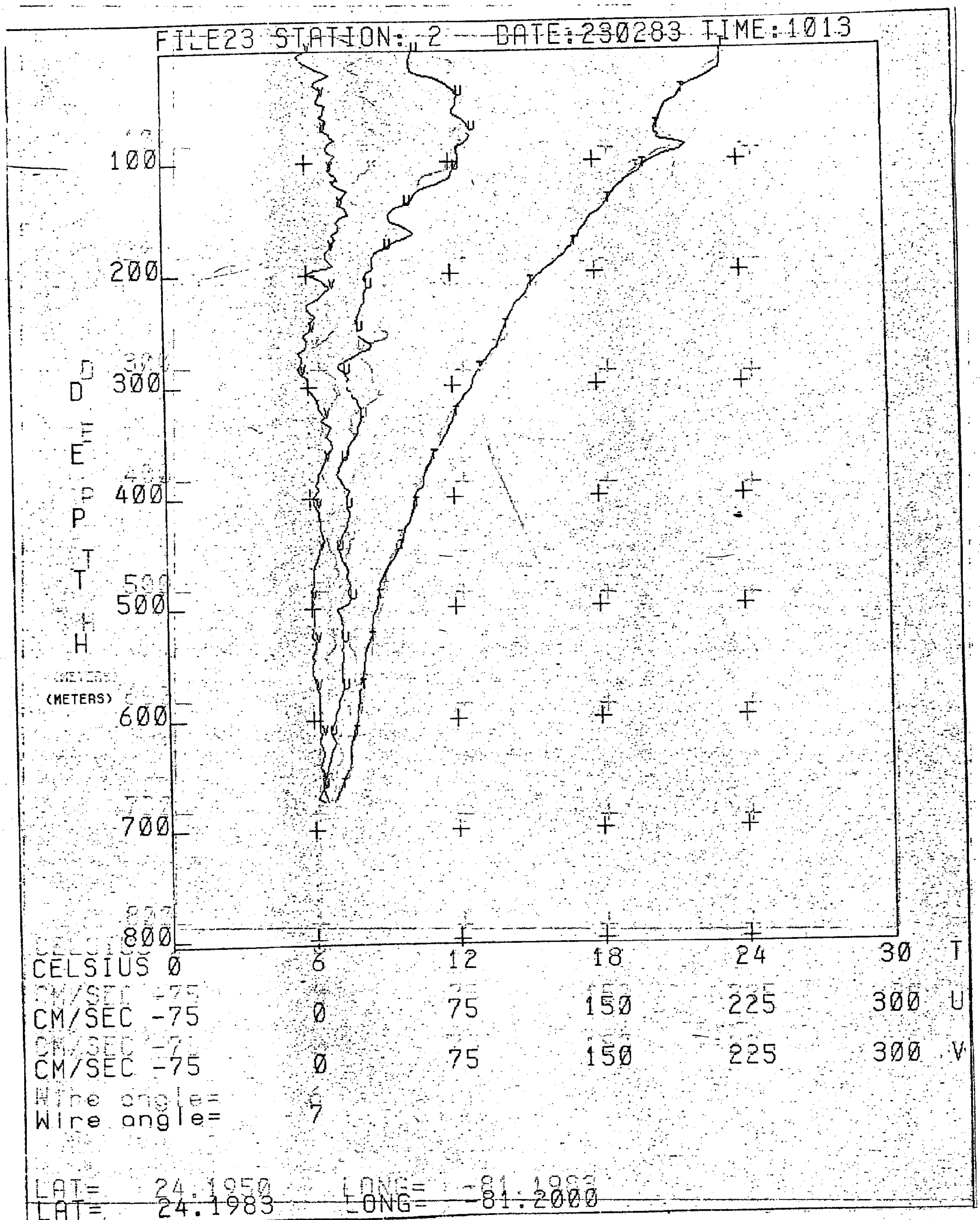
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.1950 LONG= -81.1983


FILE22 STATION: 2 DATE:230283 TIME:0758
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 6
LAT= 24.1950 LONG= -81.1983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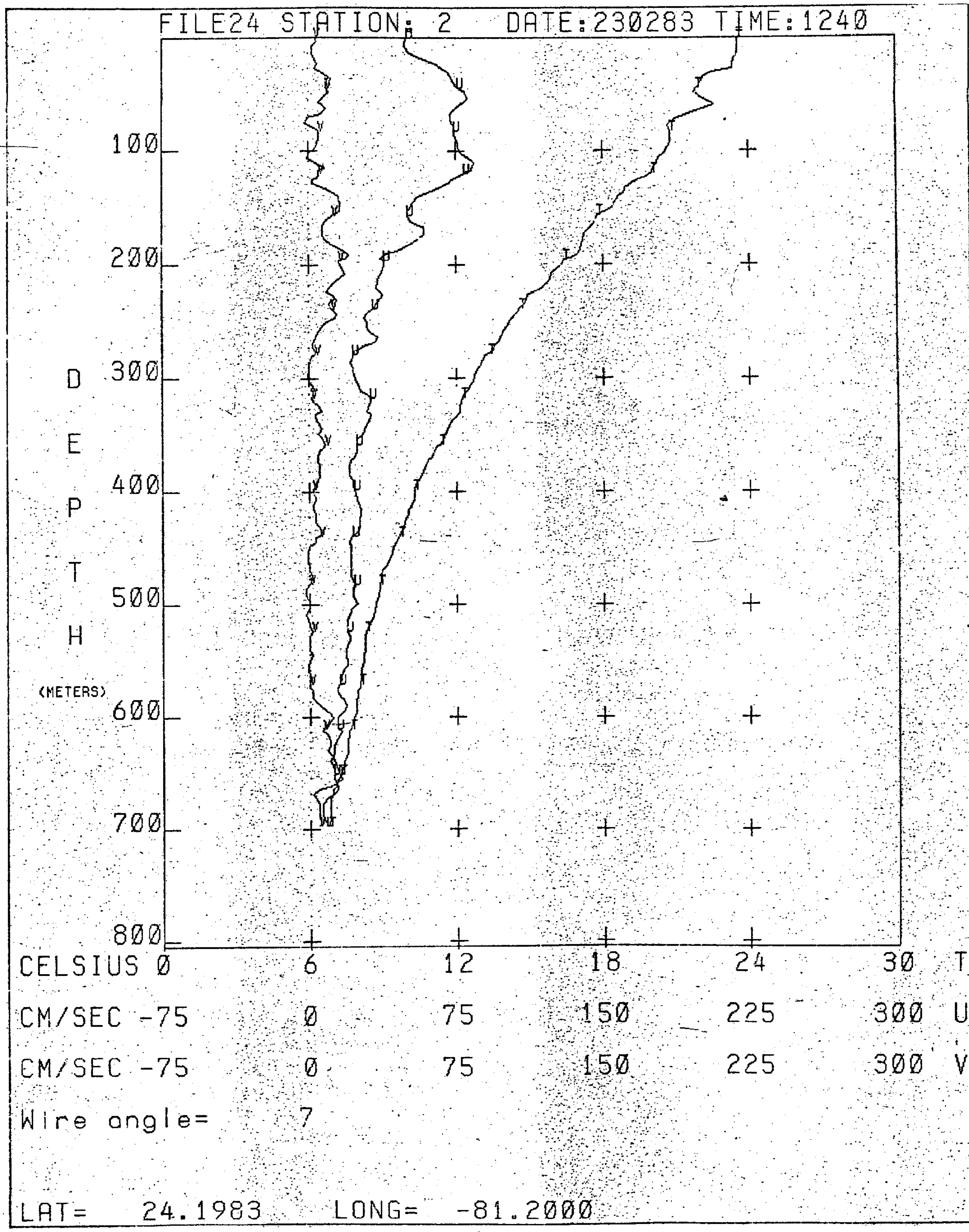
DEPTH
(METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.1983 LONG= -81.2000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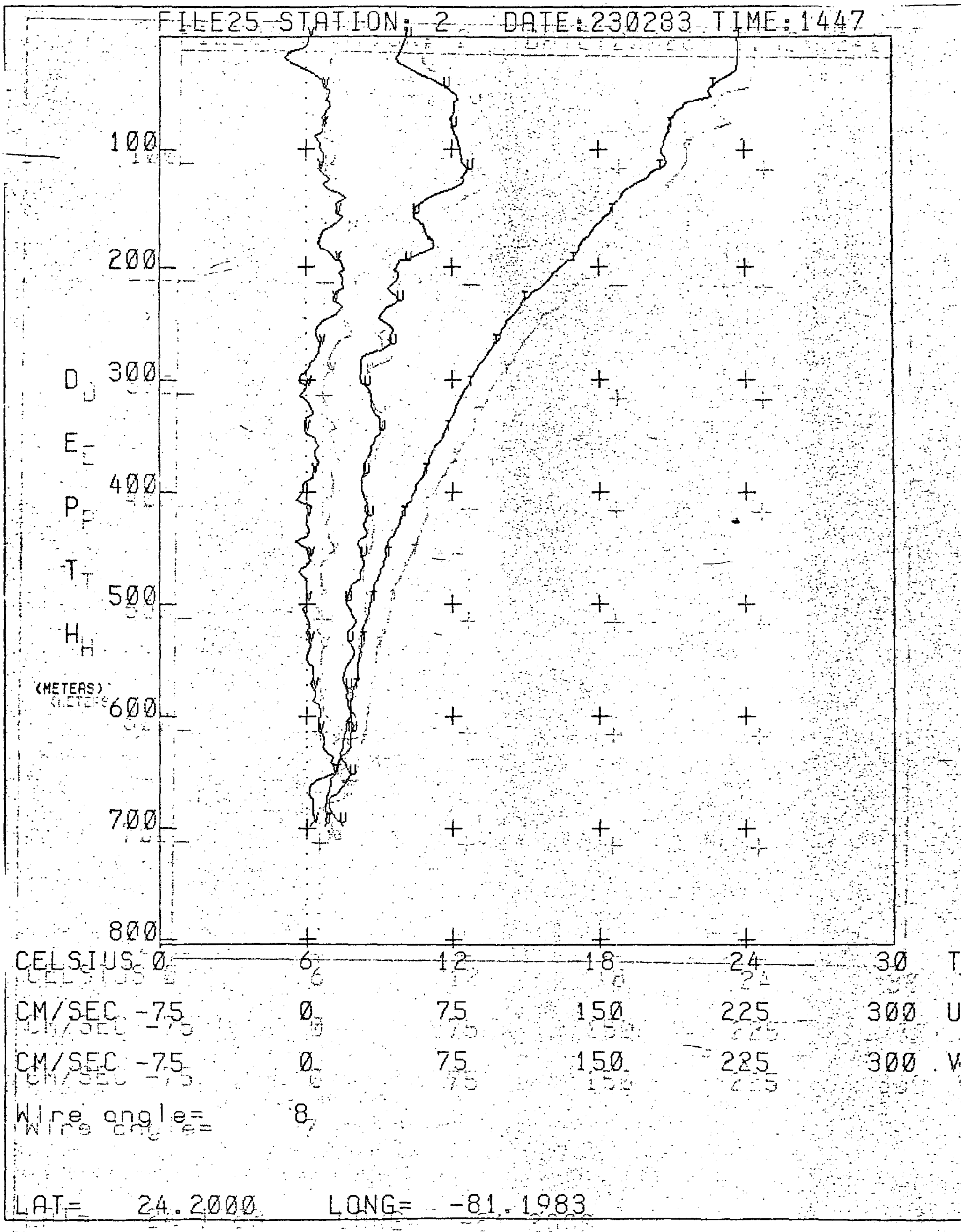
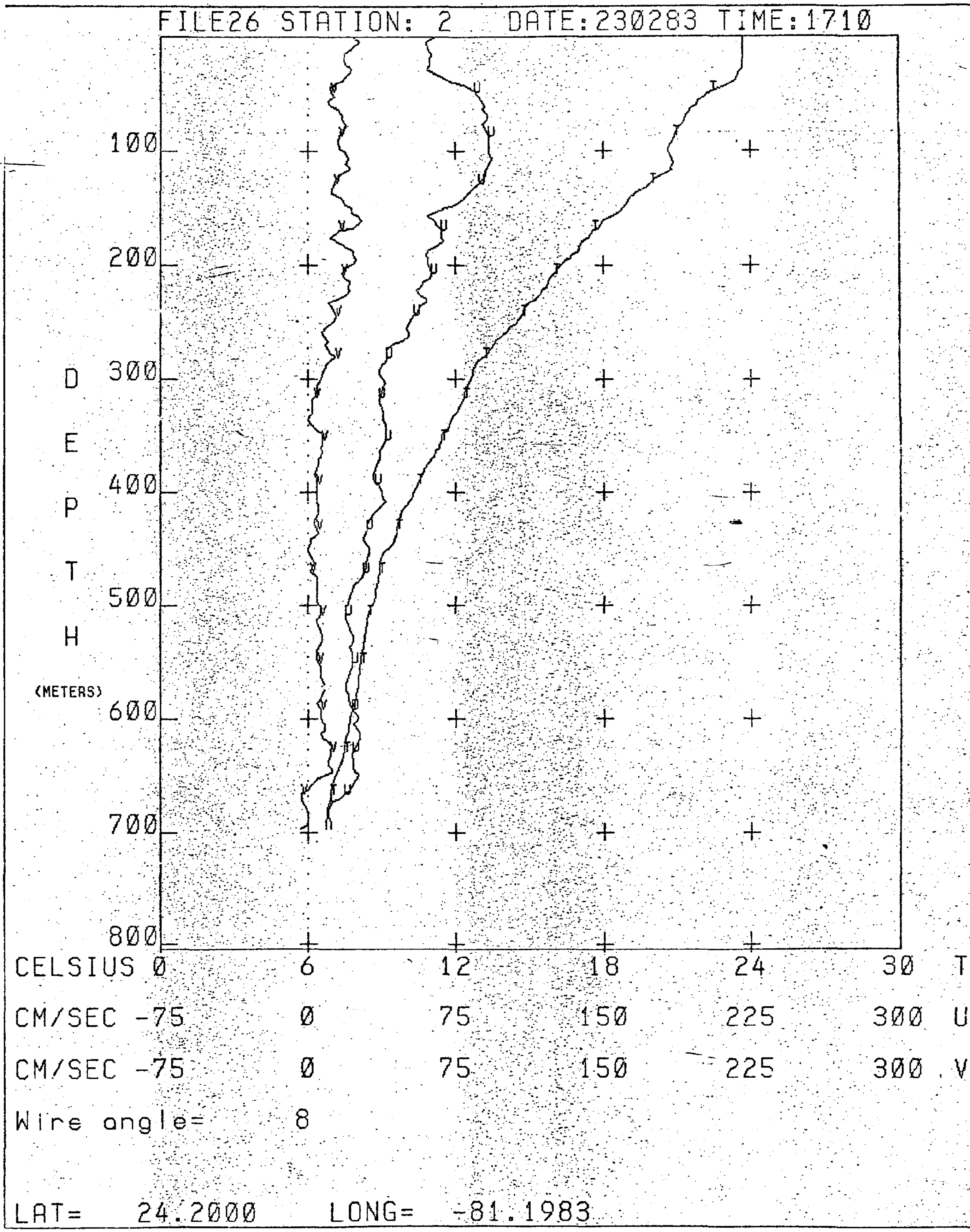
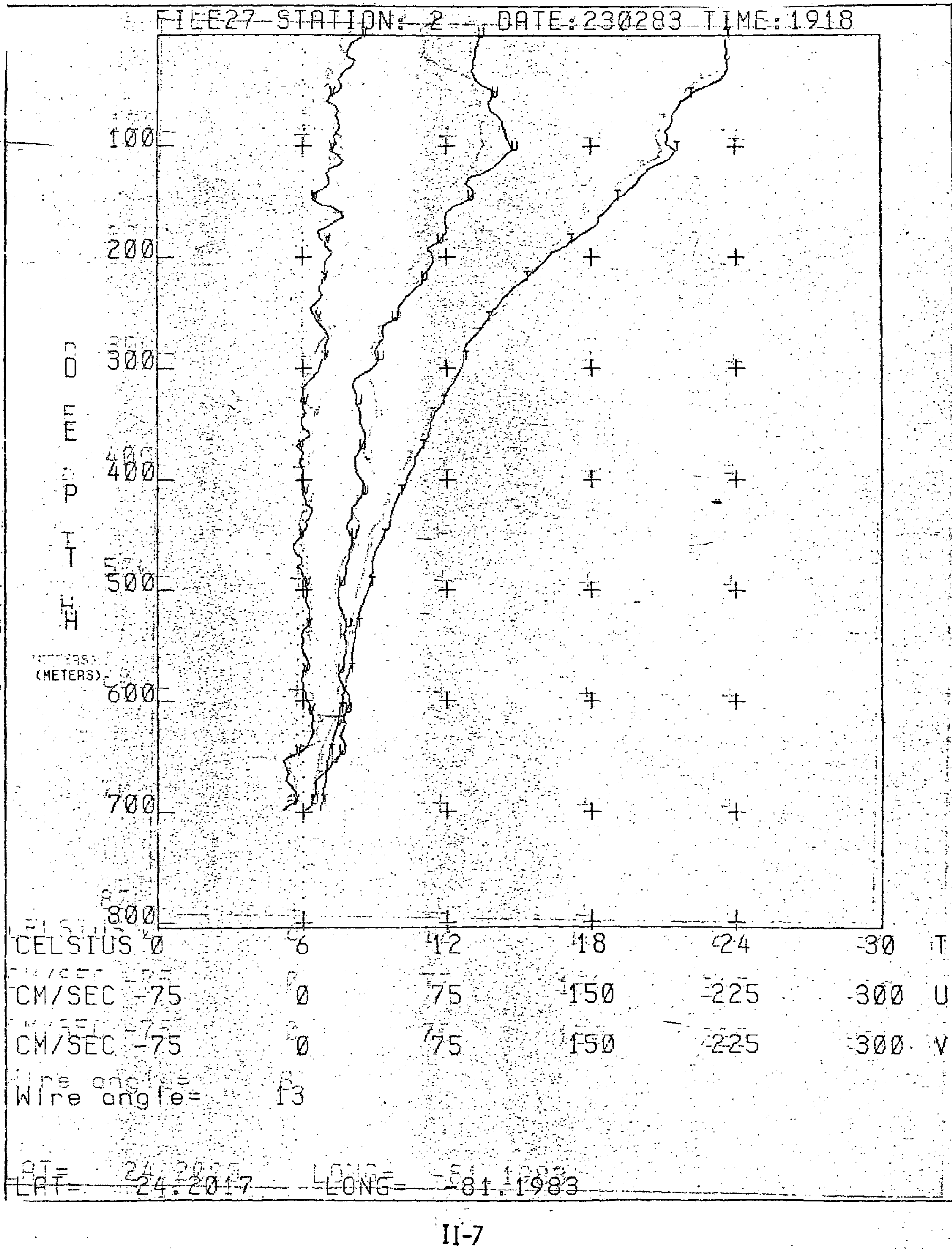
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.1983 LONG= -81.2000


FILE25 STATION: 2 DATE:230283 TIME:1447
100
200
300
400
500
600
700
800
D
E
P
T
H
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 8
LAT= 24.2000 LONG= -81.1983


FILE26 STATION: 2 DATE:230283 TIME:1710
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 8
LAT= 24.2000 LONG= -81.1983


FILE27 STATION: 2 DATE:230283 TIME:1918
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 13
LAT= 24.2017 LONG= -81.1983

a) Mean Current Profiles

The mean current profiles for the three anchor stations as seen in figures I-M, II-M, III-M are remarkably similar to each other in the upper 100 meters. Here velocities were about 75 cm per sec toward the East with a Northerly component of 10-15 cm s^{-1}. At 100 meters there was a distinct break in the velocity which coincided with a break in the temperature profile from a relic mixed layer structure with modest stratification to the top of a strong thermocline. Below 100 meters both velocity components decreased toward smaller velocities being about a half of the surface amplitude at 200 meters with a more gradual decrease toward $\pm$ 5 cm s^{-1} near the bottom.

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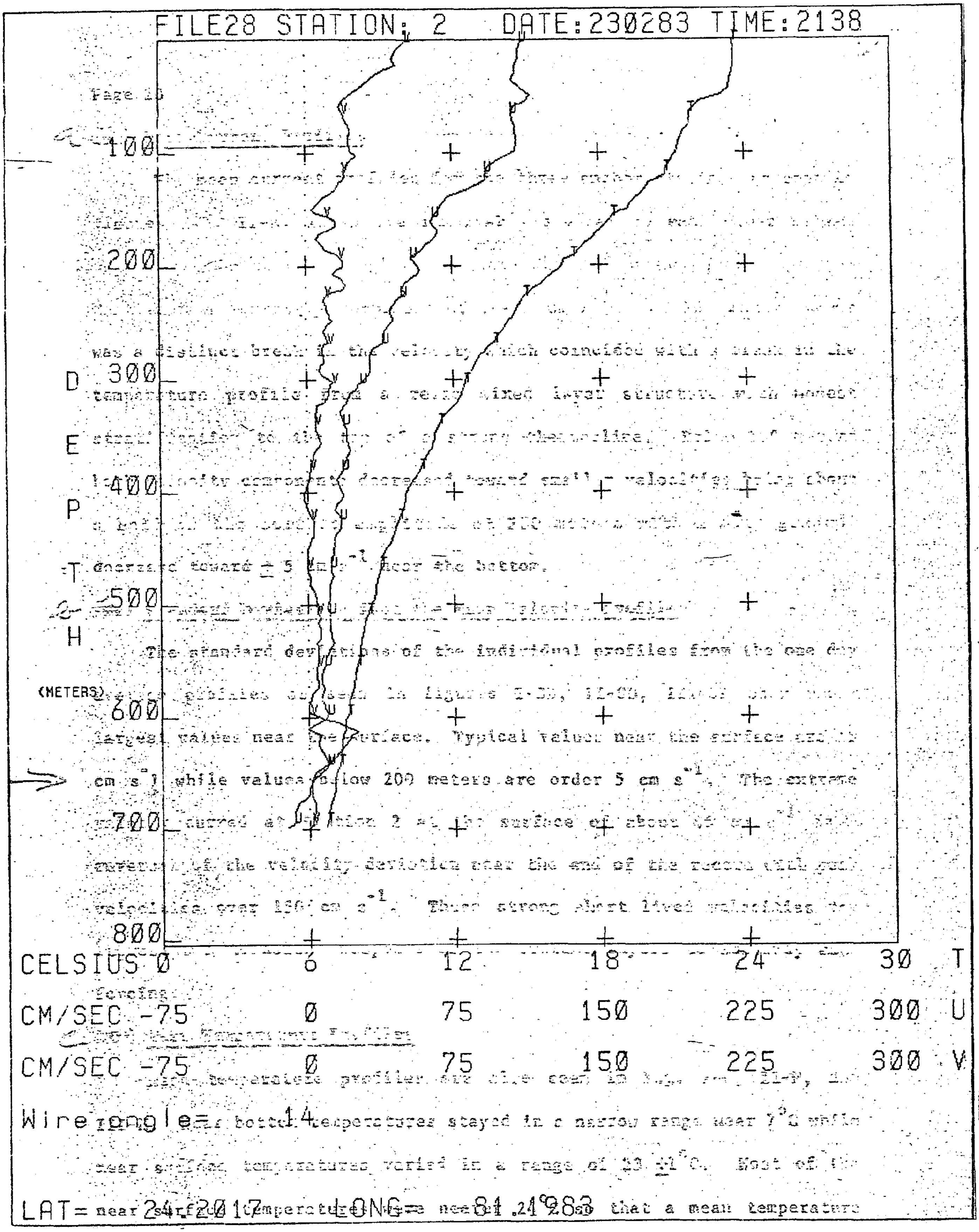
The standard deviations of the individual profiles from the one day average profiles as seen in figures I-SD, II-SD, III-SD show their largest values near the surface. Typical values near the surface are 15 cm s^{-1} while values below 200 meters are order 5 cm s^{-1}. The extreme value occurred at Station 2 at the surface of about 40 cm s^{-1} as a reversal of the velocity deviation near the end of the record with peak velocities over 150 cm s^{-1}. These strong short lived velocities may represent a transient response of the surface layers to westerly wind forcing.

c) Mean Temperature Profiles

Mean temperature profiles are also seen in Fig. I-M, II-M, and III-M. Near bottom temperatures stayed in a narrow range near 7°C while near surface temperatures varied in a range of 23 $\pm$1°C. Most of the near surface temperatures were nearer 24°C so that a mean temperature


FILE28 STATION: 2 DATE:230283 TIME:2138
100
200
300
400
500
600
700
800
DEPTH (METERS)
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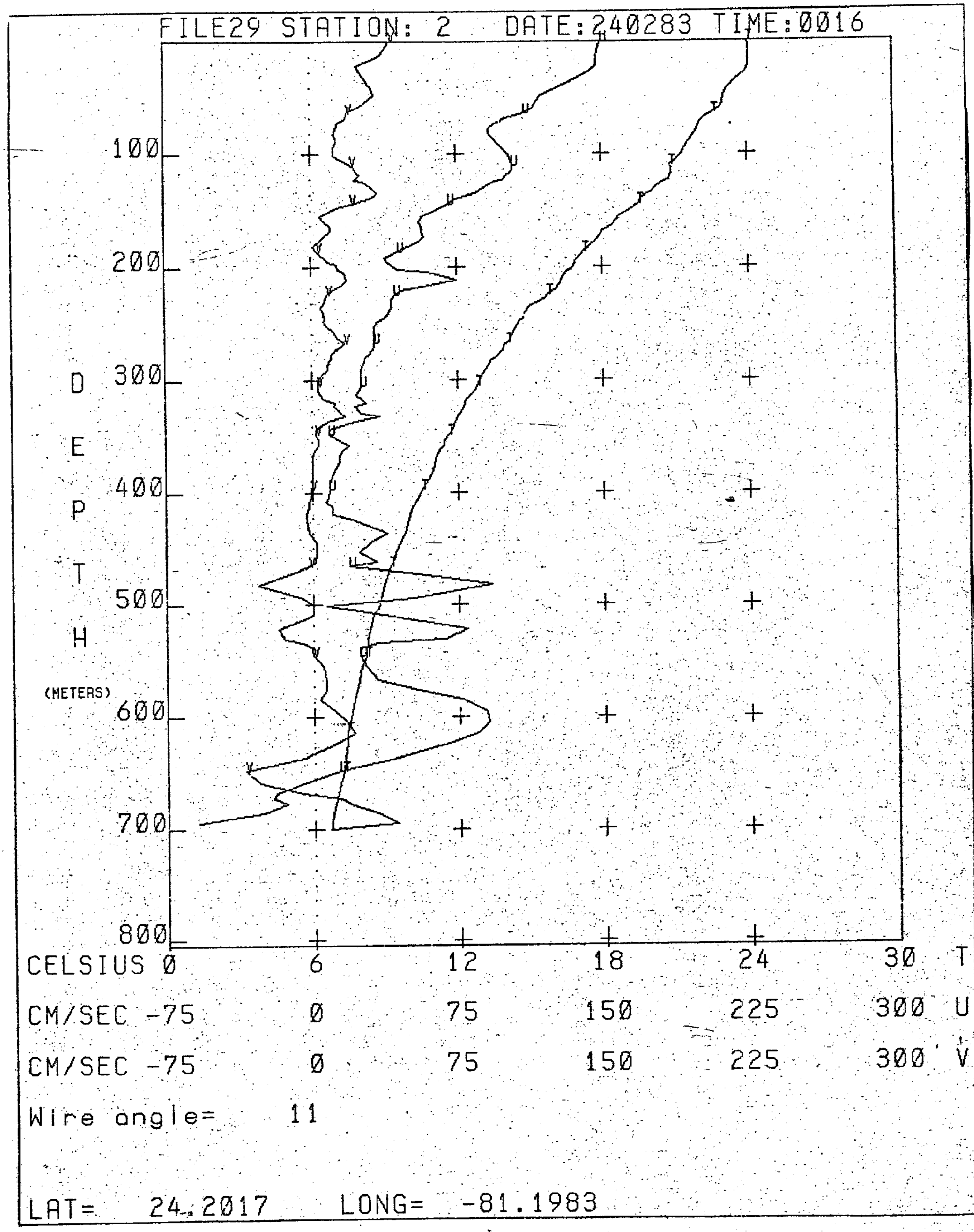
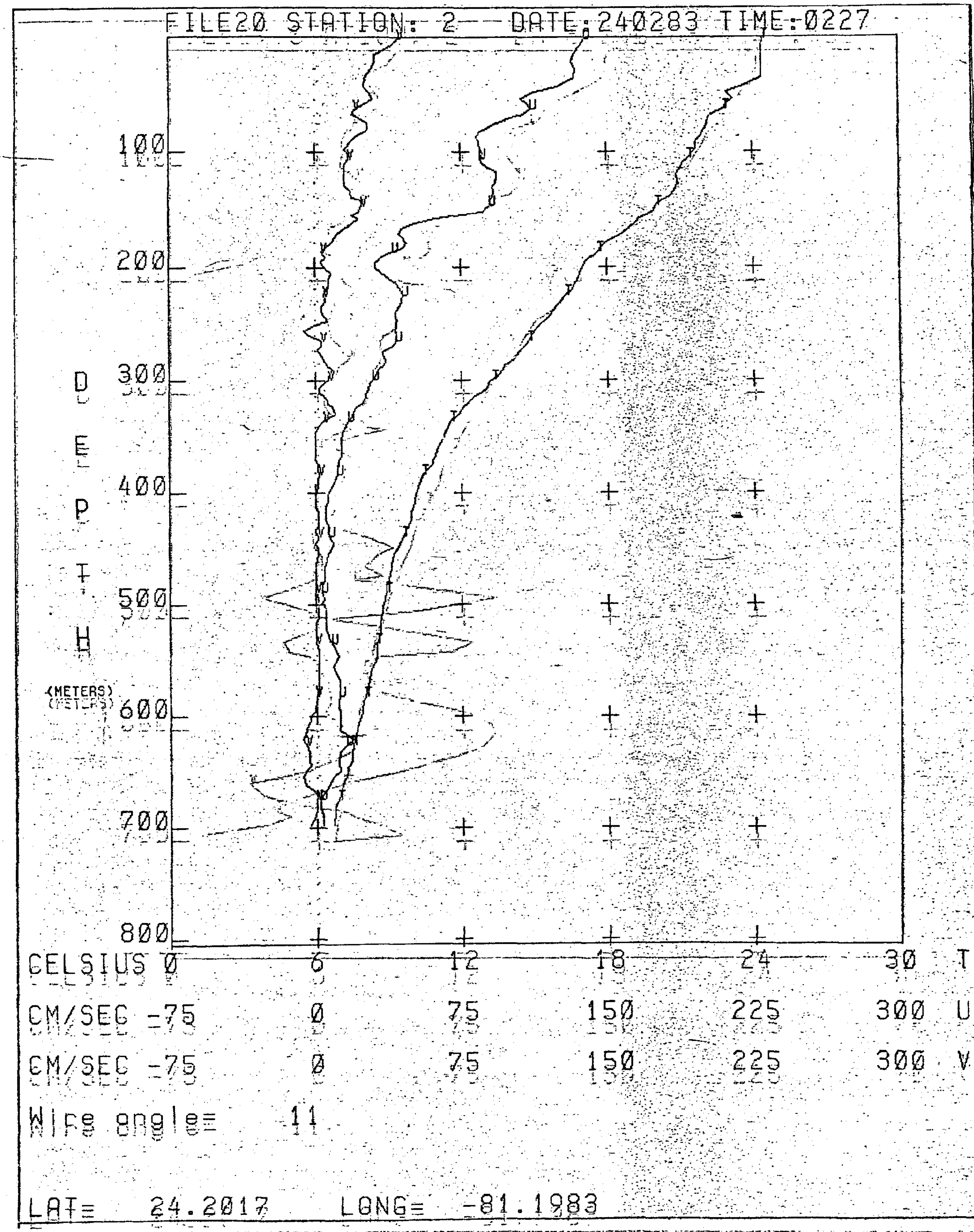
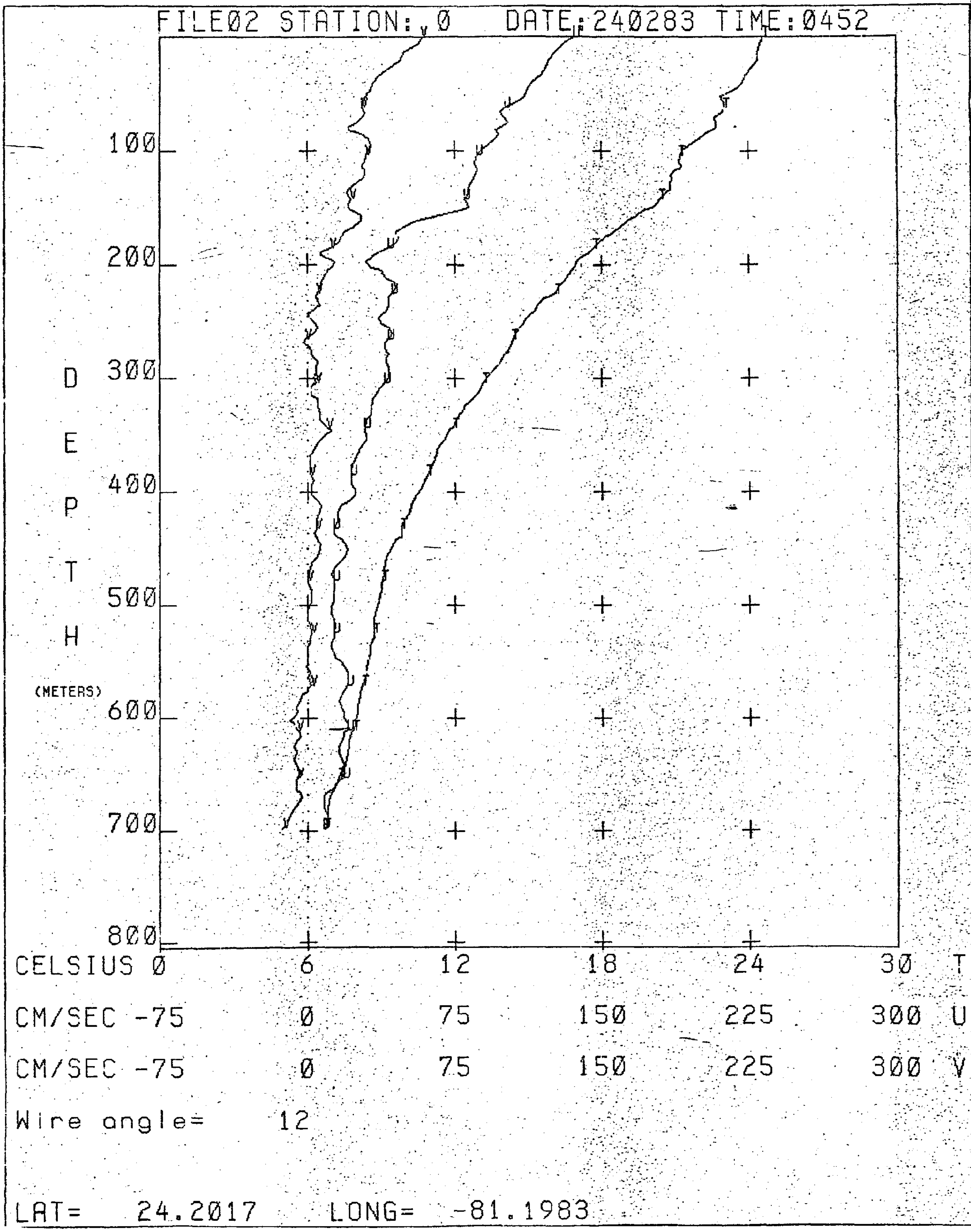
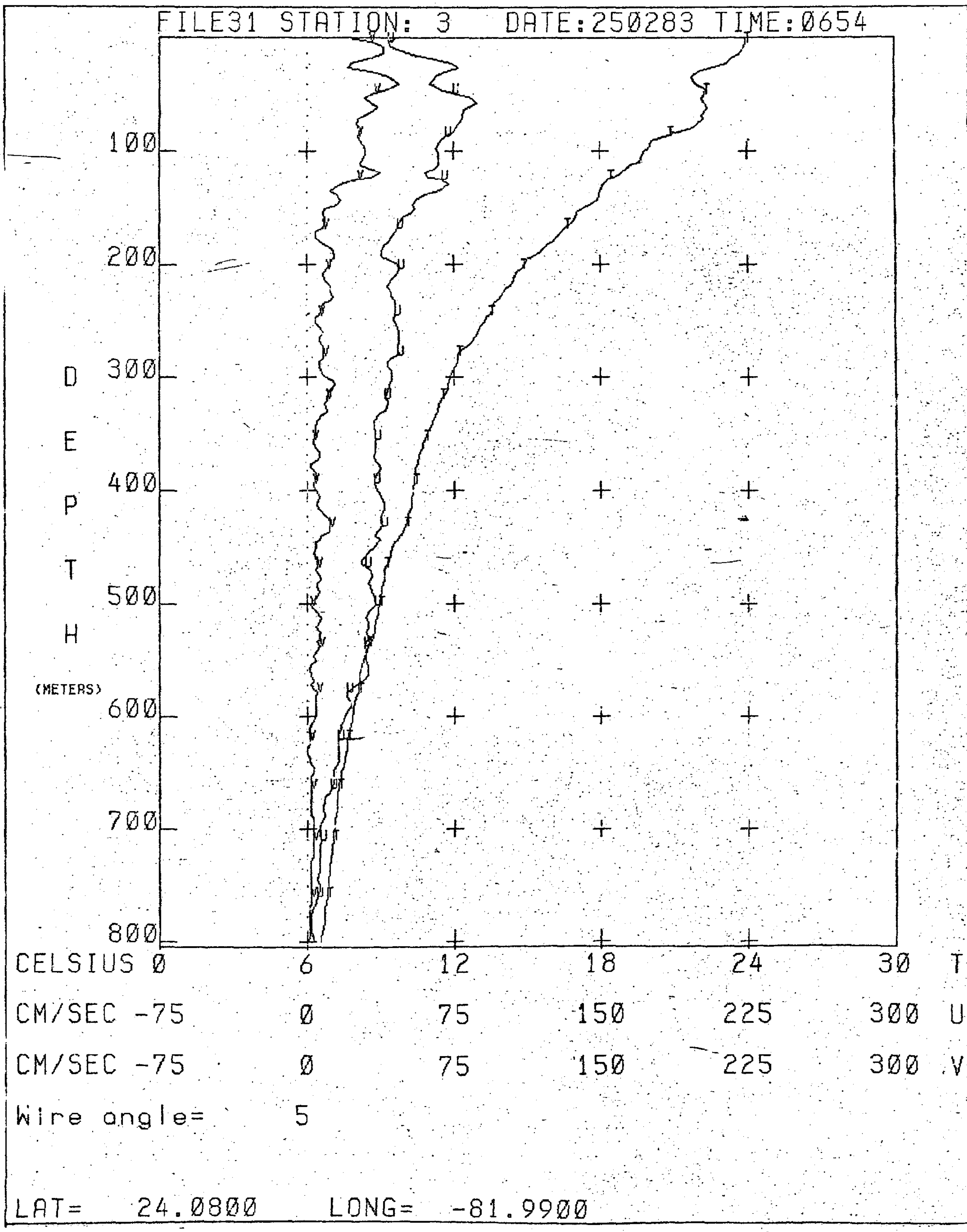
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 14
LAT= 24.2017 LONG= 81.4983

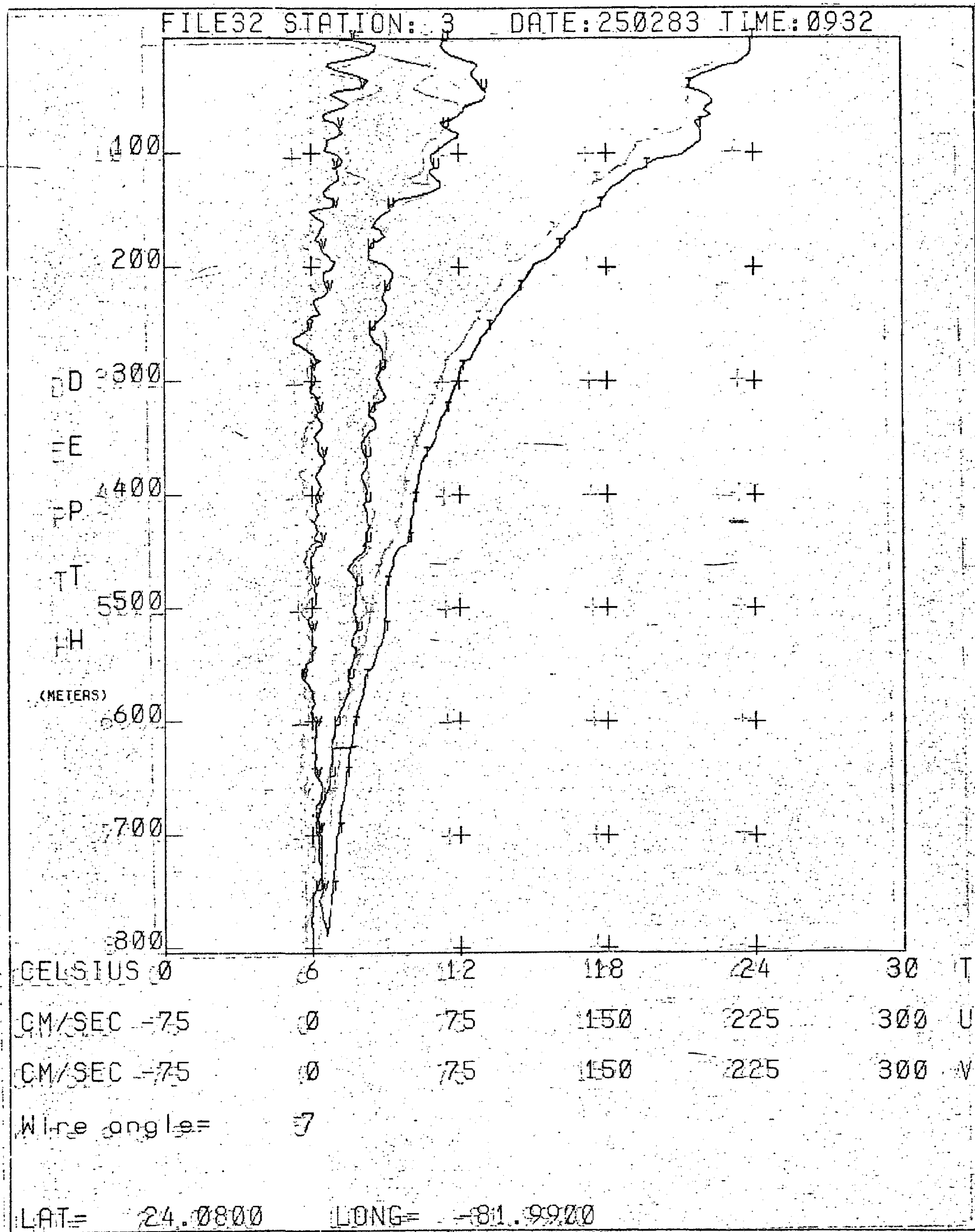


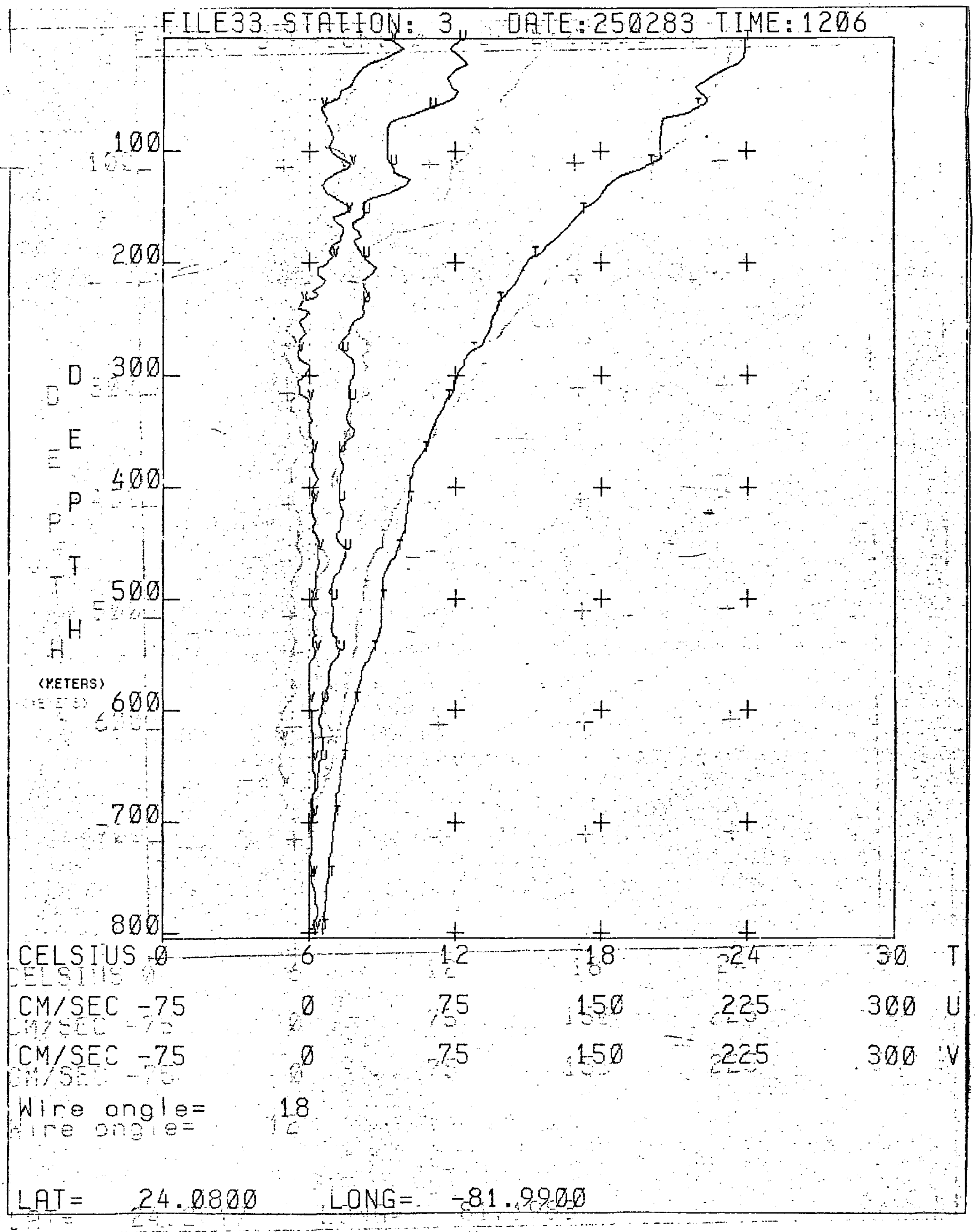
FILE29 STATION: 2 DATE:240283 TIME:0016
DEPTH
(METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 11
LAT= 24.2017 LONG= -81.1983

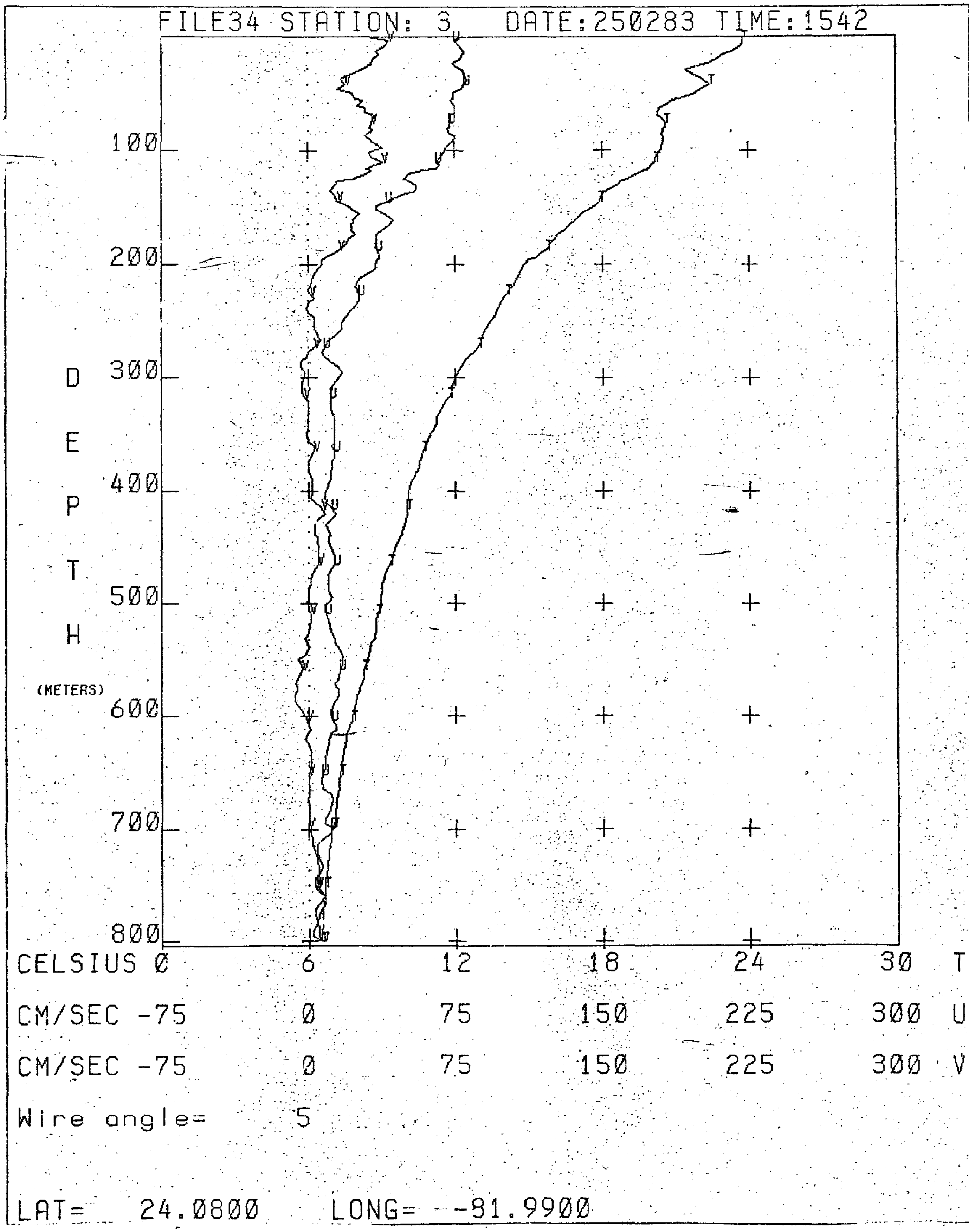

FILE20 STATION: 2 DATE:240283 TIME:0227
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 11
LAT= 24.2017 LONG= -81.1983

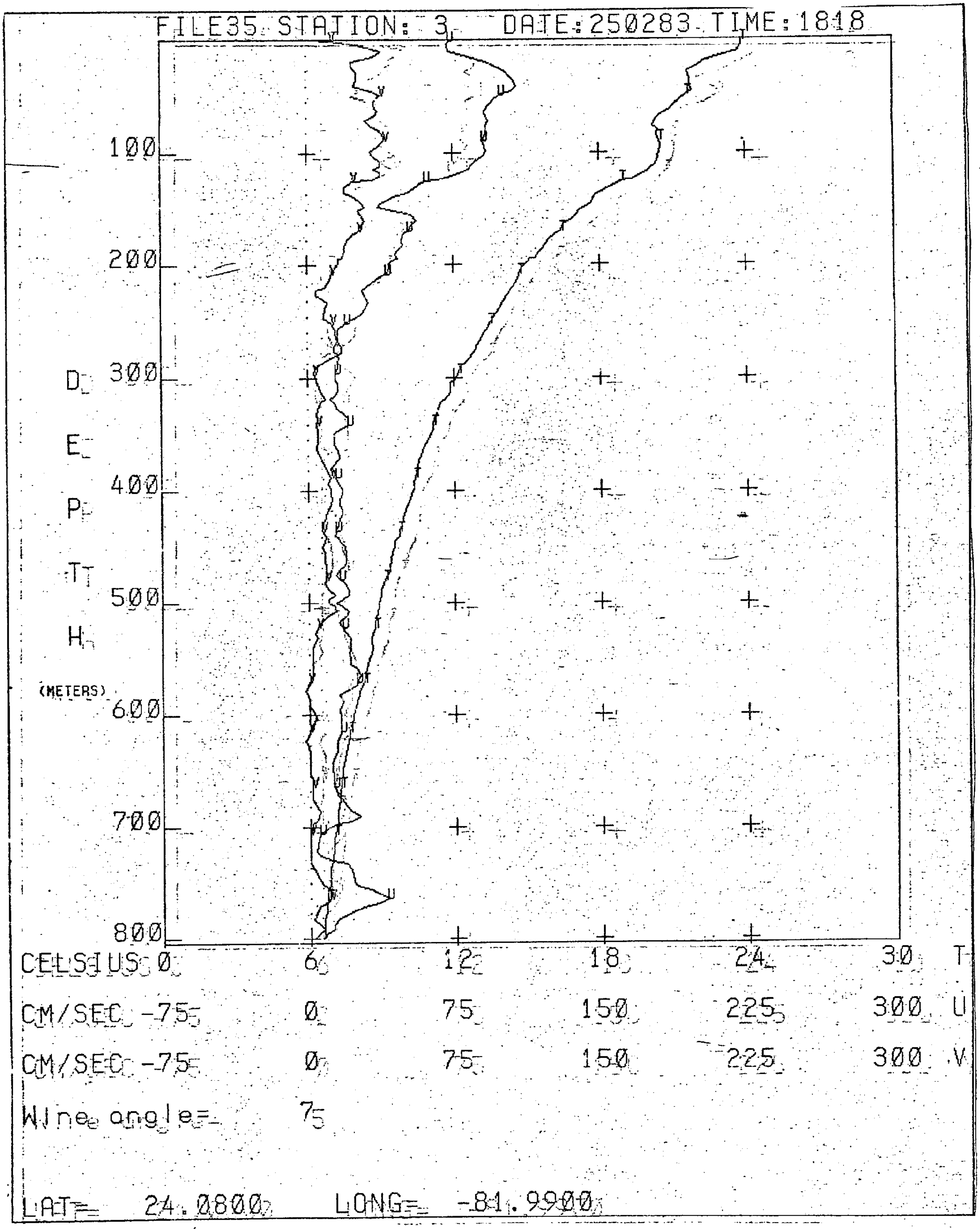

FILE02 STATION: 0 DATE:240283 TIME:0452
DEPTH (METERS)
100
200
300
400
500
600
700
800
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 12
LAT= 24.2017 LONG= -81.1983

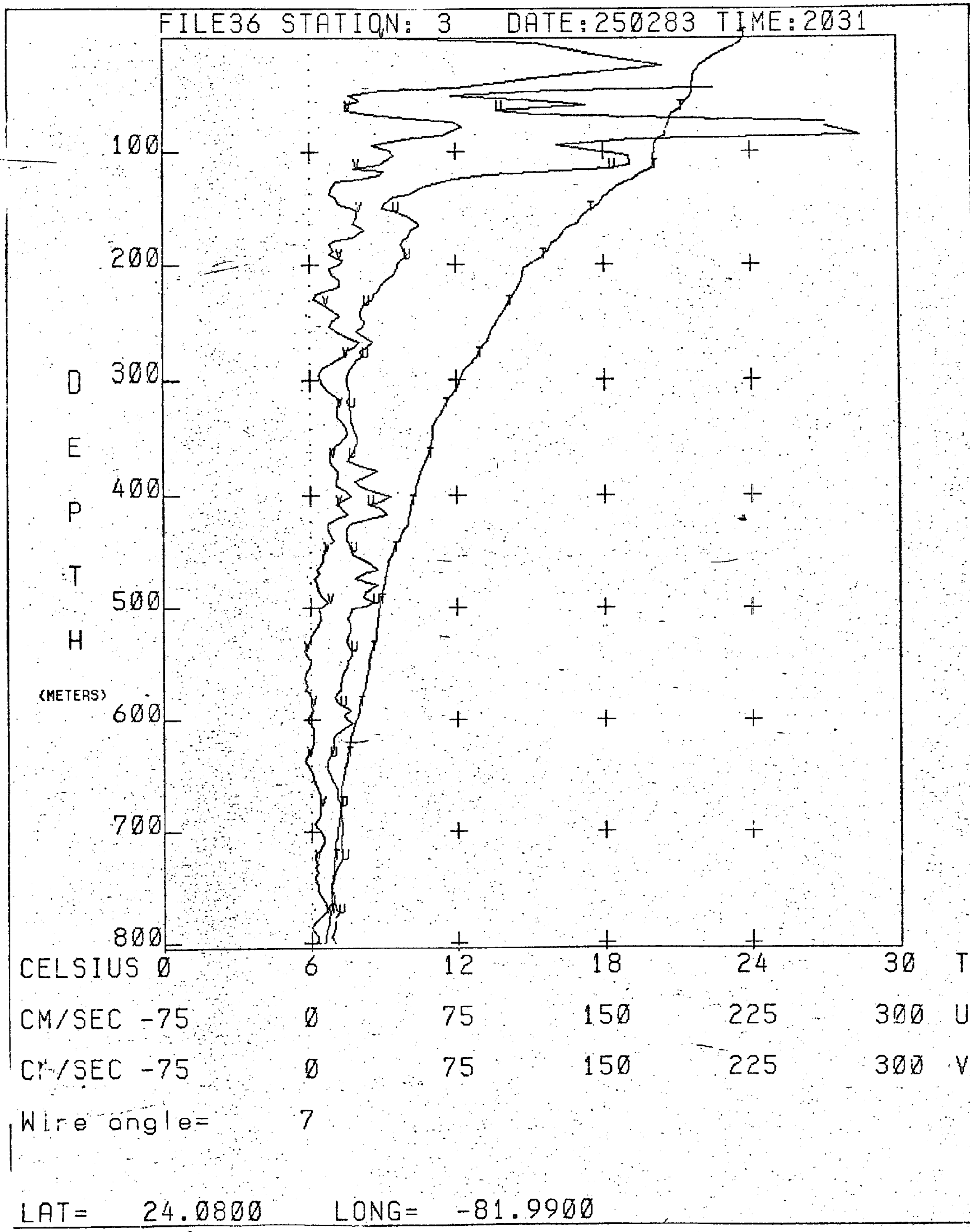

FILE31 STATION: 3 DATE:250283 TIME:0654
DEPTH
(METERS)
100
200
300
400
500
600
700
800
CELSIUS Ø 6 12 18 24 3Ø T
CM/SEC -75 Ø 75 15Ø 225 3ØØ U
CM/SEC -75 Ø 75 15Ø 225 3ØØ V
Wire angle= 5
LAT= 24.08ØØ LONG= -81.99ØØ


FILE32 STATION: 3 DATE:250283 TIME:0932
100
200
300
400
500
600
700
800
D
E
P
T
H
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.0800 LONG= -81.9900

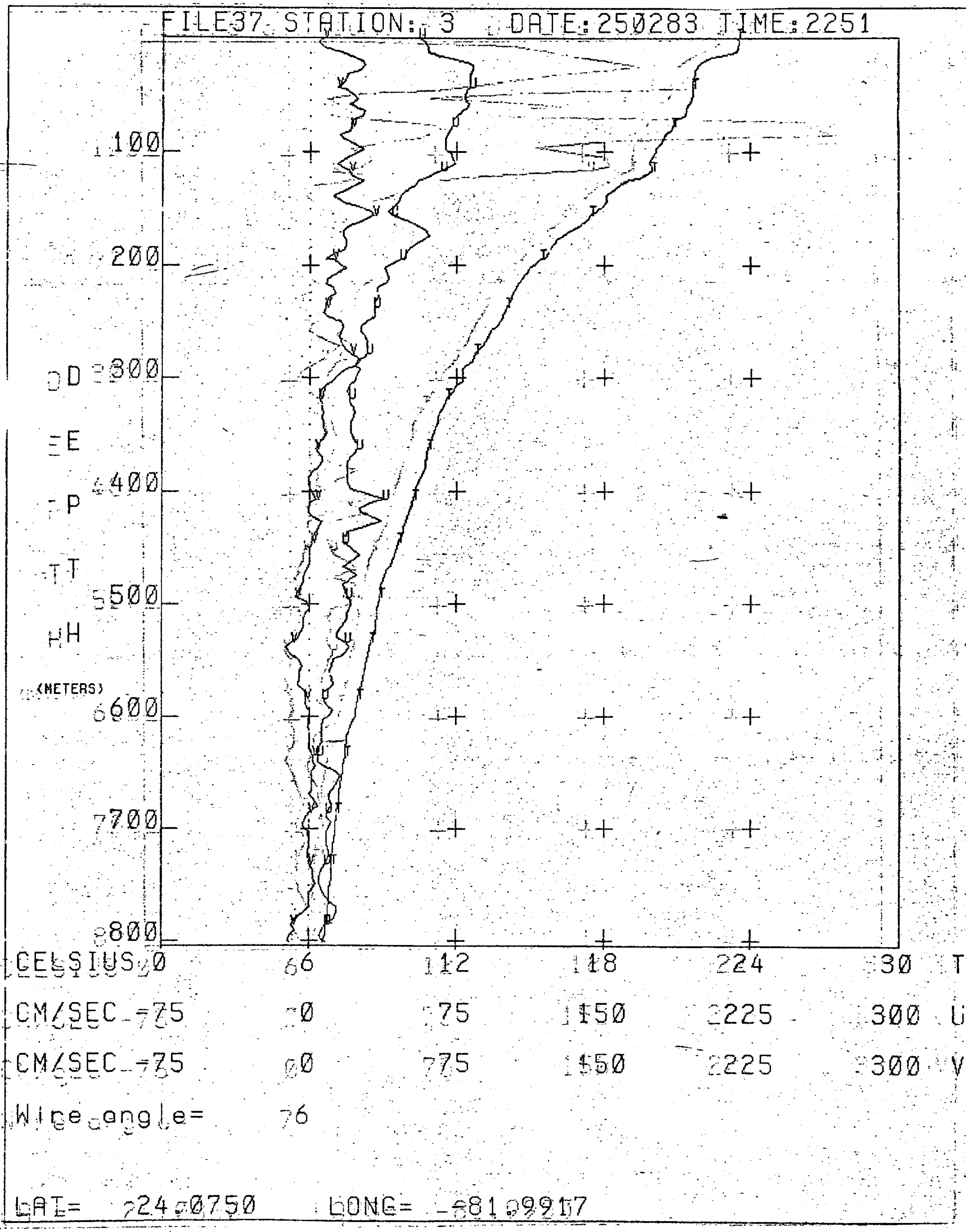

FILE33 STATION: 3 DATE:250283 TIME:1206
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 18
LAT= 24.0800 LONG= -81.9900

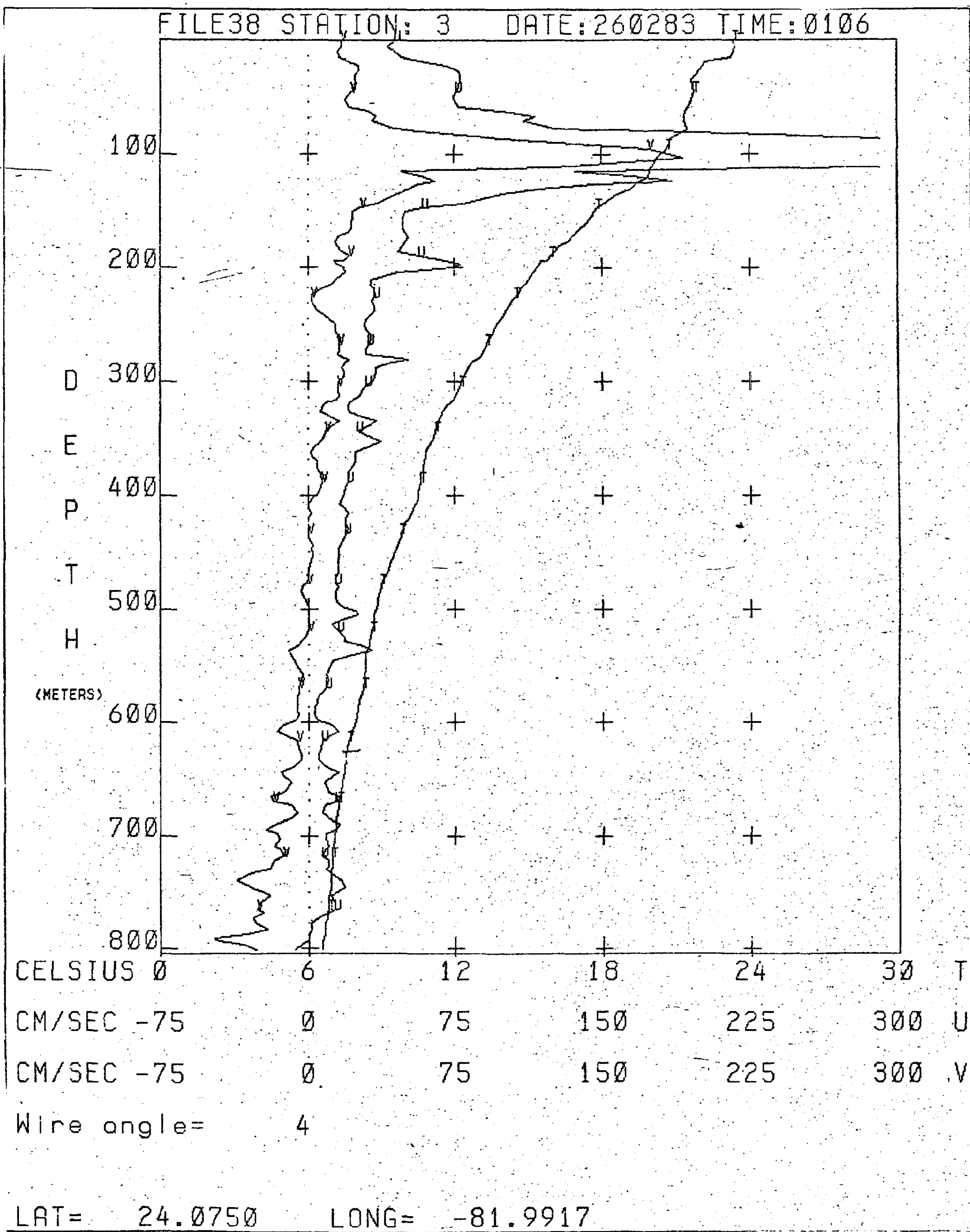

FILE34 STATION: 3 DATE:250283 TIME:1542
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS Ø 6 12 18 24 30 T
CM/SEC -75 Ø 75 150 225 300 U
CM/SEC -75 Ø 75 150 225 300 V
Wire angle= 5
LAT= 24.0800 LONG= -81.9900


FILE35 STATION: 3 DATE:250283 TIME:1818
100
200
300
400
500
600
700
800
DEPTH
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wine angle= 75
LAT= 24.0800 LONG= -81.9900



FILE36 STATION: 3 DATE:250283 TIME:2031
100
200
300
400
500
600
700
800
D E P T H
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 7
LAT= 24.0800 LONG= -81.9900


FILE37 STATION: 3 DATE:250283 TIME:2251
100
200
300
400
500
600
700
800
D
E
P
T
H
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 6
LAT= 24.0750 LONG= -81.9917


FILE38 STATION: 3 DATE:260283 TIME:0106
100
200
300
400
500
600
700
800
D E P T H
(METERS)
CELSIUS 0 6 12 18 24 30 T
CM/SEC -75 0 75 150 225 300 U
CM/SEC -75 0 75 150 225 300 V
Wire angle= 4
LAT= 24.0750 LONG= -81.9917

4) Temperature Section Data

Before or after each profile anchor station, a temperature section was recorded which passed through the approximate location of the anchor station as seen in Fig. 17 and were roughly normal to the bathymetric contours. These sections give some idea about context in which the anchor station was occupied and make it possible to relate the anchor station data to both historic data and remotely sensed surface temperature data.

The temperature data were observed using Expendable Bathythermograph (XBT) probes (T-5) manufactured by Sippican Corporation in Marion, Massachusetts. The XBT is a temperature profiling system which senses temperature with a thermistor and relates the nearly constant fall velocity of a weighted streamlined housing to depth as described by Williams (1973). Unlike hydrographic stations the ship can continue moving as the XBT unspools wire from both ends in much the same way that line is released from a fisherman's spinning reel. The XBT data were finally recorded on a pressure sensitive constant speed strip chart to display a temperature profile. XBT recorded temperatures are accurate to about $\pm.05^{\circ}$C and depths ± 20 meters.

The temperature data from each XBT drop was plotted at 1°C intervals at the appropriate geographic spacing to form each section. The sloping piecewise linear line at the bottom depths observed at each XBT station by PDR. Inflection points indicate each XBT location and the number below denotes the station location and order as seen on Figs. 18, 19, and 20.

Hydrographic data were also gathered at both ends of each section

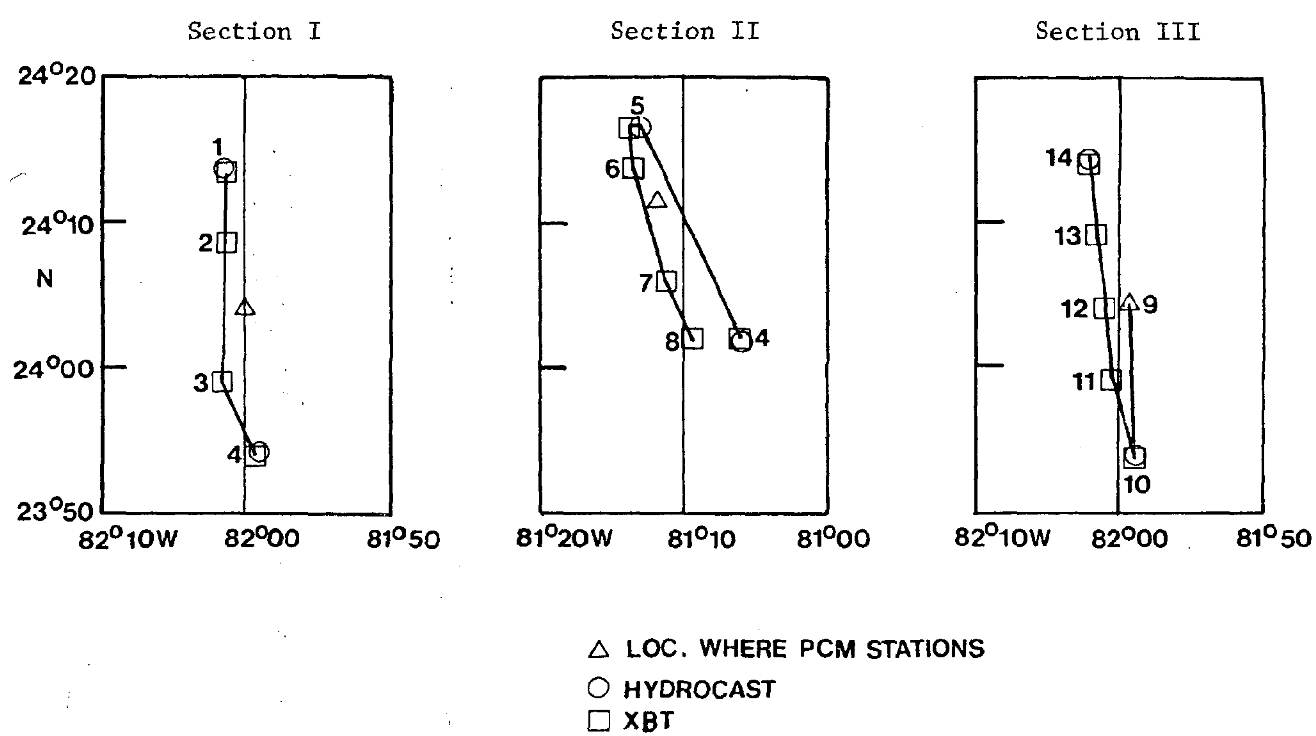


Figure 17: Location maps for section data below. XBT station numbers correspond to those in figures 18, 19, and 20. The location where the PCM stations also correspond to the A's on these respective figures.

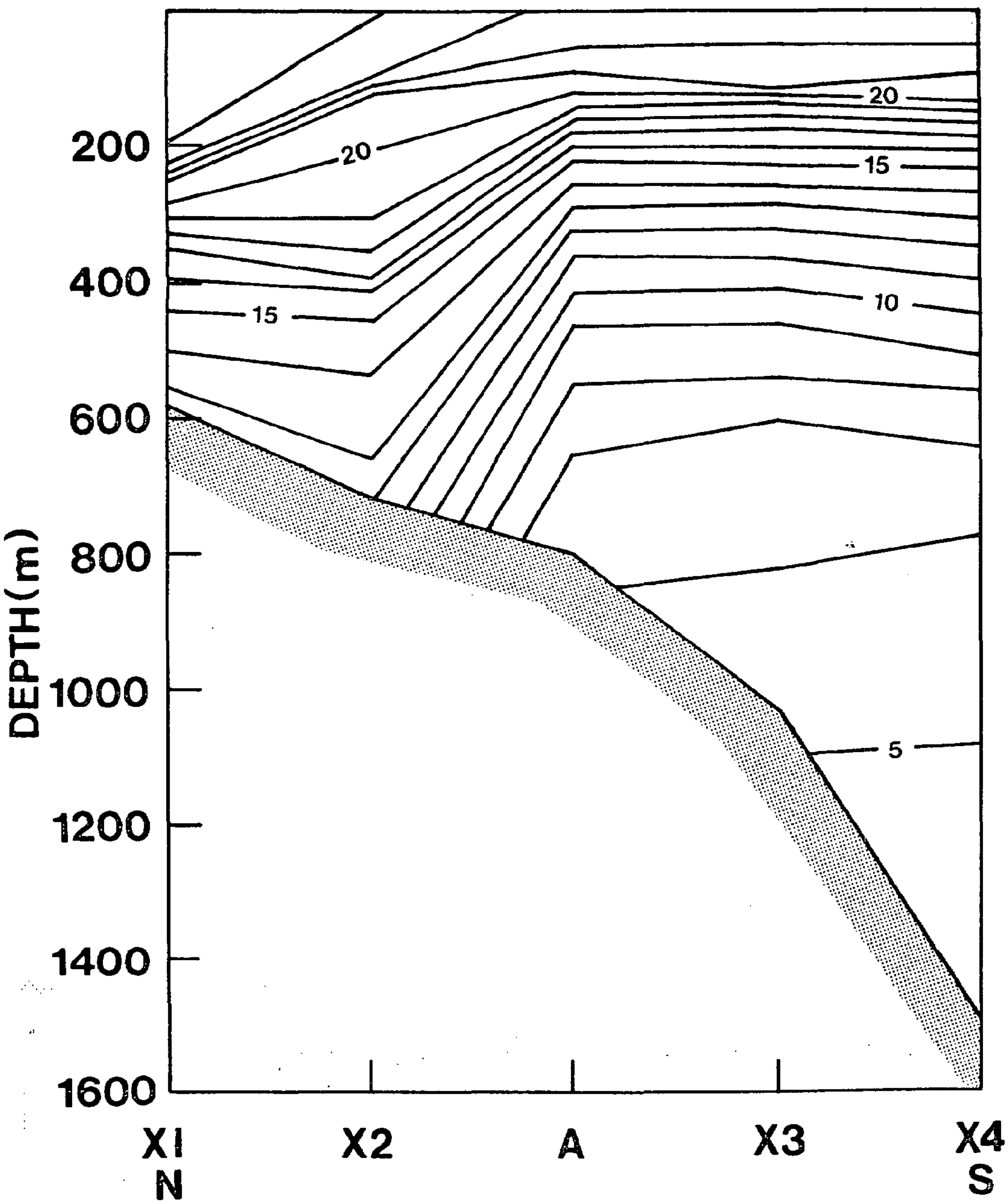


Figure 18: Section I shows contours of XBT temperature data in degrees C. Locations of XBT drops X1, X2, X3 and X4 are shown together with anchor station I at A.

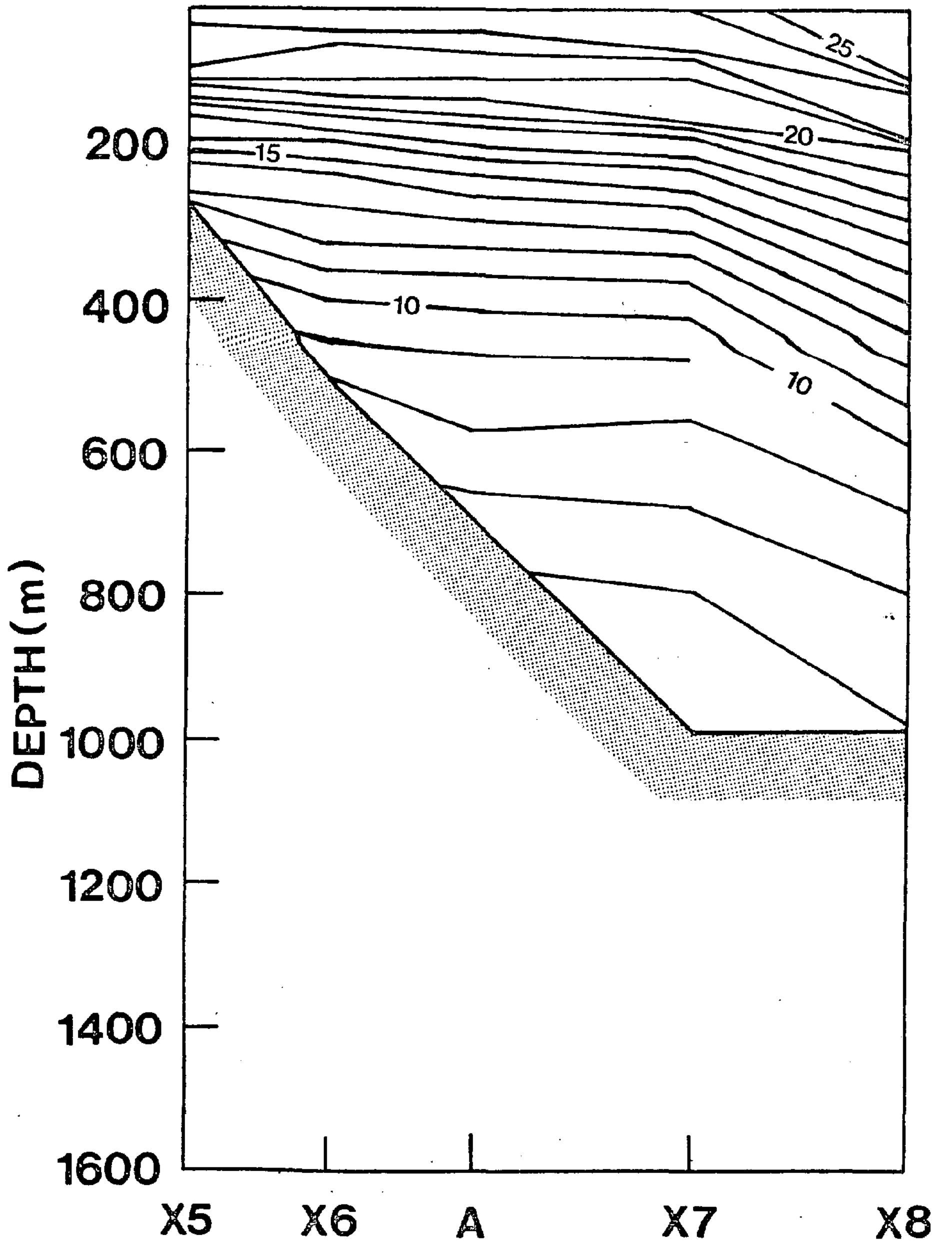


Figure 19: Section II shows contours of XBT temperature data in degrees C. Locations of XBT drops X5, X6, X7 and X8 are shown together with anchor station II at A.

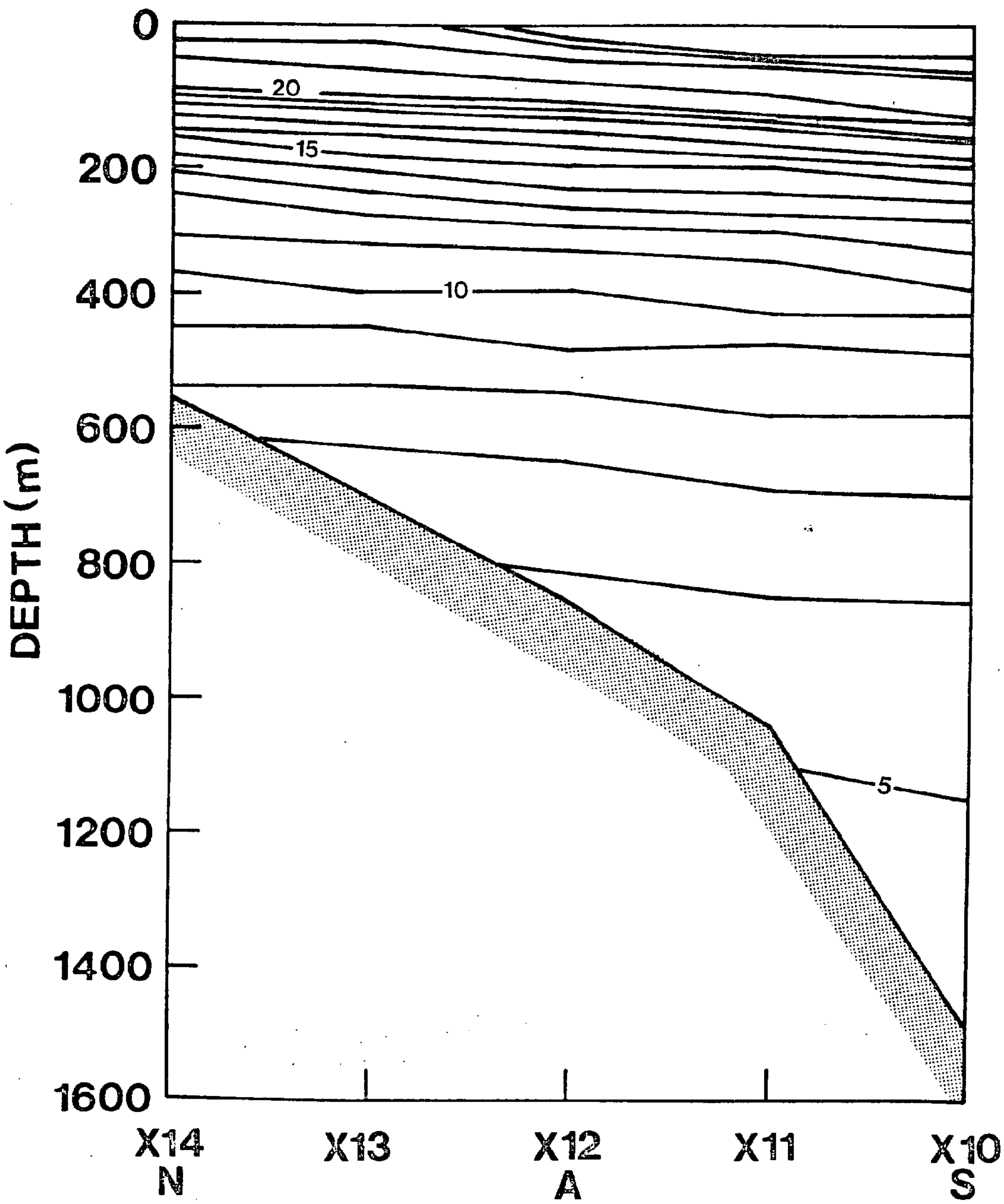


Figure 20: Section III shows contours of XBT temperature data in degrees C. Locations of XBT drops X10, X11, X12, X13 and X14 are shown together with anchor station III at A.

using Niskin bottles with reversing thermometers. However the great difference in depth between in the inshore and offshore ends of the section, the complexity of the intervening temperature structure and the low vertical resolution made geostrophic calculations unreliable. These data are given in Table I and will not be discussed further.

DESIRED DEPTH	P[1]	P[2]	U	THERMOMETRIC DEPTH	WIRE OUT	WIRE ANGLE	DEPTH BY WIRE ANGLE	SALINITY
Cast #1	24° 13.67	82° 01.52	2/18/83	0245 (GMT)				
5	22.12	22.11			5	5°	5	36.2626
100	19.10	19.10			100	5°	95	-
350	13.29	13.19	14.15	87(?)	350	5°	345	36.2641
500	-	-	-	-	500	5°	495	35.0188
Cast #2	23° 53.74	81° 59.68	2/19/83	0810 (GMT)				
5	23.38	23.38			5	18°	5	36.2537
250	15.62	15.62	19.69	315	250	18°	238	36.0353
500	10.01	10.01	19.15	801	500	18°	475	35.1946
650	7.84	7.84	12.76	400	650	18°	620	34.9506
1000	5.46	5.43	12.75	582	1000	18°	950	34.9813
Cast #3	24° 16.89	81° 13.72	2/23/83	0843 (GMT)				
5	23.61	23.60			5	15°	5	36.1620
50	21.99	21.99			50	15°	48	36.2773
100	18.13	18.12			100	15°	96	36.2591
200		14.92			200	15°	192	35.9218
250	21.89	21.91(?)			250	15°	240	35.5925
Cast #4	24° 02.74	81° 06.66	2/23/83	1230 (GMT)				
5	23.91	23.91			5	40°	4	36.2637
200	15.44	15.44	17.65	180	200	40°	153	36.0187
500	9.95	9.94	13.66	220	500	40°	383	35.0672
750	7.06	7.05	16.86	765	750	40°	575	34.9391
950	4.97	4.96	18.51	1122	950	40°	728	34.9255
Cast #5	23° 53.52	81° 57.35	2/26/83	0700 (GMT)				
5	24.69	24.63			5	28°	4	36.0451
250	16.20	16.21	17.99	142	250	28°	212	36.1255
500	9.98	10.30	13.94	295	500	28°	425	35.2626
750	8.48	-	13.18	413	750	28°	662	34.9326
1000	6.71	6.73	-		1000	28°	850	34.8806
1250	6.72	6.71	13.26	544	1250	28°	1109	34.9138
Cast #6	24° 13.83	82° 02.37	2/26/83	0115 (GMT)				
5	22.45	22.45			5	8°	5	35.9772
200	21.33	13.53	15.18	135	200	8°	197	35.7386
300	-	12.05	14.21	190	300	8°	296	35.3639
400	-	10.63	12.97	206	450	8°	444	35.0505
550	7.52	7.52	12.47	411	550	8°	542	34.4433

Table I: Hydrographic Data

5) Satellite Sea Surface Temperature Data

Thirty-nine maps of sea surface temperature were provided by NOAA Miami Satellite Field Service Station spanning the period 3 January 1983 to 30 March 1983. During this time of year a strong temperature contrast exists between the cooler inshore waters and the warmer waters of the Gulf Stream offshore. During the late spring, summer and early fall the temperature contrast becomes too small for easy interpretations.

As with all satellite IR data, intervening clouds and moisture interfere with accurate interpretation so that composite charts are drafted which include a large number of individual images spanning several days or even a week or more. This technique relies on the assumption that the position of the edge of the stream varies slowly. However the historical data in section 2 is rich in energetic motion with 4 to 10 day periods. Further questions persist about how representative surface temperatures are of the underlying temperature structure.

Even with the above drawbacks these data give a good general idea of the variability to be expected in the location of the Gulf Stream within the Straits of Florida. Clearly one can see large variations in edge position from very near the keys to two thirds of the way to Cuba. Also evident are spin-off eddies as described in section 2 above.

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STEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 03 JAN 1983

228B60 235B55 239B50
244B20 245B10 249B02
2// WARM EDDY BOUNDED BY:
247B87 256B87 262B82
263B47 254B44 245B48
241B71 240B76//

270799 3007
327768 348
381690 381
390637 390

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

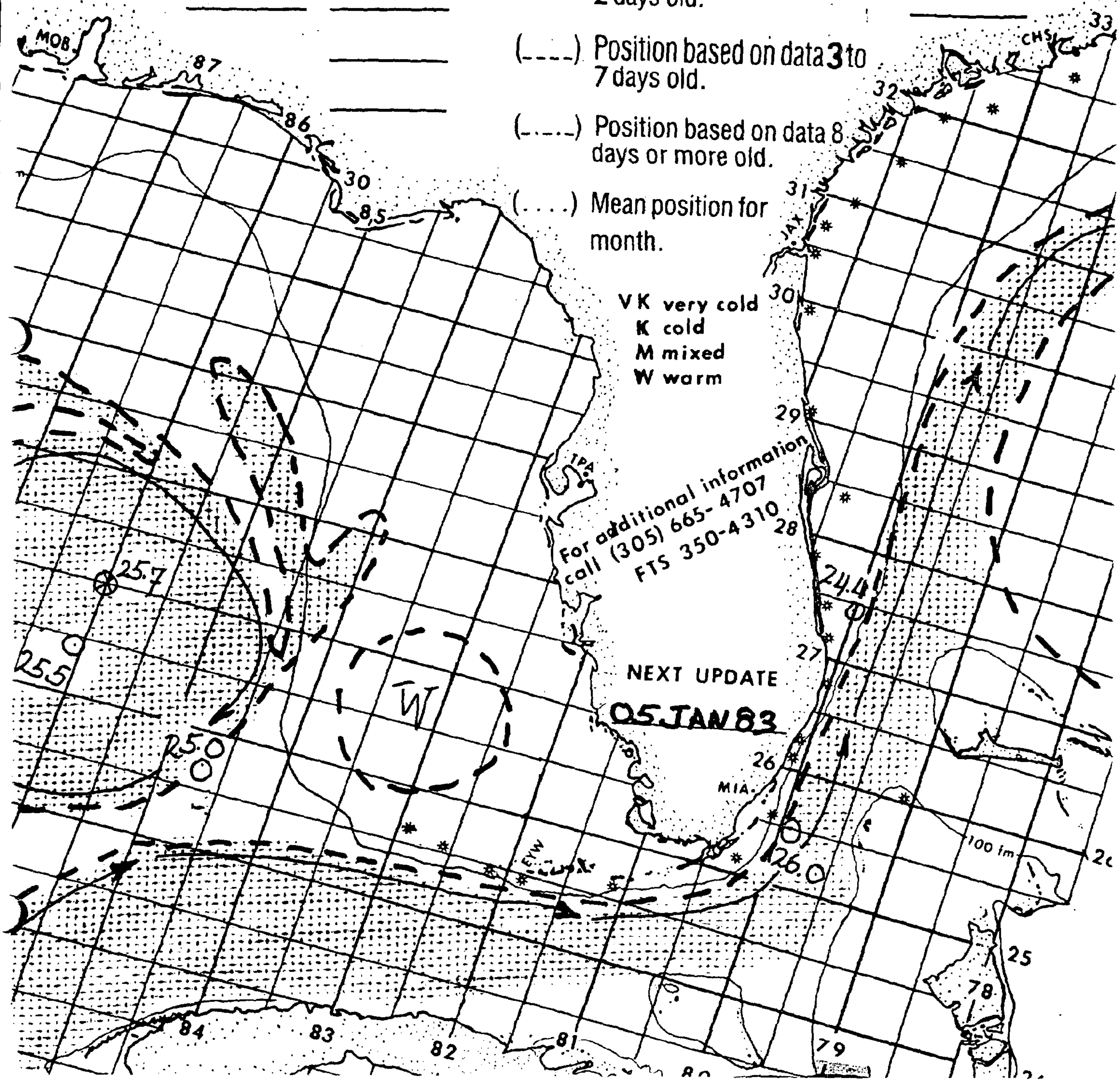
(____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



NEXT UPDATE
05JAN83

EM FLOW CHART #2450

NOAA Miami SFSS

GULF STREAM

Date: 05 JAN 1983

231858 238852 241844
246808 248803 253801
EDDY BOUNDED BY:
249888 256888 264880
268850 261847 254845
241875 241876 //

270792 2807
321775 32676
382685 37766

Depicted land should not be used for navigation.

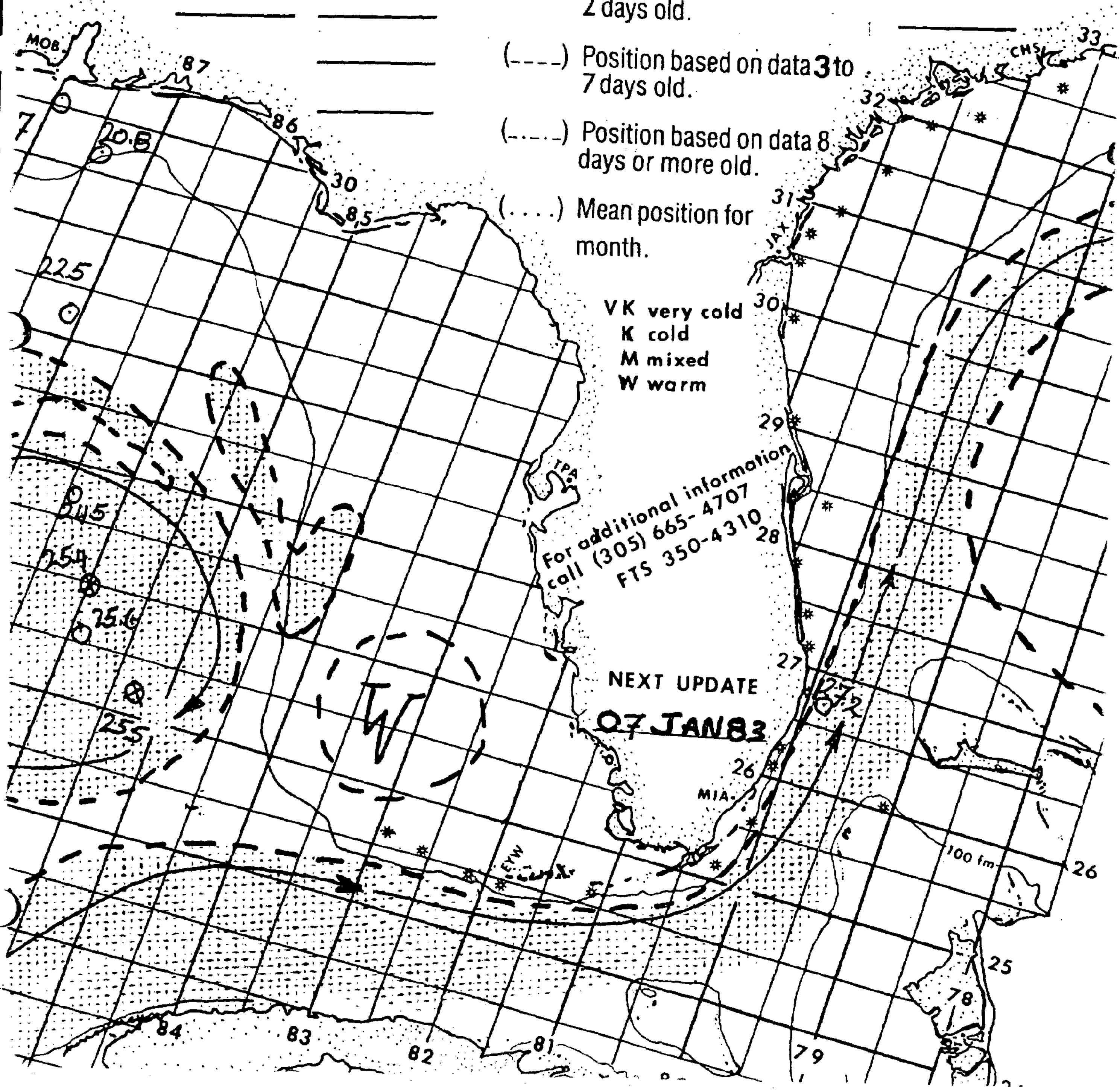
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(——) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.



Date: 07JAN 1982

232858 238852 243835 270792 2777

253800 260800|| 317783 3257

BOUNDED BY: 242882 360742 3627

263883 270872 272866 375714 3757

257846 252846 245850 375655 3776

242882//

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

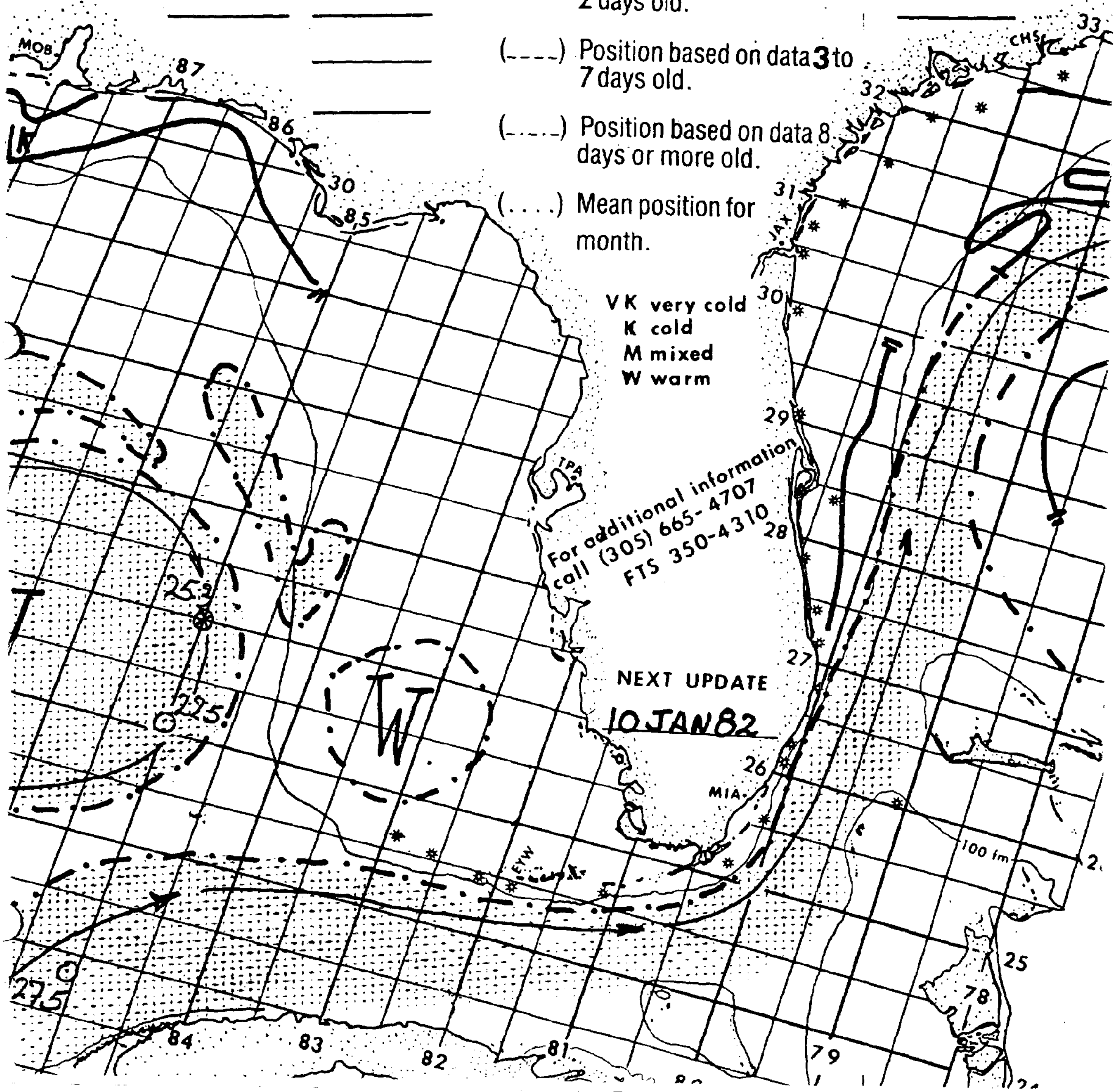
(_____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



STEM FLOW CHART 2450

NOAA Miami SFSS

GULF STRE

BOUNDED BY:

245882 252885 268886

263847 257845 249846

MAIN LOOP CURRENT:

232858 238852 240846

244818 246808 249803

Date: 10 JAN 1983

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(——) Position based on data 0 to 2 days old.

(– – – –) Position based on data 3 to 7 days old.

(– . – . –) Position based on data 8 days or more old.

(. . . .) Mean position for month.

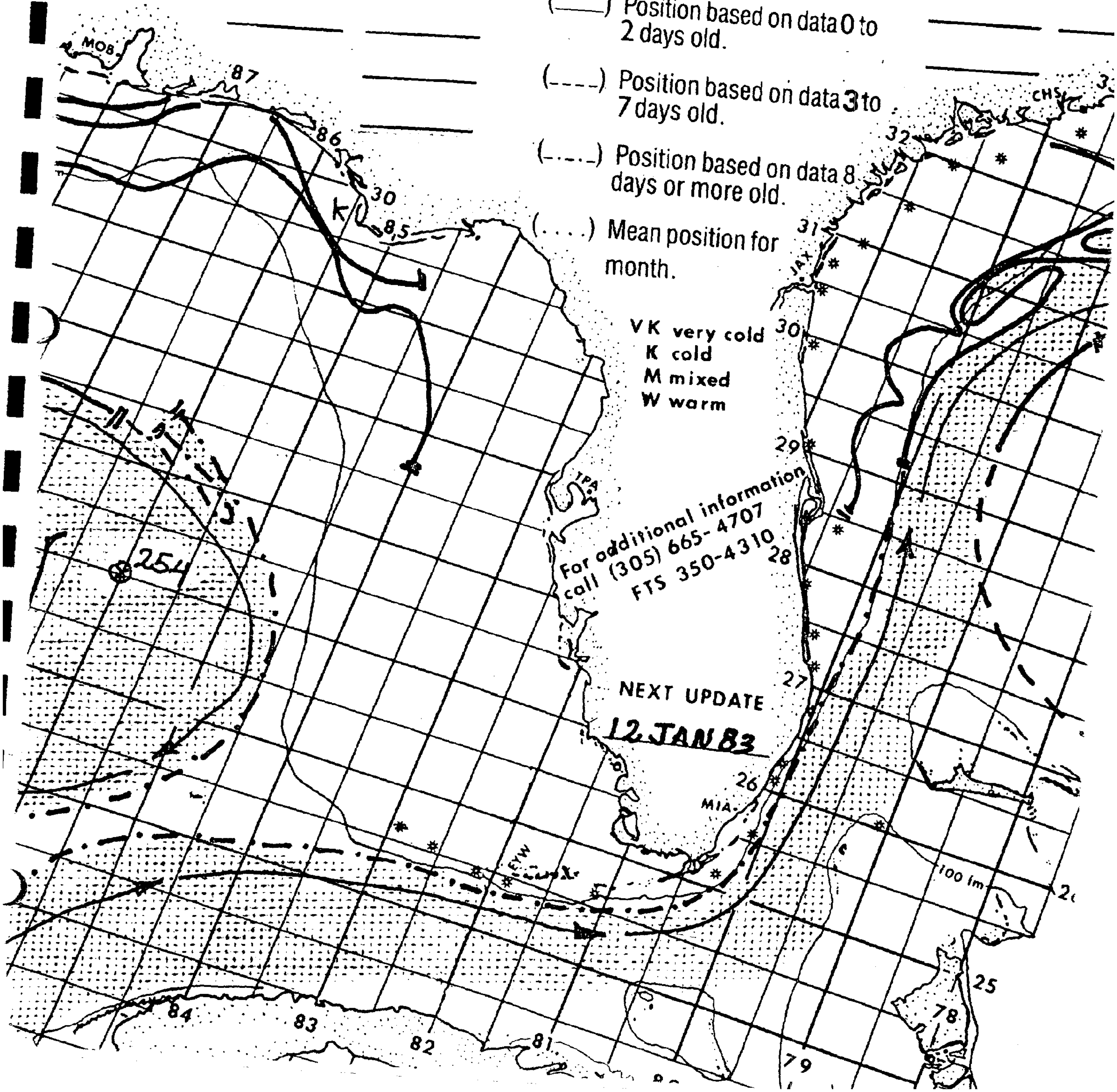
270800 278

317782 320

353747 361

372717 377

377672 375



TEM FLOW CHART #2450 — NOAA Miami SFSS — GULF STREAN

Date: 12 JAN 1983

233857 239849 243833
252801 260800//
BOUNDED BY:
245881 251885 267886
263852 260848 255846
236865//

270800 280
316785 317
335760 347
369725 3707
376670 3766

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

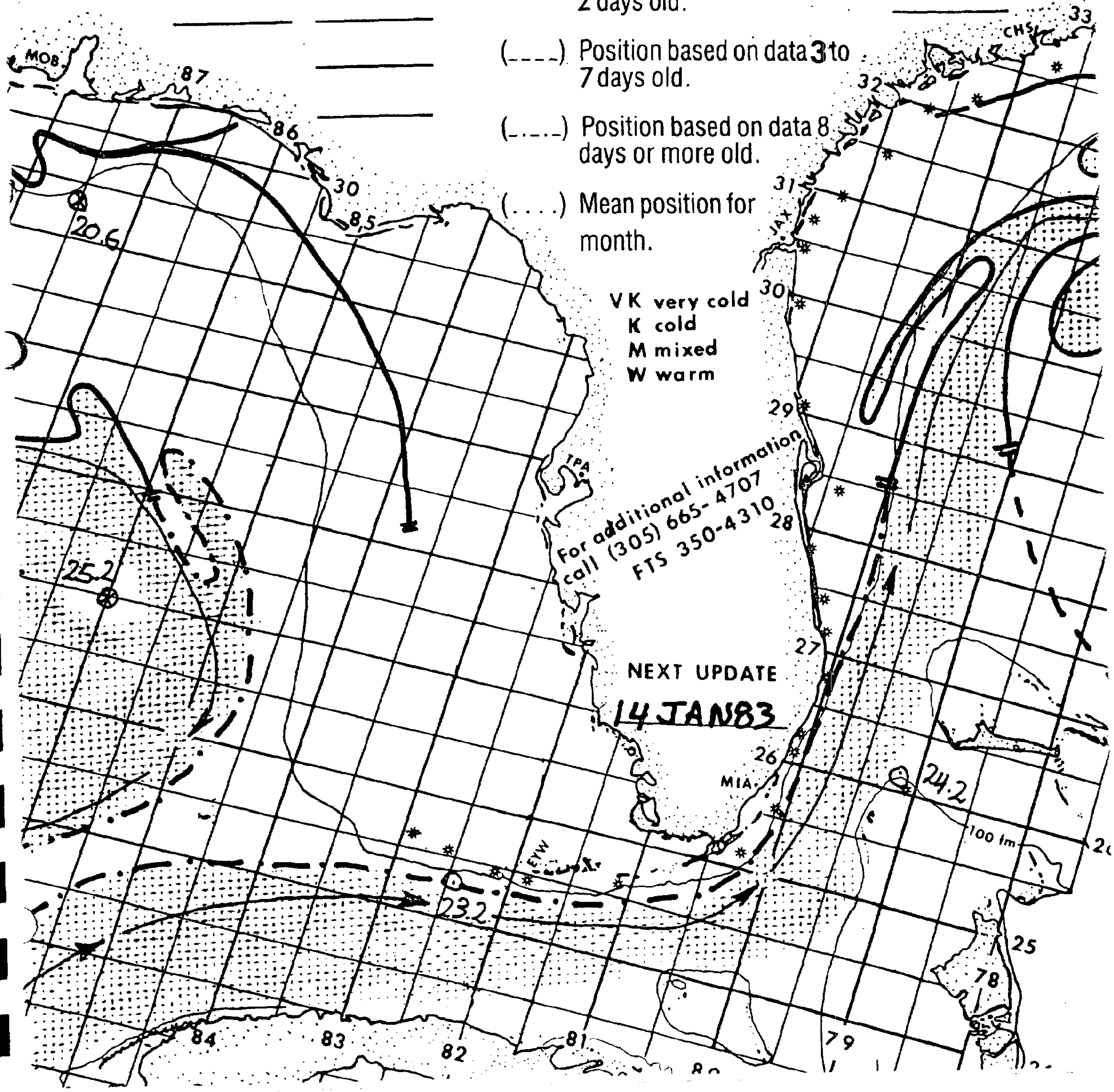
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



FEM FLOW CHART #2450 | NOAA Miami SFSS | GULF STREAM

Date: 14 JAN 1983

229859 235855 244838
245805 254800 260798//
BOUNDED BY:
244881 255888 265888
272861 259853 252852
239866//

270799 2753
318785 3197
353749 3695
385683 3766
380650// SAM

Depicted land should not be used for navigation.

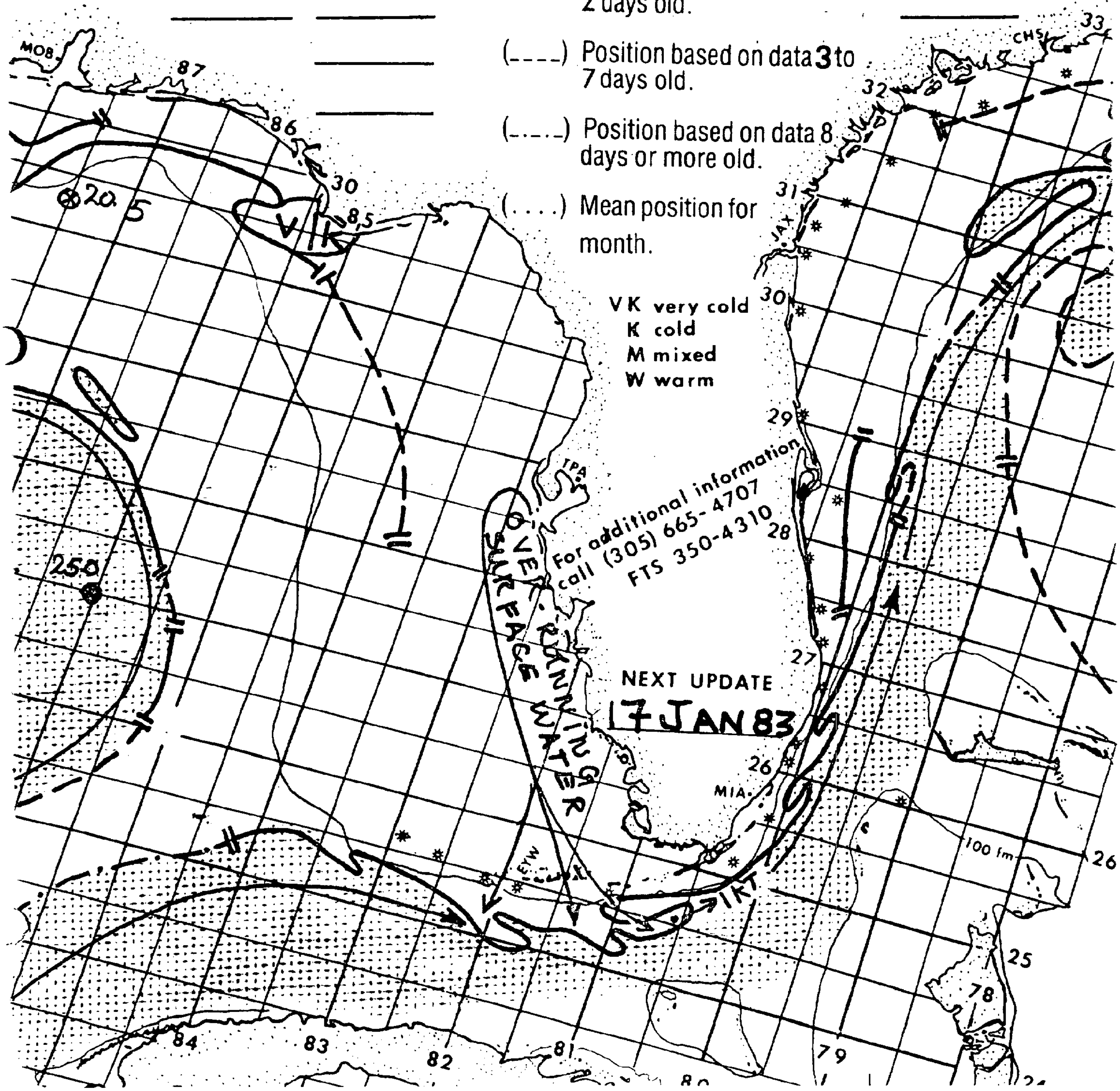
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 — NOAA Miami SFSS — GULF STREAM

Date: 17 JAN 1983

6	238866	240868	238873	270798	280
	240886	242888	250889	314790	318
)	271882	273878	273867	338760	343
5	254852	248854	246852	369733	373
7	238845	241836	240830	384680	3806
)	240816	241809	243806	376661	3806
		246805	248803		
			254800		
			260799 //		

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(_____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

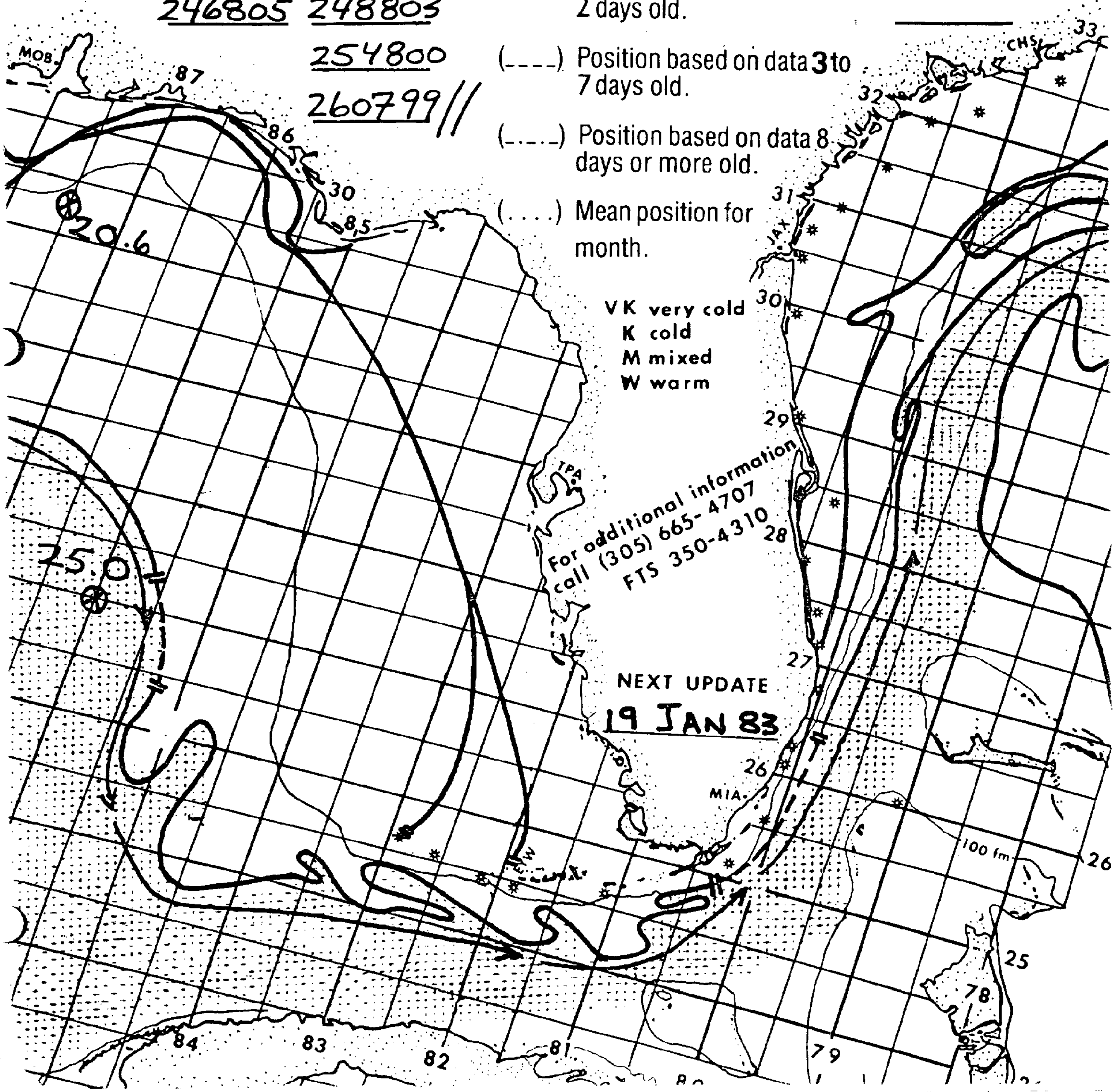
(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm

For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 19 JAN 83



TEM FLOW CHART #2450

NOAA Miami SFSS

GULF STREAM

Date: 19 JAN 1983

240867 243883 266888
278866 269860 262859
239844 239837 241825
246803 251800 260800 ||

270797 2757
313792 3167
324775 3407
366736 3677
385680 3766
379650 // SME

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

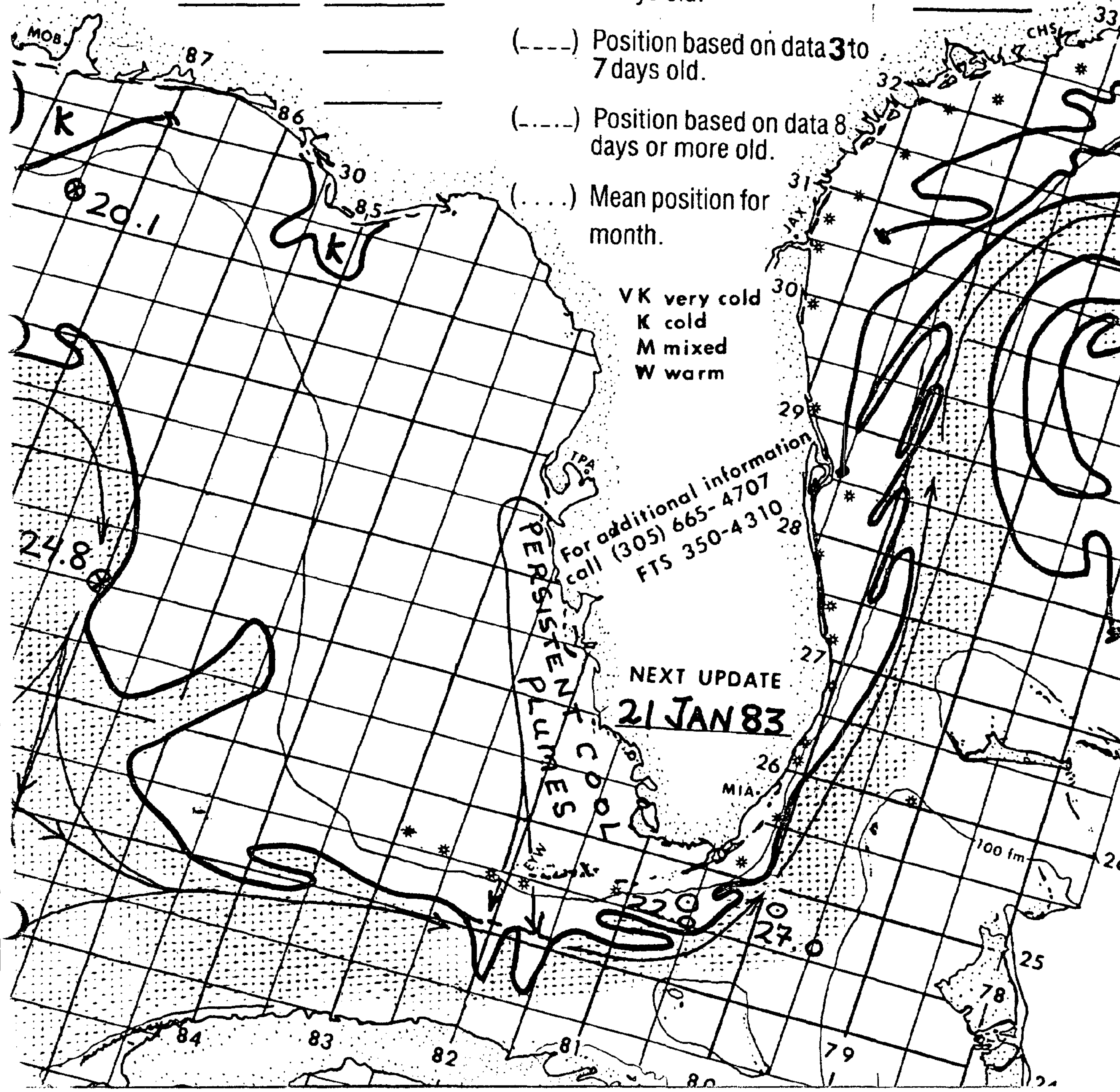
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



TEM .FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 21 JAN 19 83

1	240867	241881	243889	270797	275'
	273878	278875	275865	314795	317
2	245852	239842	239837	331769	3407
3	242806	247802	252800	371720	370
				378650 //	

Depicted land should not be used for navigation.

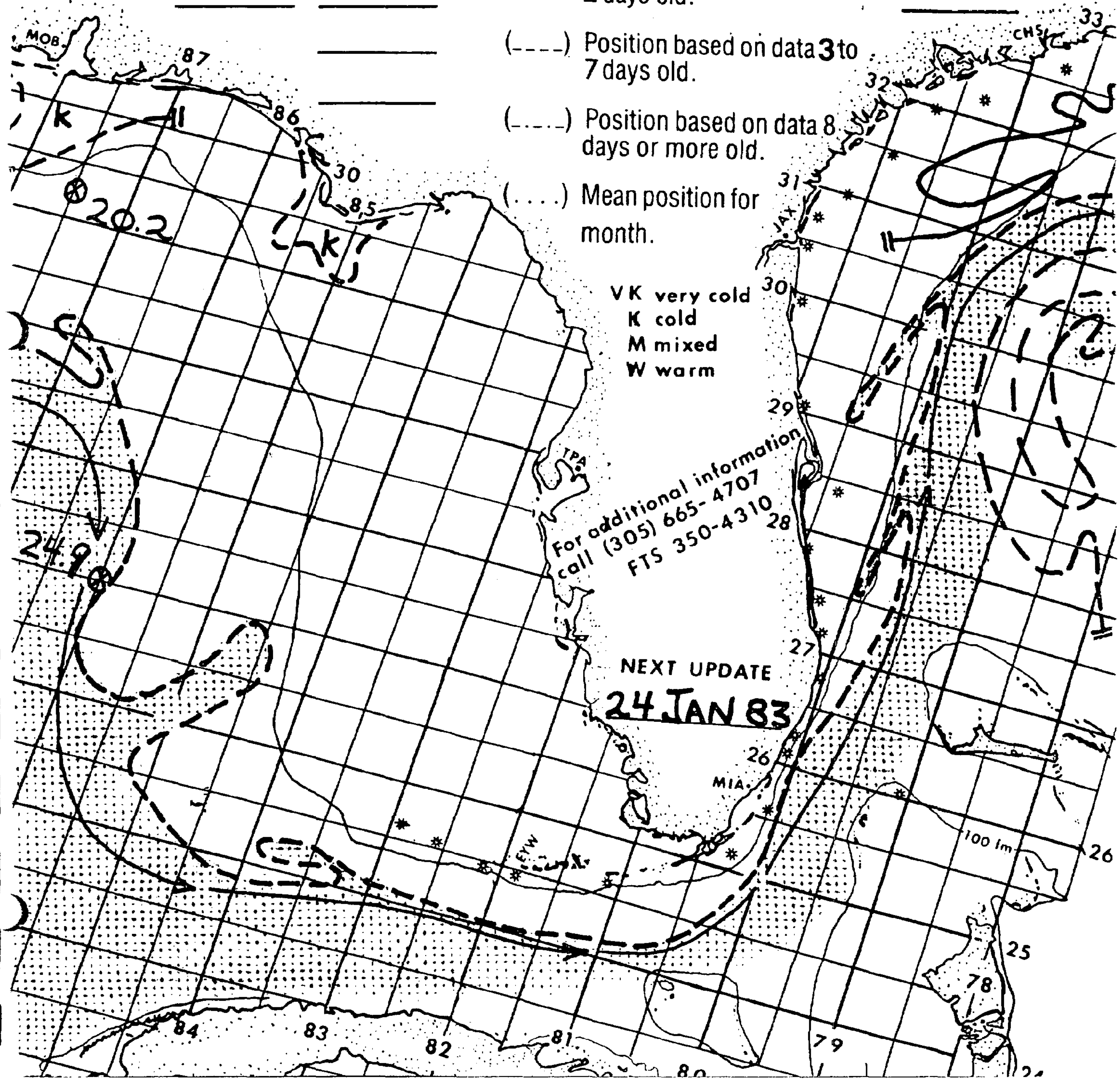
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(\- - - -) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 24 JAN 1983

232860	235862	236872	270799	2797
247903	251905	258894	318789	3217
266859	256859	251857	366737	3707
239846	239835	240827		
246801	251800	260800//		

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

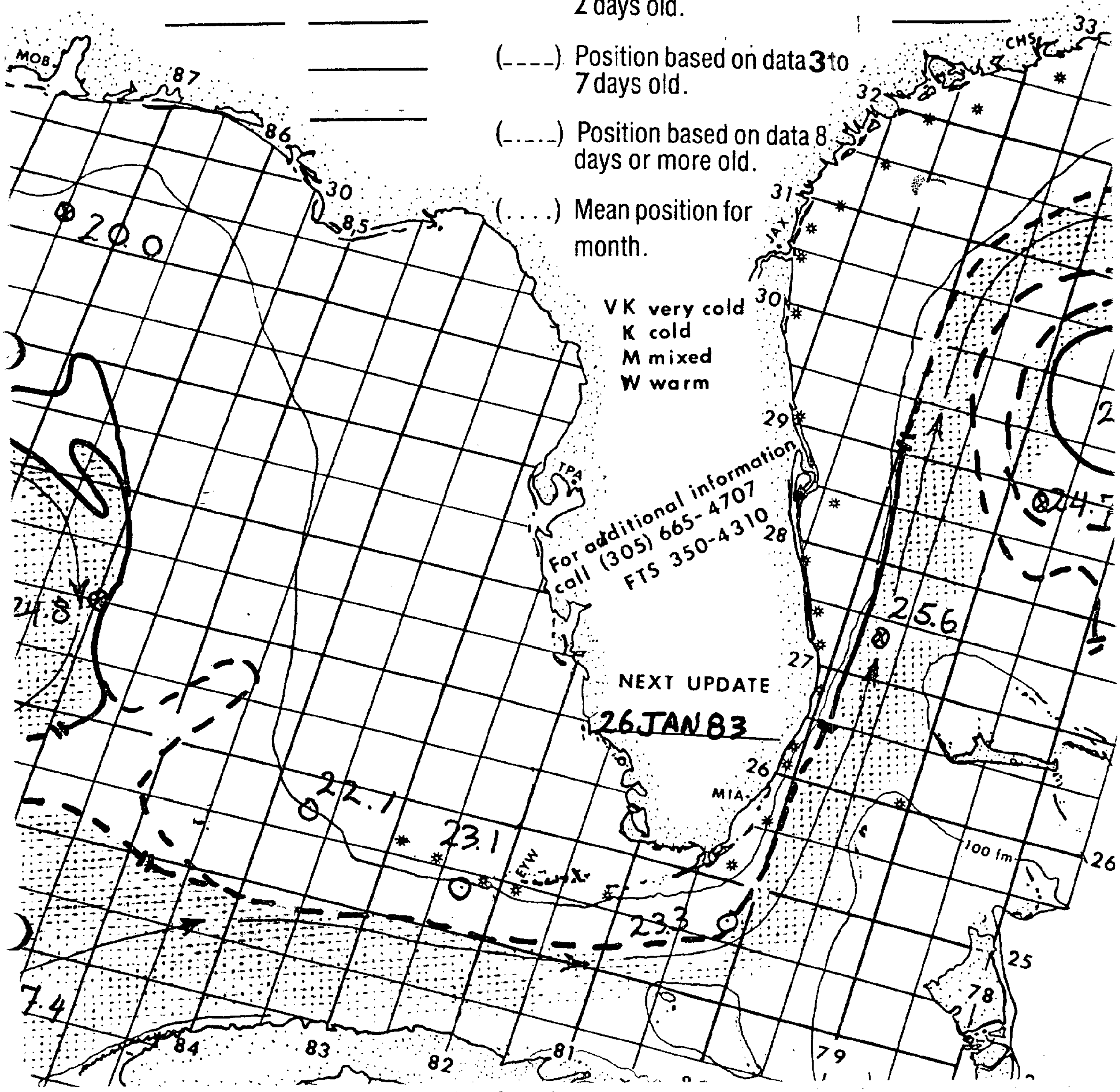
(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm

For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 26JAN83



EM FLOW CHART 2450 NOAA Miami SFSS GULF STREAM

Date: 26 JAN 1983

240861	239870	243880	270798	2877
252903	262895	268875	316790	3257
258852	253856	245869	370724	3767
240840	244832	242820		
242806	252798	260797 //		

Depicted land should not be used for navigation.

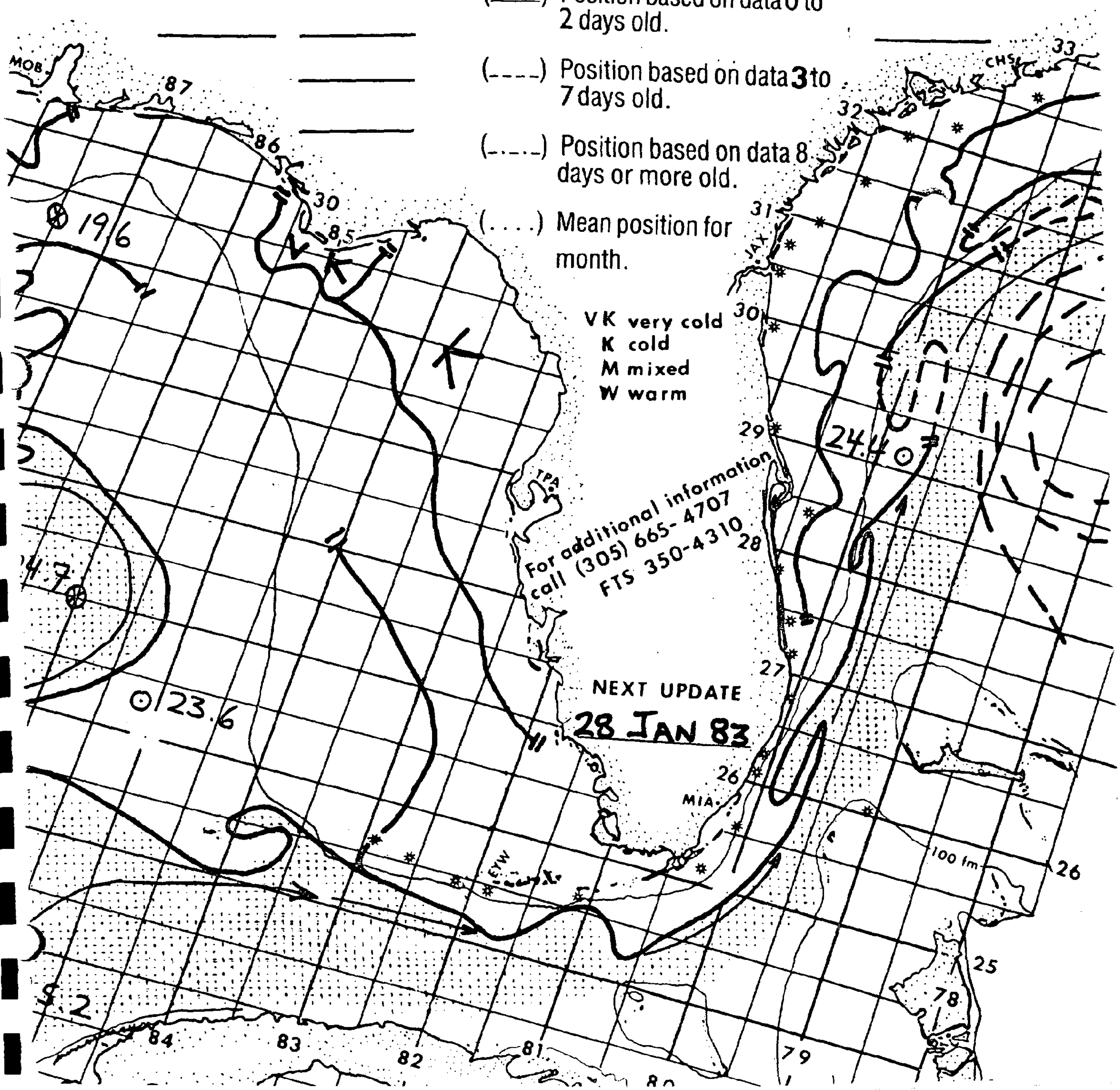
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(——) Position based on data 0 to 2 days old.

(----) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(....) Mean position for month.



FEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 28 JAN 1983

228857 238858 243847
243817 242811 246802
// WARM EDDY BOUNDED BY
247882 241895 245900
270862 264853 260852
239870 //

270796 2857
319785 32976
371721 3807

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

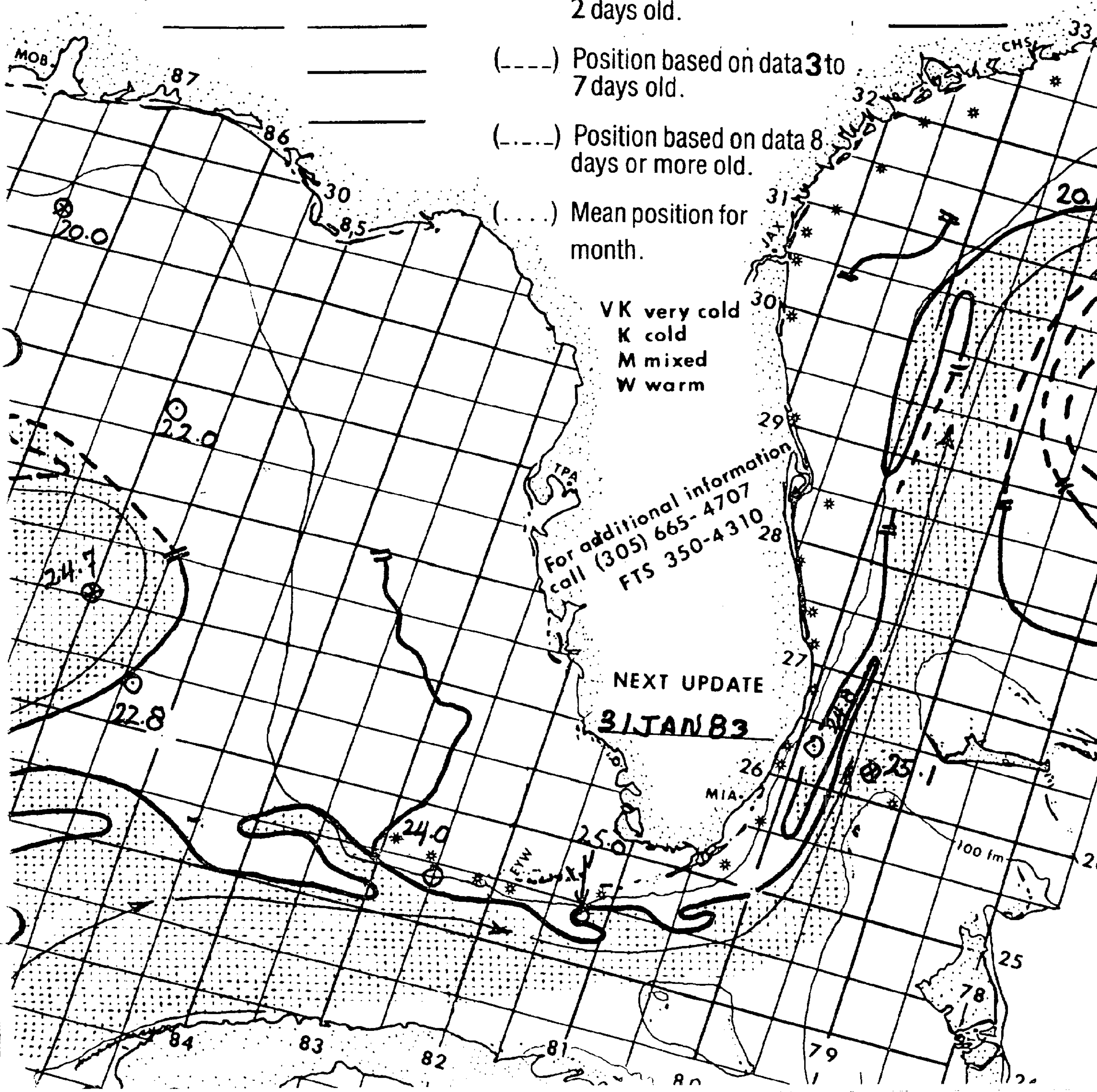
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_._._) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



(EM FLOW CHART #2450 — NOAA Miami SFSS — GULF STREAM

Date: 31 JAN 1983

236866 246854 246844
241816 245810 245805
260798// WARM EDDY
240875 247889 242896
259899 265886 267873
266854 260850 257849
255850 239872
240875//

270797 2807
314794 3217
340757 3477
374733 3727
385694// SAP

Depicted land should not be used for navigation.

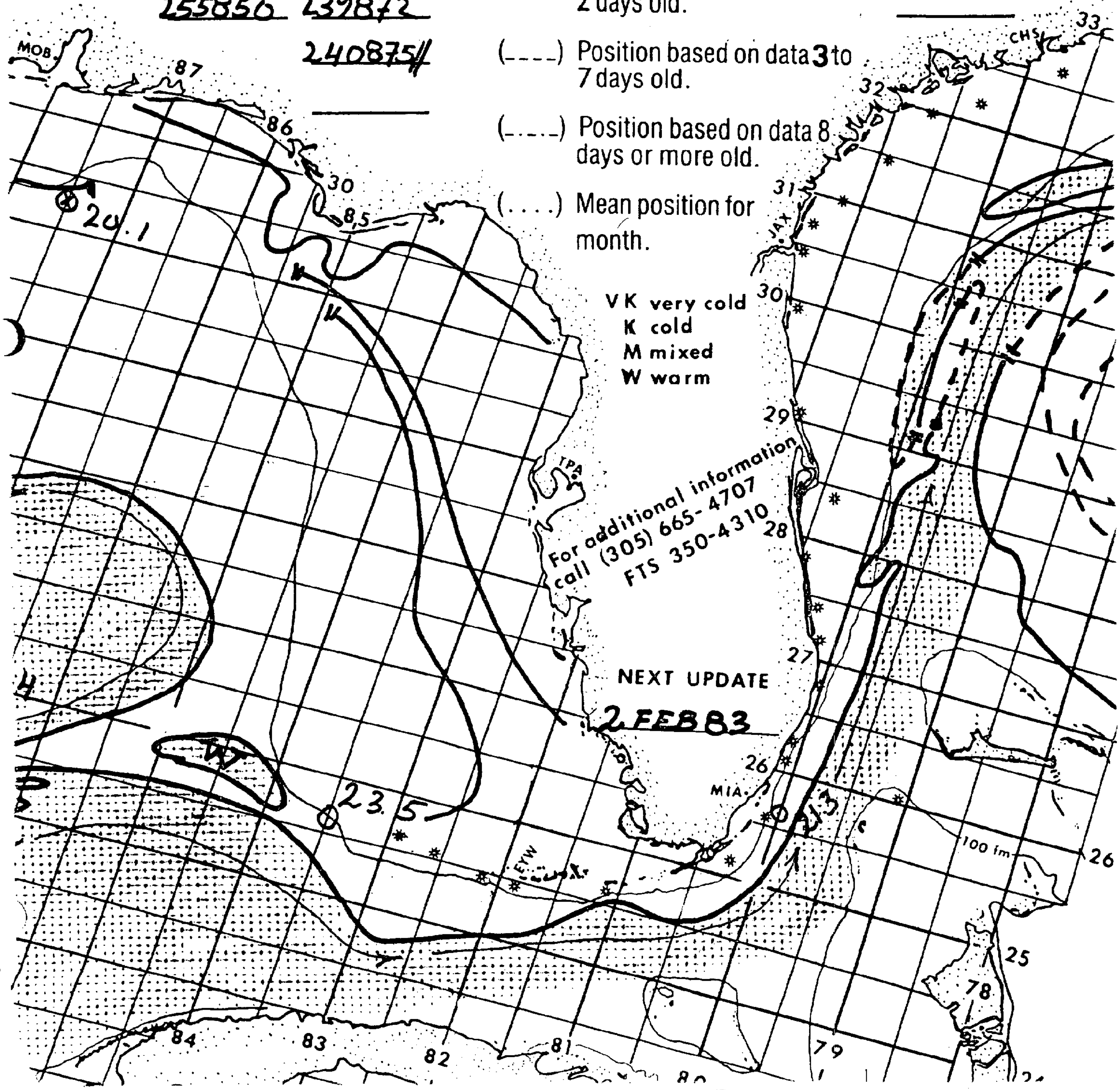
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.



,TEM, FLOW CHART #2450 NOAA Miami SFSS GULF STREAN

Date: 02 FEB 1983

,3	230866	237864	246852	
7	242830	243820	240815	
y	252800	256799	260798 //	
2ED BY:		240875	247889	
2	254903	259899	266883	
.	268855	265849	262848	
		258849	252854	
			246862	
			239872 //	

270798	284'
322785	322
360743	371
374720	374
385693	3846
386663	385
381644	—

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(_____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

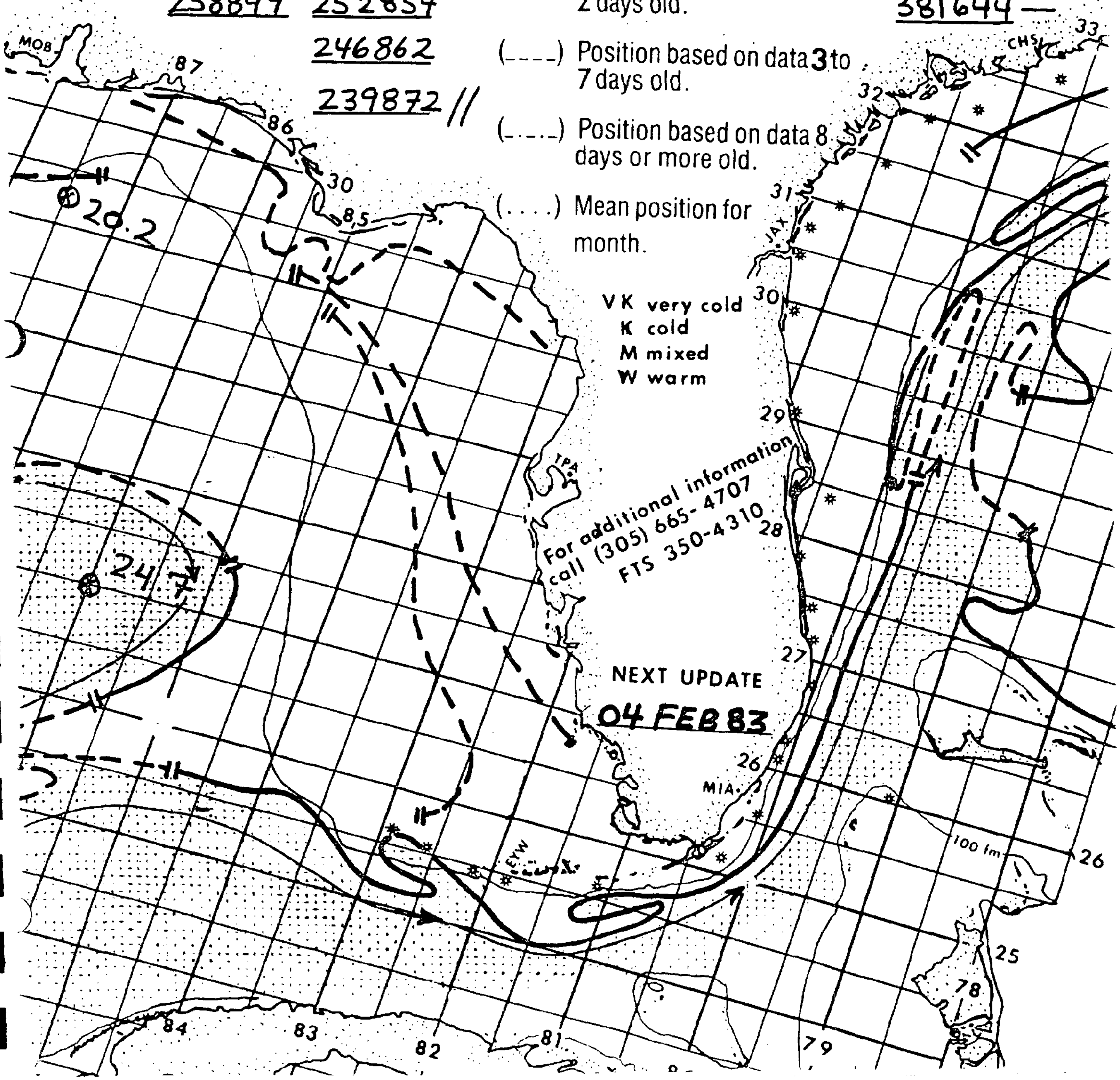
(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm

For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 04 FEB 83



[…]TEM FLOW CHART #2450 | NOAA Miami SFSS | GULF STREAM

Date: 04 FEB 1983

240868 245860 247850
248805 249802 254799
EDDY BOUNDED BY: 240870
246895 255897 264898
266855 264849 257848
240870//

270798 27479
314795 3227
342754 3477
379729 3757
386685 3796
386652 3826
383640//

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

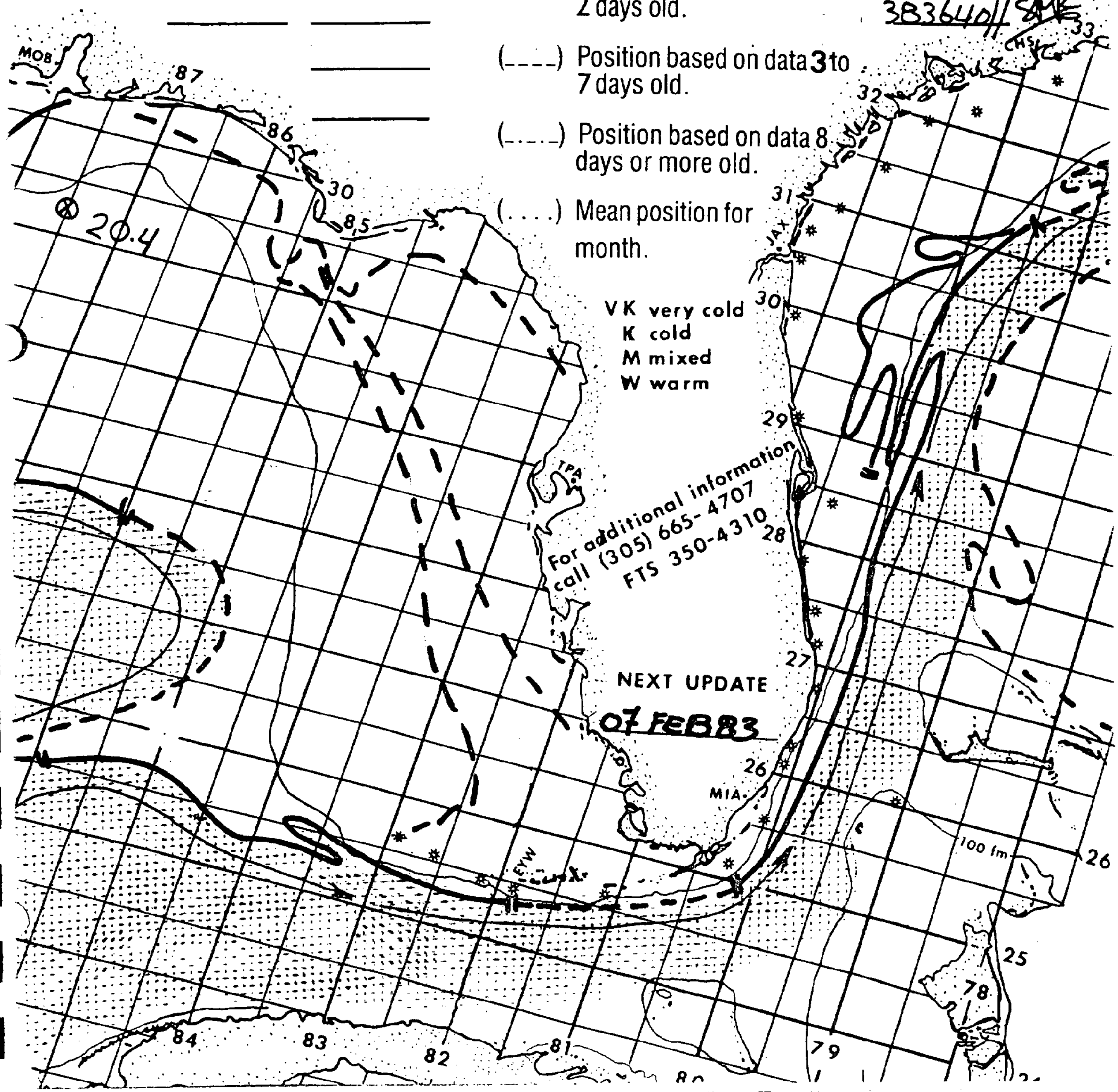
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



Date: 07 FEB 1983

…5 241870 245859 245852
…0 241830 239829 241825
…5 245808 252799 255798
EDDY BOUNDED BY: 241873
…8 248896 259899 264899
…5 267857 263853 258848
252851 248854
245866
241873//

270798 280…
320785 321…
341755 347…
378725 375…
385685 379…
386655 386…
380640//

Depicted land should not be used for navigation.

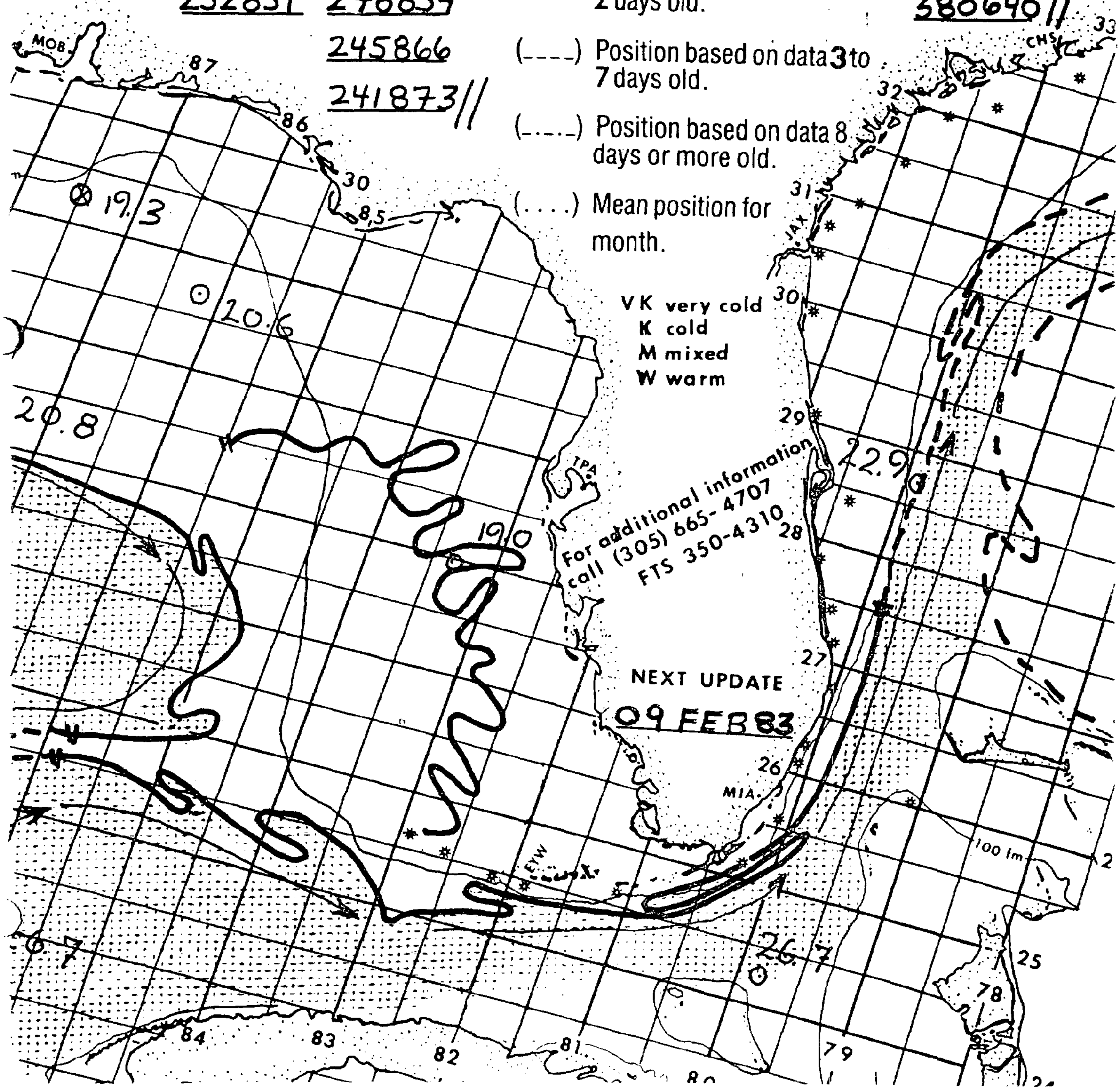
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



Date: 09 FEB 1983

230869	240873	246874	270800	286
250895	260897	266899	319787	319
266876	266867	260855	337762	340
250853	249860	247862	378724	373
244840	241825	238818	386683	385
250801	253800	260800//	378669	387
			386646	—

Depicted land should not be used for navigation.

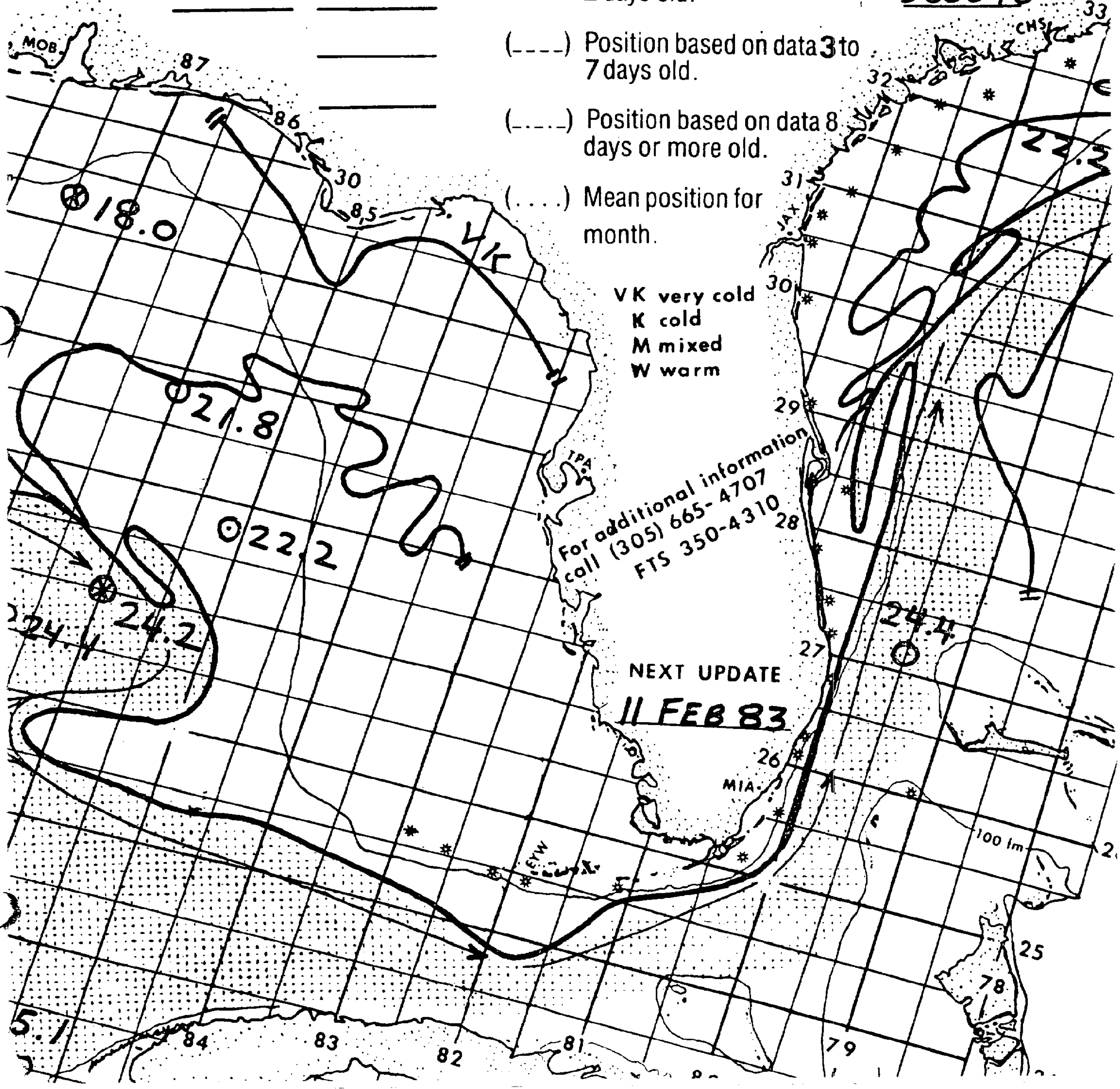
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 | NOAA Miami SFSS | GULF STREAM

Date: 11 FEB 1983

232866	245875	248879
270893	271879	263860
248850	249857	252860
246862	246856	240846
247812	250801	253806

270799	2797
313791	3207
374728	3747
376669	3856

Depicted land should not be used for navigation.

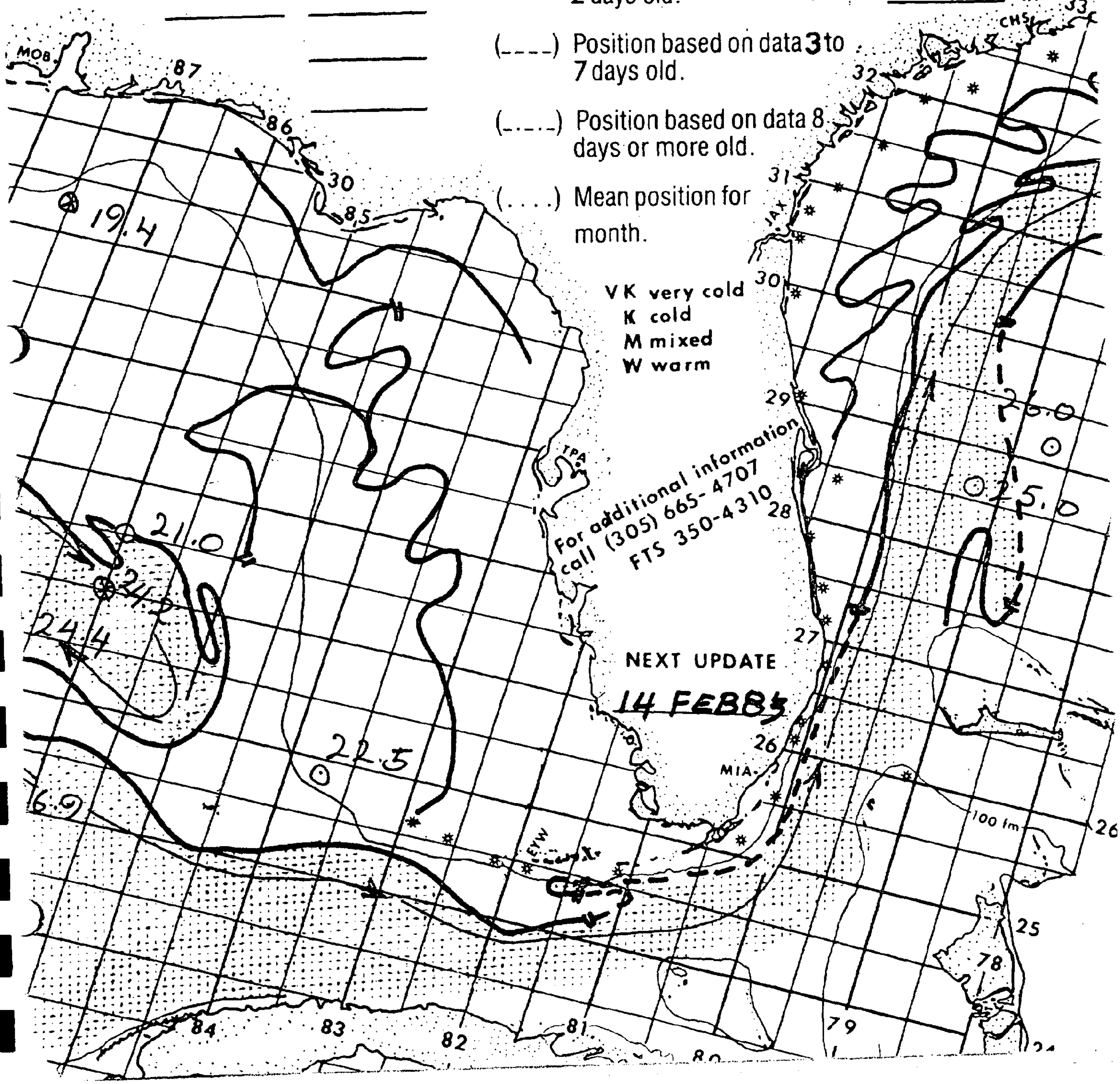
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



EM FLOW CHART #2450 — NOAA Miami SFSS — GULF STREAM

Date: 14 FEB 1983

231866	240874	249878	270799	3058[illegible]
262900	266899	270821	321774	3247[illegible]
260853	252842	248848	356739	3727[illegible]
253866	249866	237849		
241816	247806	249804		
260799//				

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

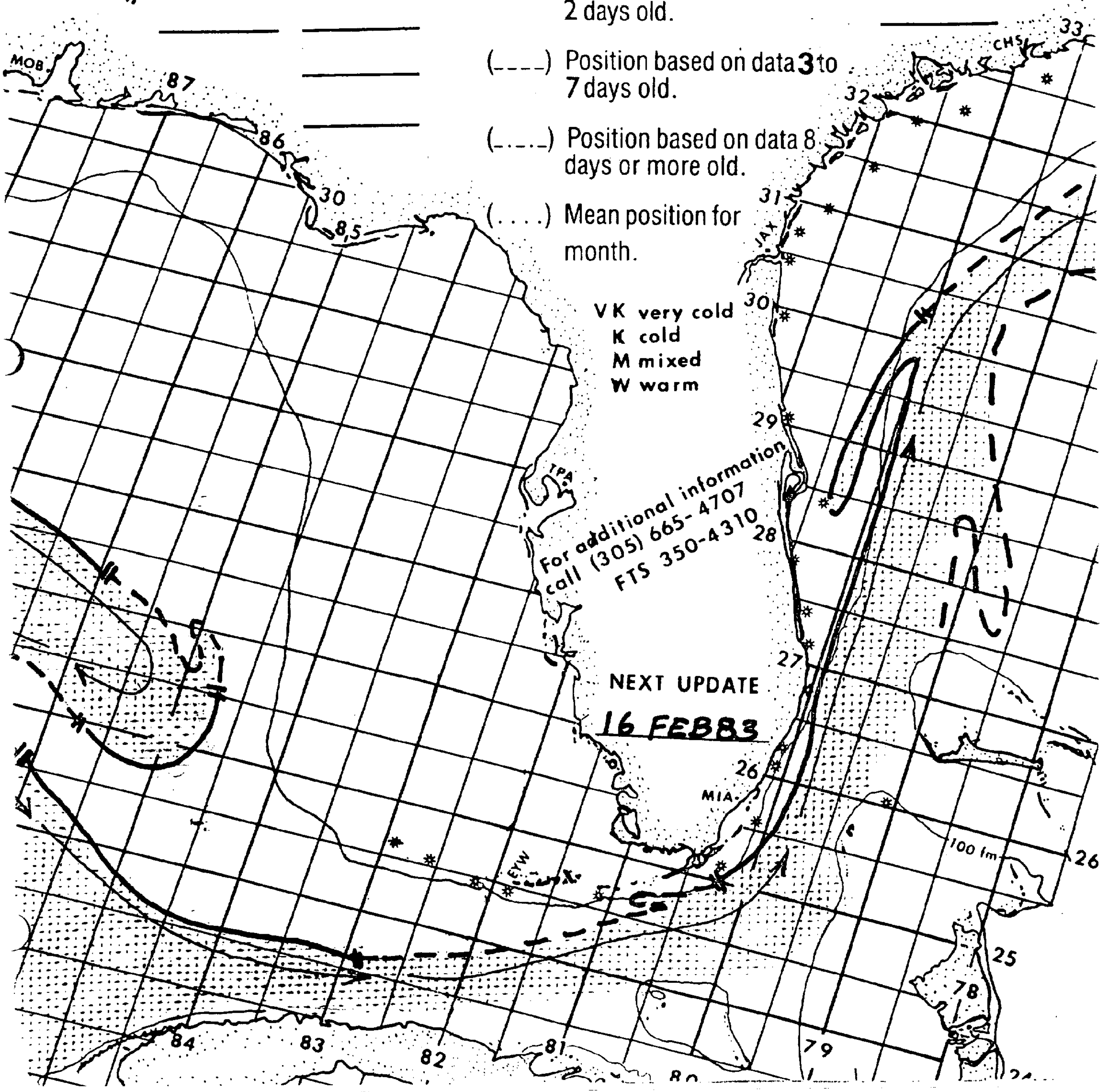
(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm

For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 16 FEB83



TEM FLOW CHART #2450 — NOAA Miami SFSS — GULF STREAM

Date: 16 FEB 1983

235869	246876	252883
264900	270900	272893
265865	258854	251844
244850	251859	251861
231851	230846	234835
235815	240807	245804
	248800	254799
		260798 //

270798	2887
320782	3207
340760	345
357738	366
375710	3816
384673	3856
381650 //	

Depicted land should not be used for navigation.

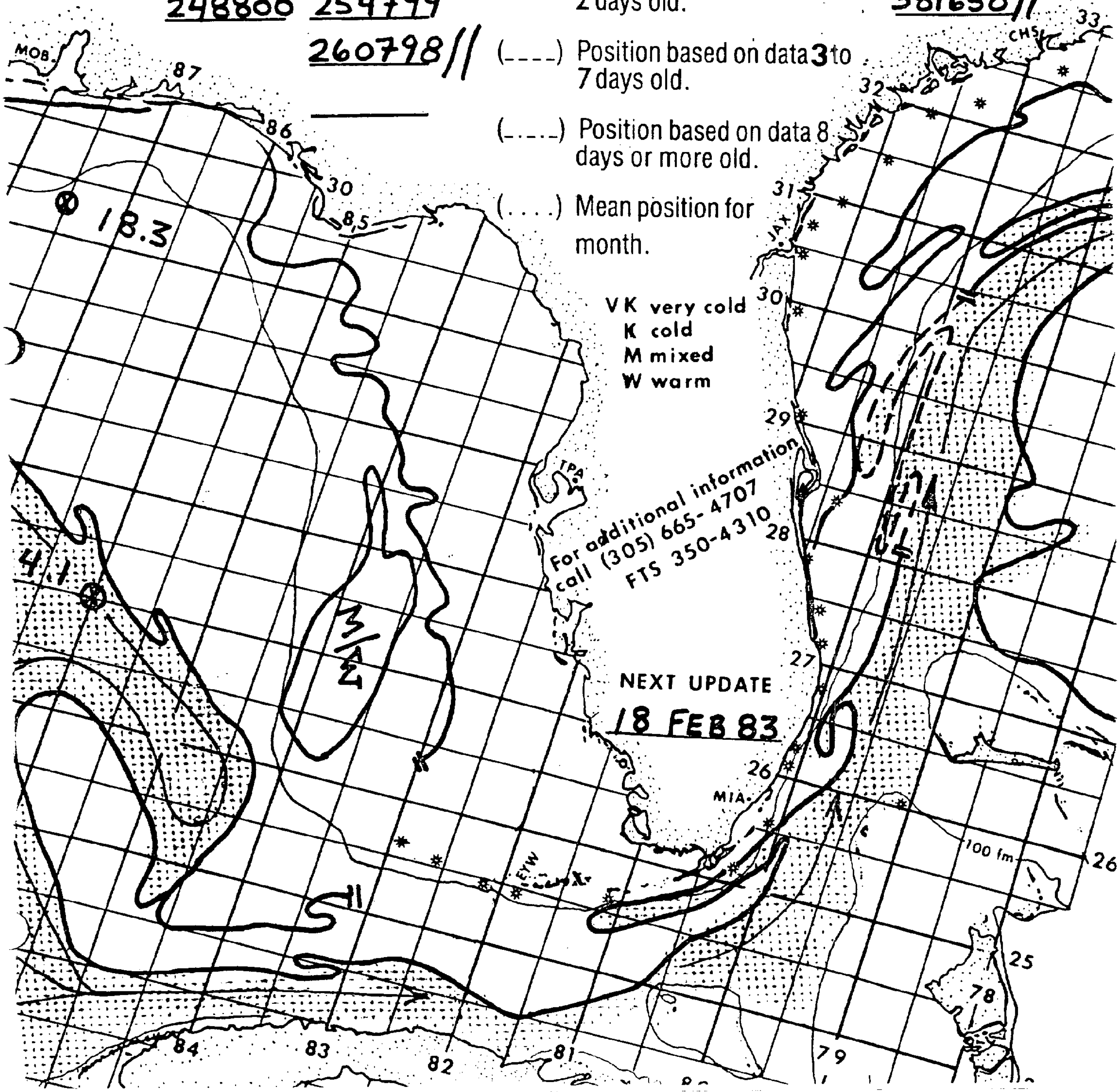
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(_____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



STEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 18 FEB 1983

228869	233869	237867	270797	2917
252880	254885	252890	328770	330
270900	272887	270887	358740	374
249843	243843	233847	380679	385
251860	249864	236855		
230845	237828	239809		
	247798	260796		

Depicted land should not be used for navigation.

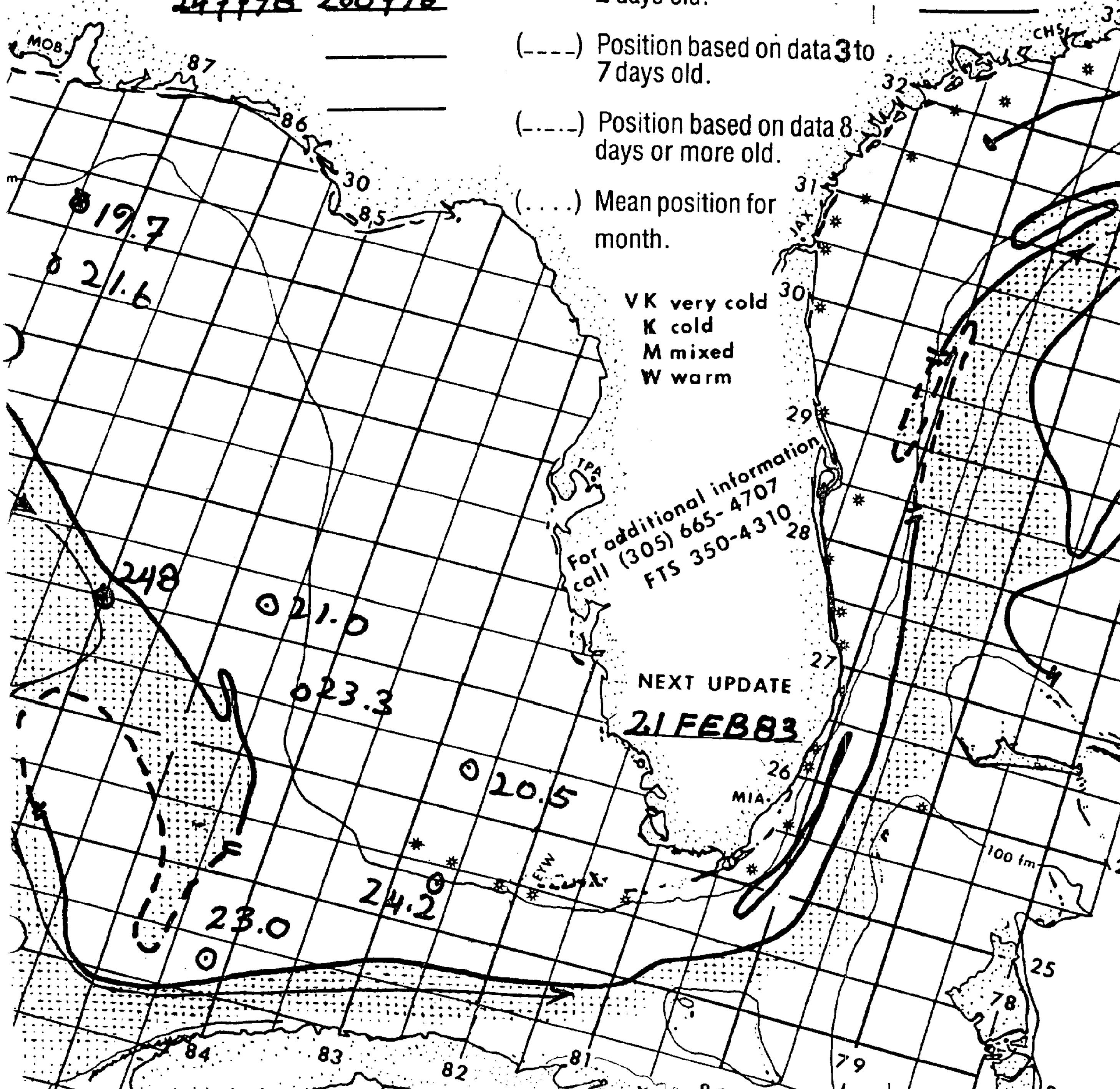
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(_____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(- . - . -) Position based on data 8 days or more old.

(. . . . .) Mean position for month.



STEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 21 FEB 1983

226819	238872	251872	270797	300
261900	265910	275900	328770	3297
270873	252844	242844	365738	375
237825	239811	245800	383690	3816
			382645	3876

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

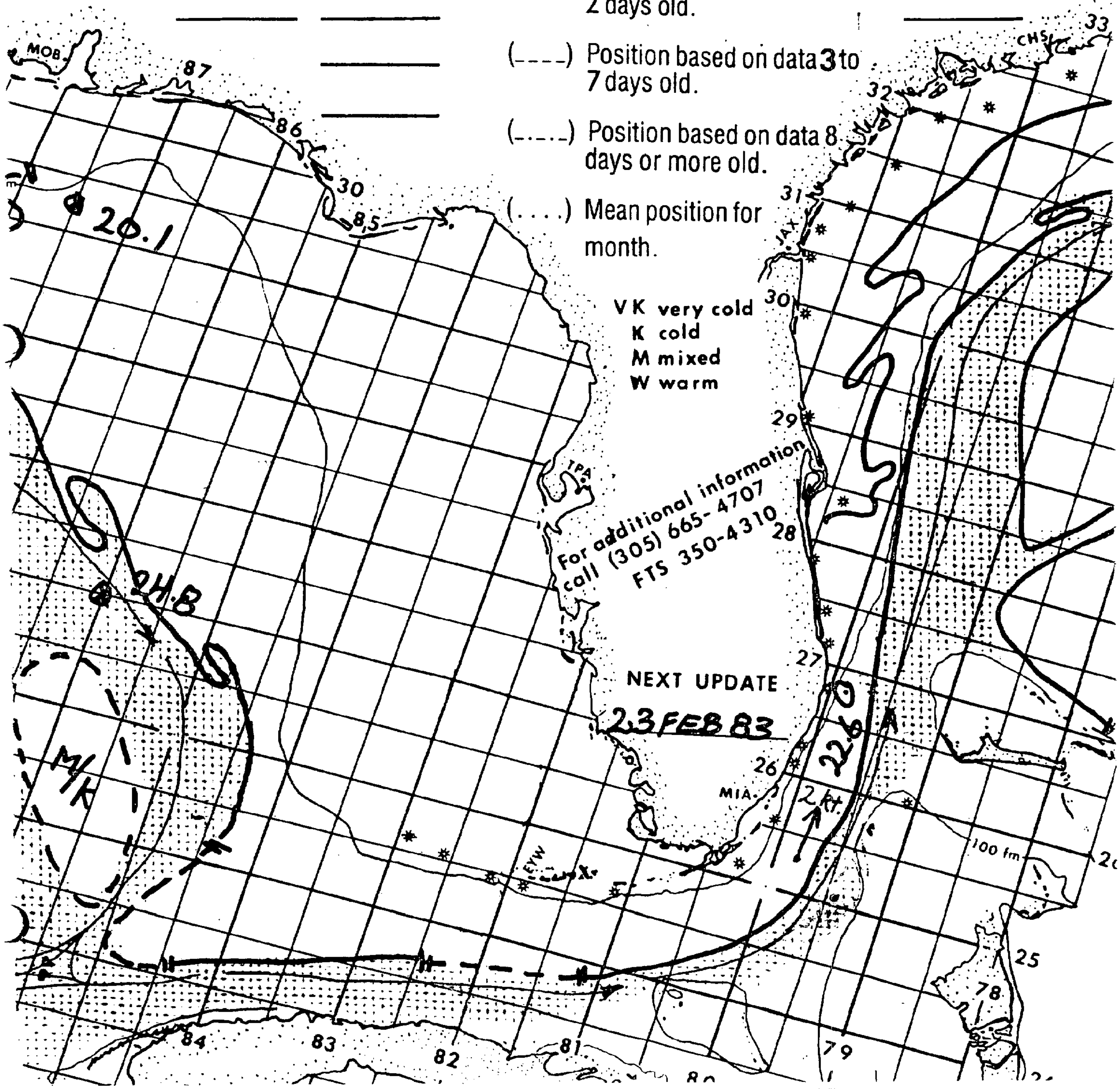
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 23 FEB 83

TEM FLOW CHART #2450 — NOAA Miami SFSS — GULF STREAM

Date: 23 FEB 1983

5	235871	245876	256883	270797	2908
7	268910	273905	277895	320780	325
	257855	253848	249844	346757	357
	230850	230846	236825	374726	378
2	248798	256796	260795//	385694	3836
				382671	388
				385650//	

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(——) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

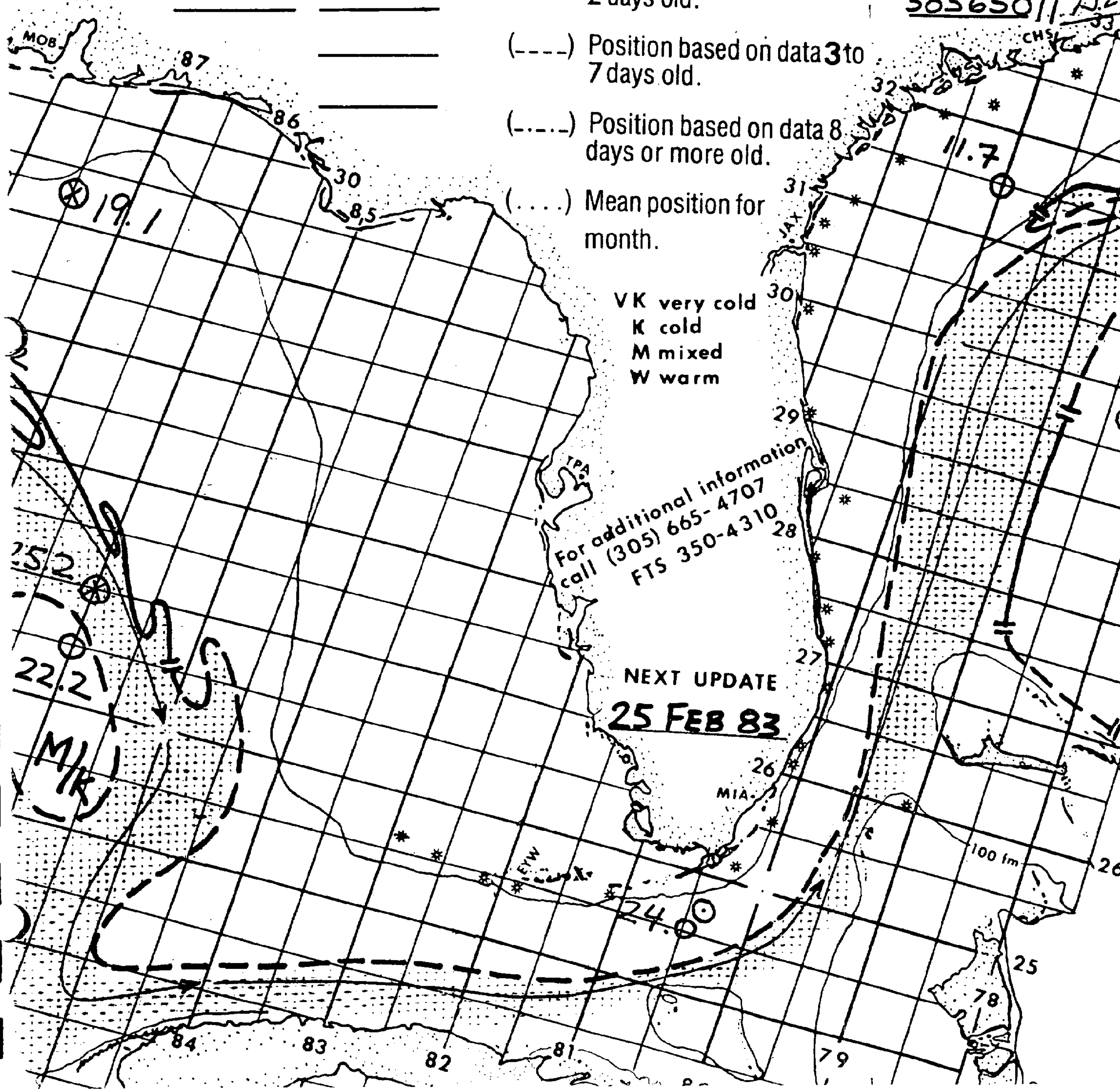
(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm

For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 25 FEB 83



TEM FLOW CHART #2450 | NOAA Miami SFSS | GULF STREAM

Date: 25 FEB 1983

2	255881	260890	267905	270797	290
3	276900	274893	274885	318785	3197
t	260859	255854	254850	340755	349
3	232847	230845	236825	370705	385
?	250796	260796//		385650//	

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

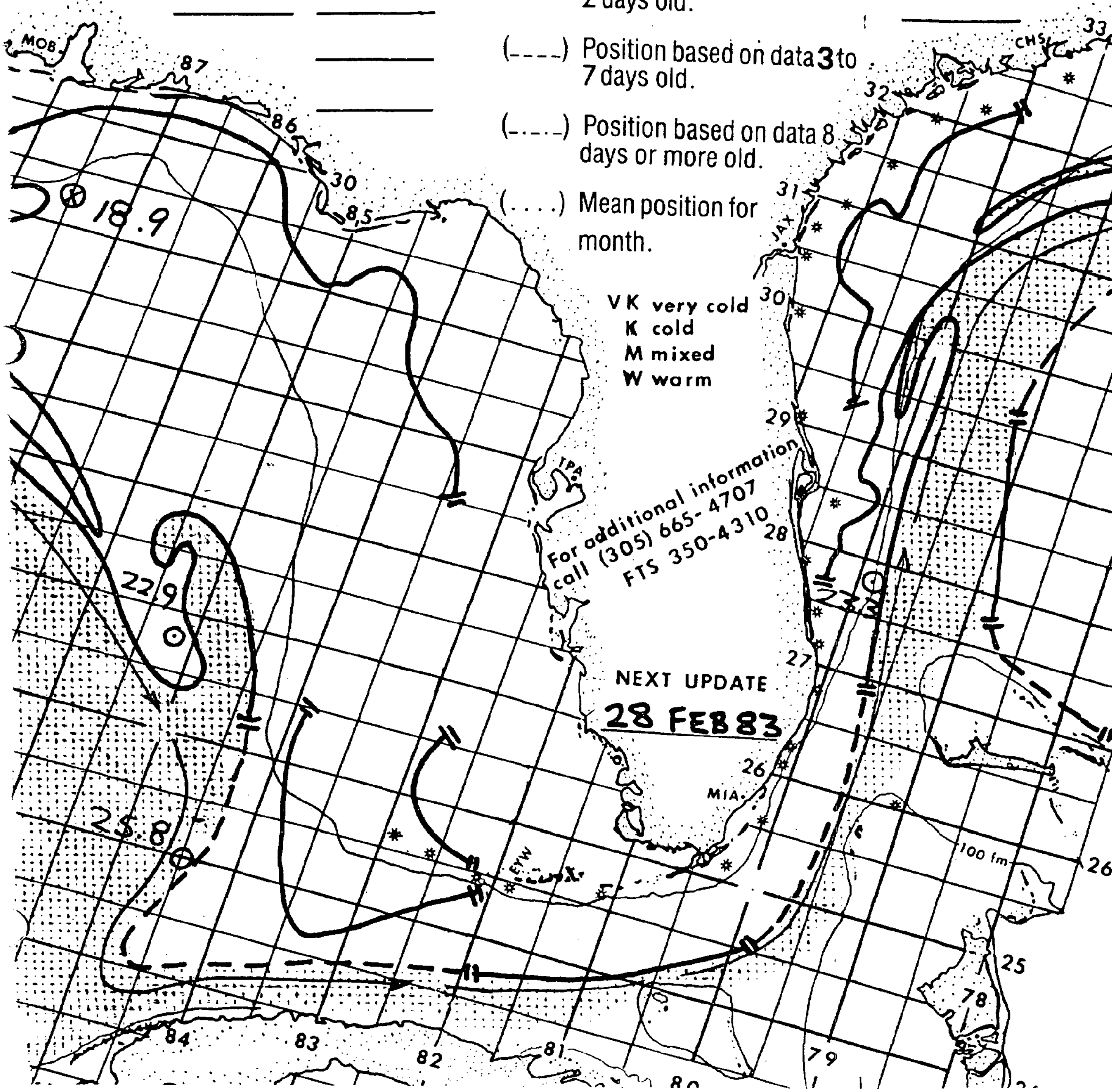
(——) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 28 FEB 1983

238873	242878	254879	270797	2857
267906	271913	277903	320777	33176
255852	250839	238834	359740	3687
260797//			371707	3757
			382656	3856

Depicted land should not be used for navigation.

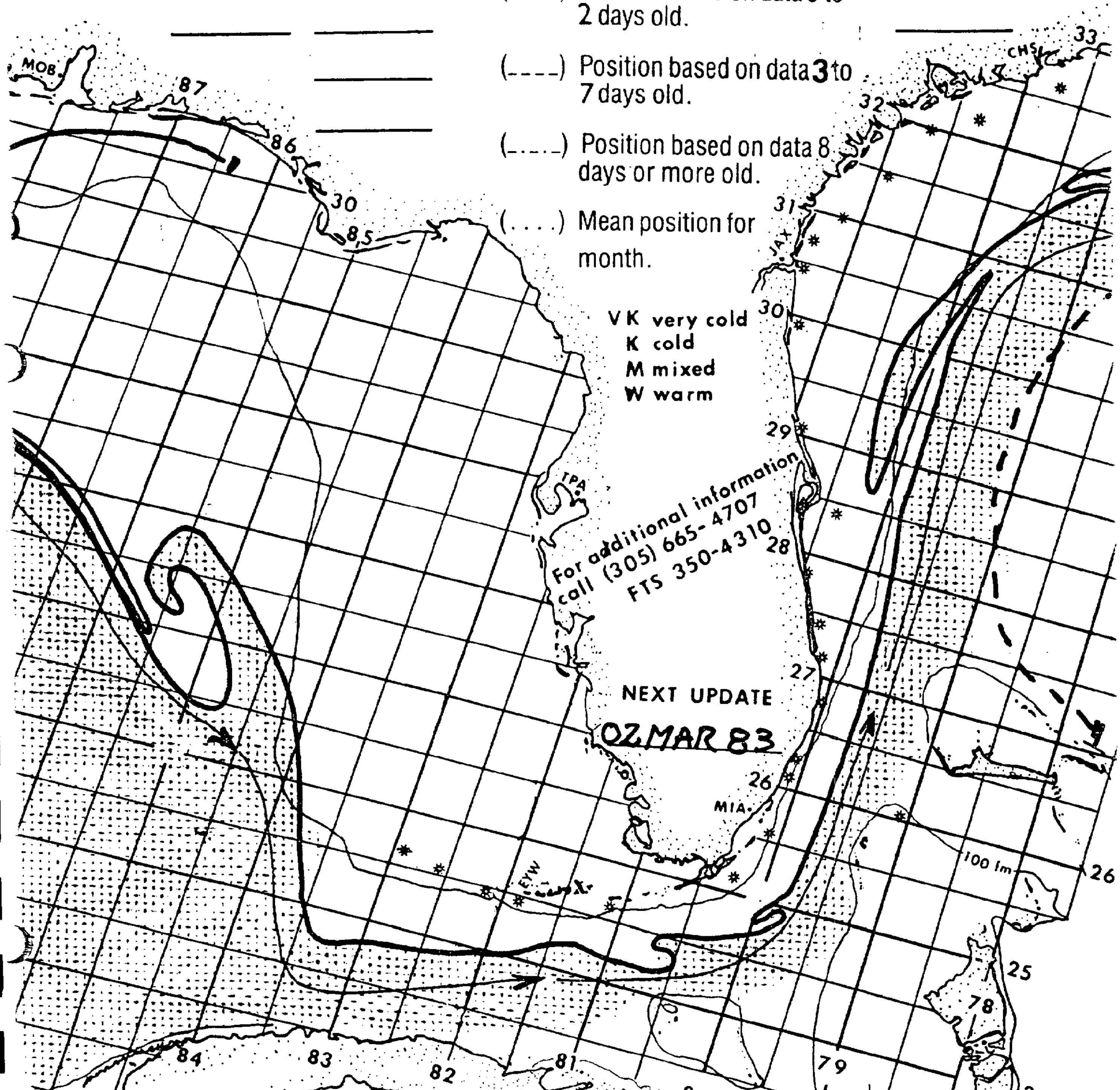
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 02 MAR 1983

228868	231874	240876	270797	2957
268868	264862	259860	327765	3347:
246845	245837	240836	375720	3757
243815	246804	249800	385680	3796
			377632//	D.E.W.

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

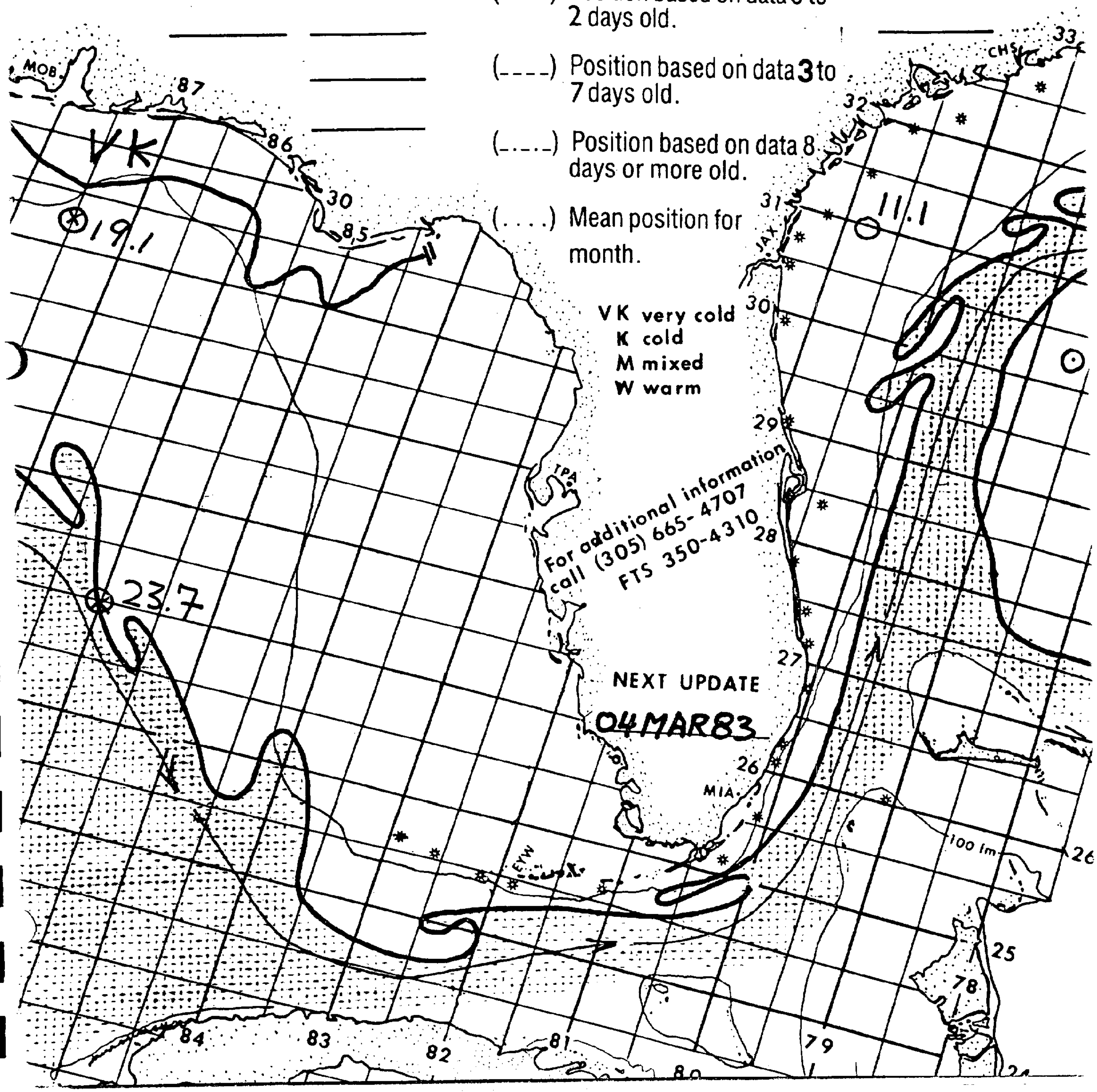
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_._._) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



ƐEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 04 MAR 1983

235872	250884	262882	270799	2907
265862	259858	250840	324770	330
237825	240816	245808	356745	357
260797//			376715	3727
			386684	3866
			380660	3836

Depicted land should not be used for navigation.

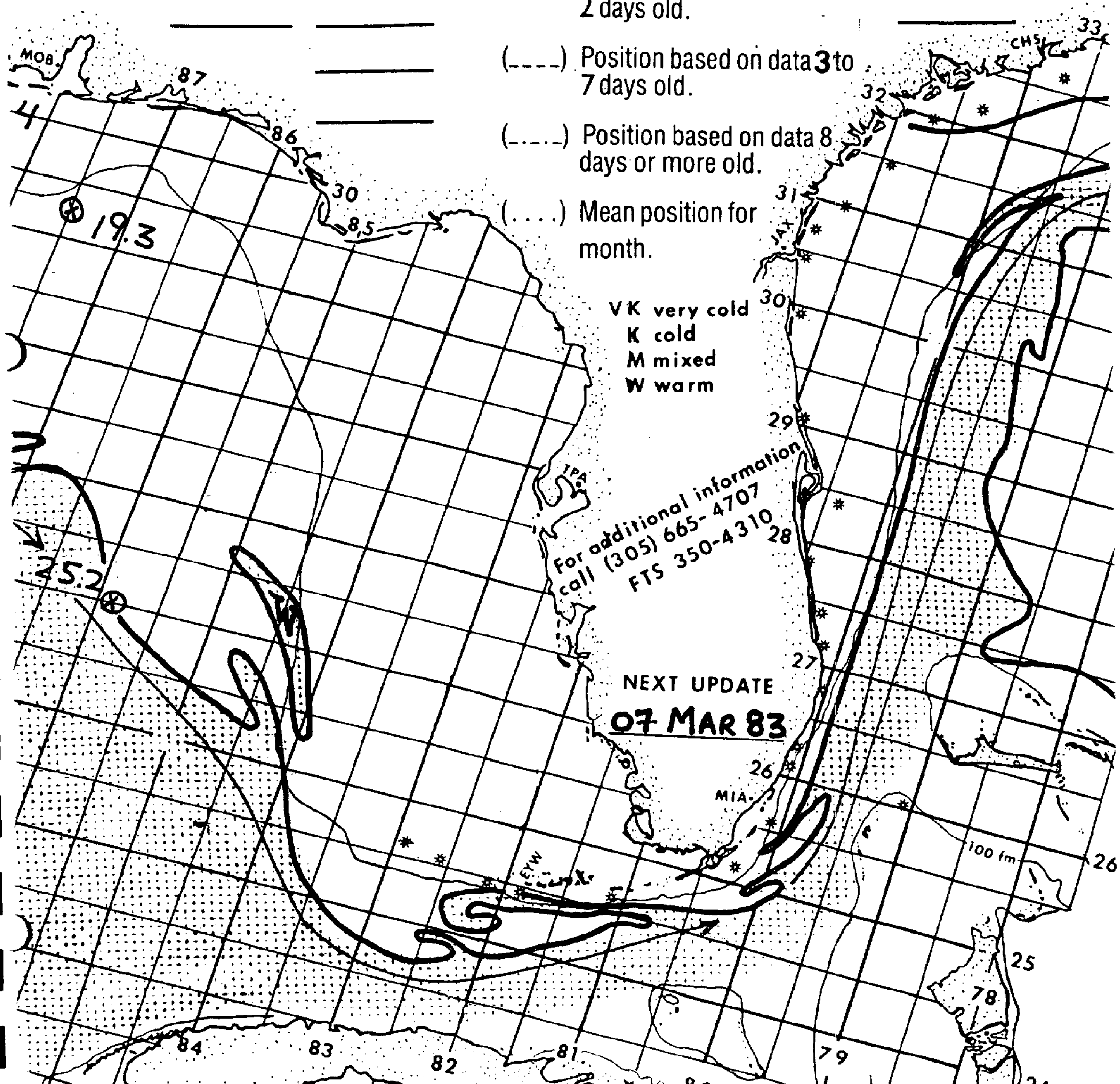
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(_____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 07 MAR 1983

232871 244873 250881
270867 268860 258855
242837 236831 238821
257797 260797//

1983 MAR

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

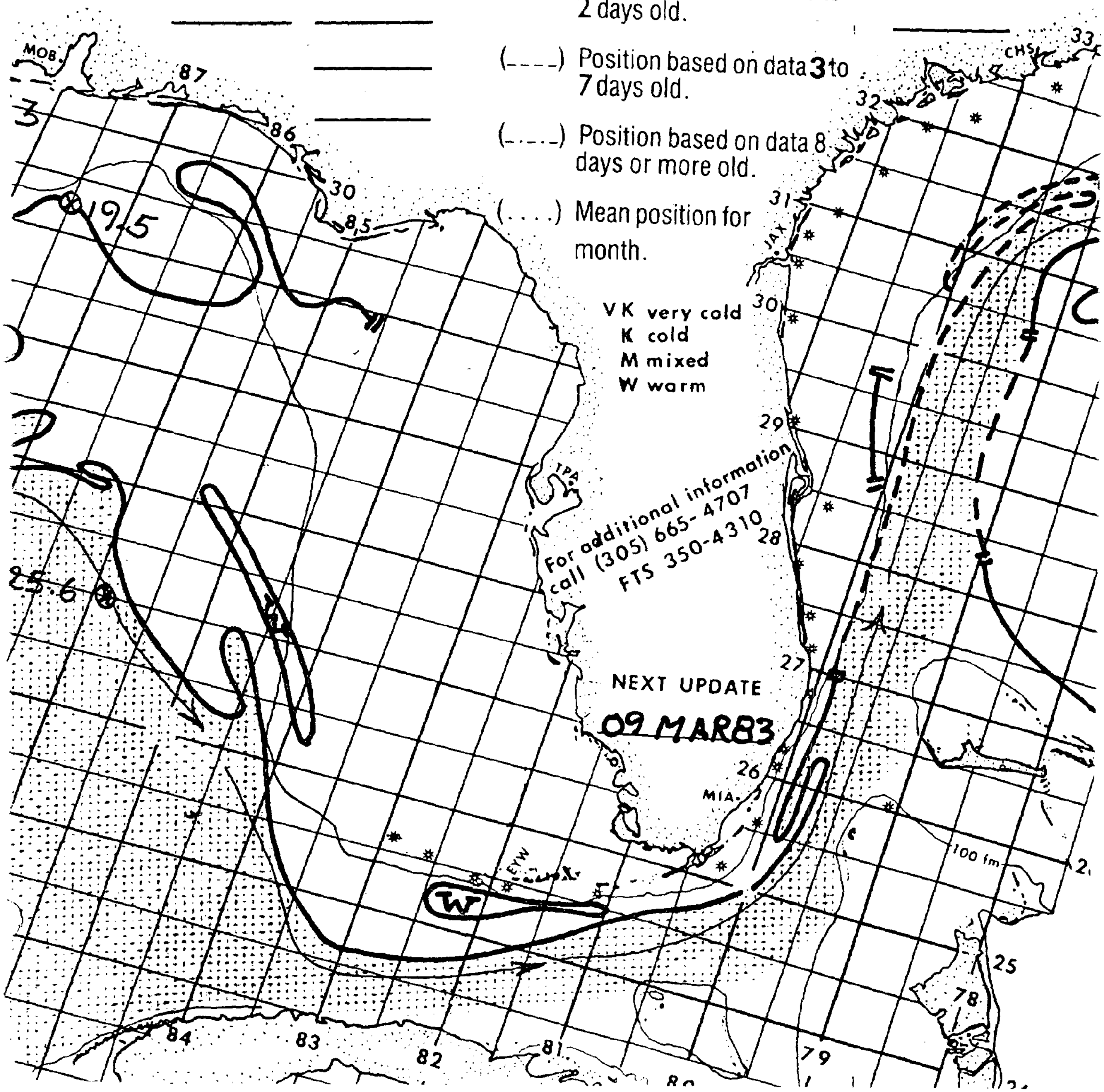
270799 3018
327768 3357
367729 3747
371700 3746
376660 3896

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.



EM FLOW CHART 2450

NOAA Miami SFSS

GULF STREAM

Date: 09 MAR 1983

229870 239873 247878
268878 268870 258859
242836 239833 238822
260798

270798 2908
331771 3307
362739 3627
372703 3716
378659 3806
390640 3916

Depicted land should not be used for navigation.

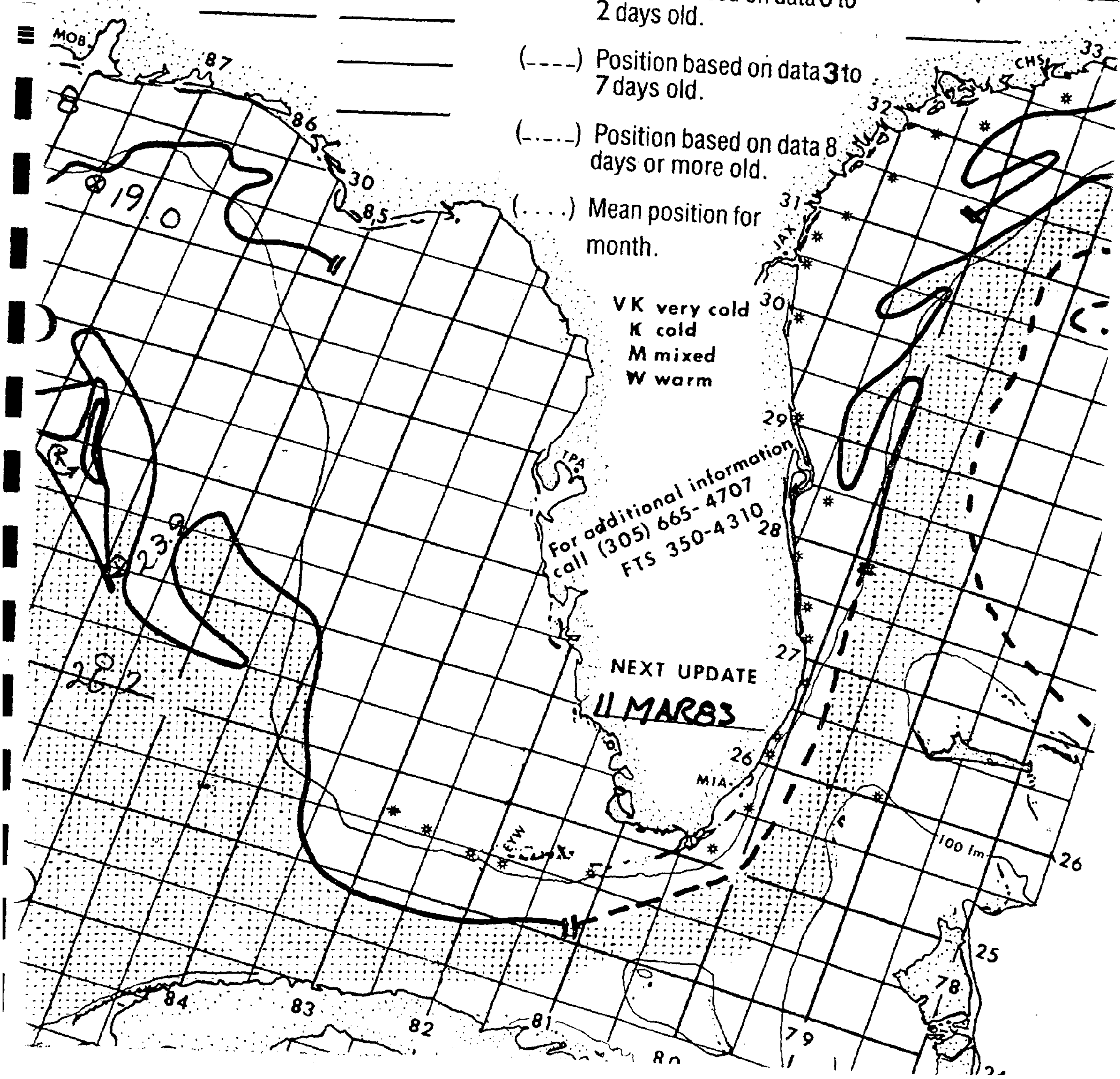
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 11 MAR 1983

230870	249877	261882	270799	2827
265865	253855	253838	320790	3247
239828	240816	244807	364731	378
			375690	3866
			389645	3946

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

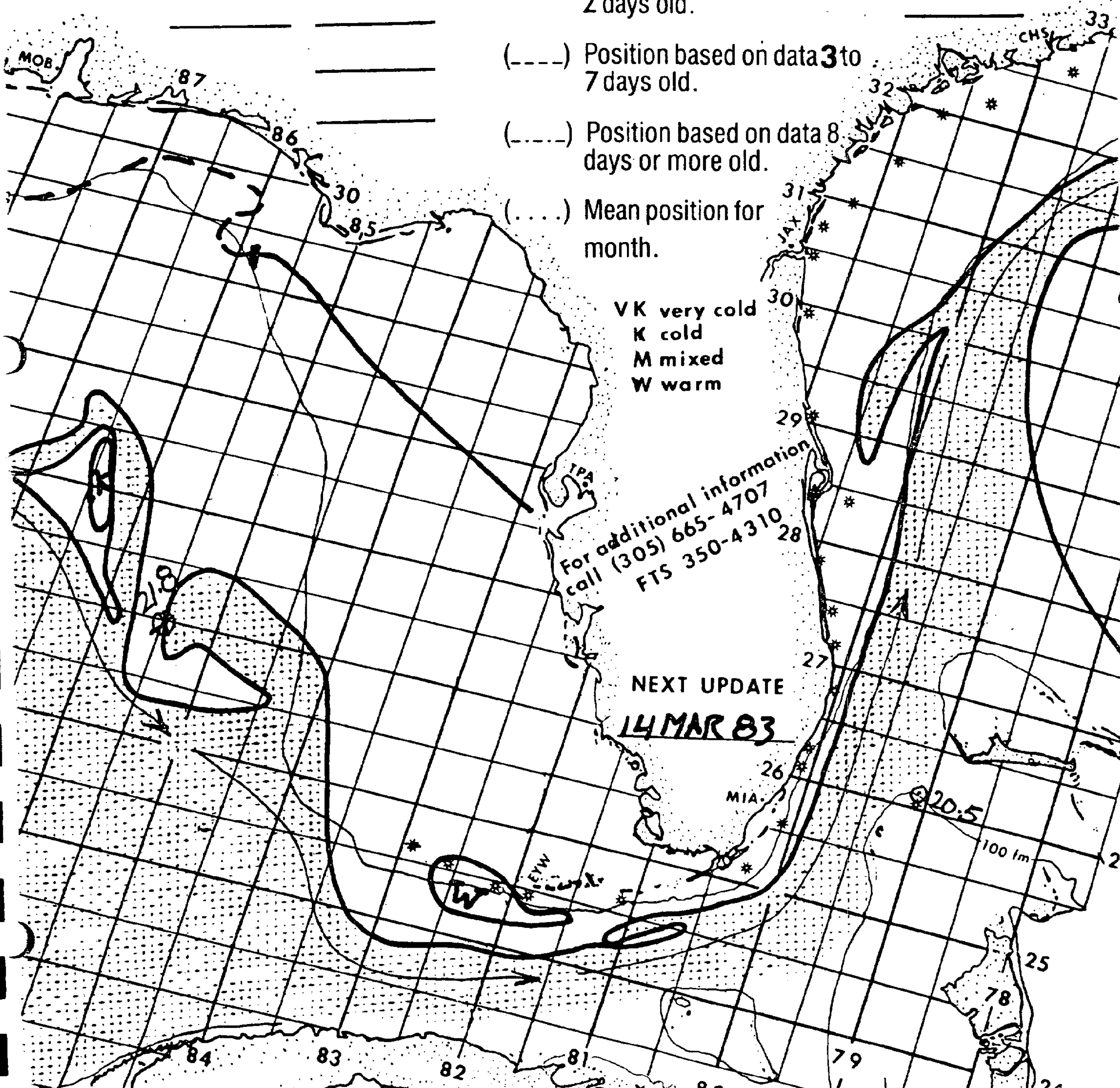
(____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



TEM FLOW CHART #2450 | NOAA Miami SFSS | GULF STREAM

Date: 14 MAR 1983

	226868	235872	250879	270799	285
	270871	265864	256857	324775	333
8	240834	238832	240819	360730	379
9	257798	260799	//	373692	386
				390640	3956

Depicted land should not be used for navigation.

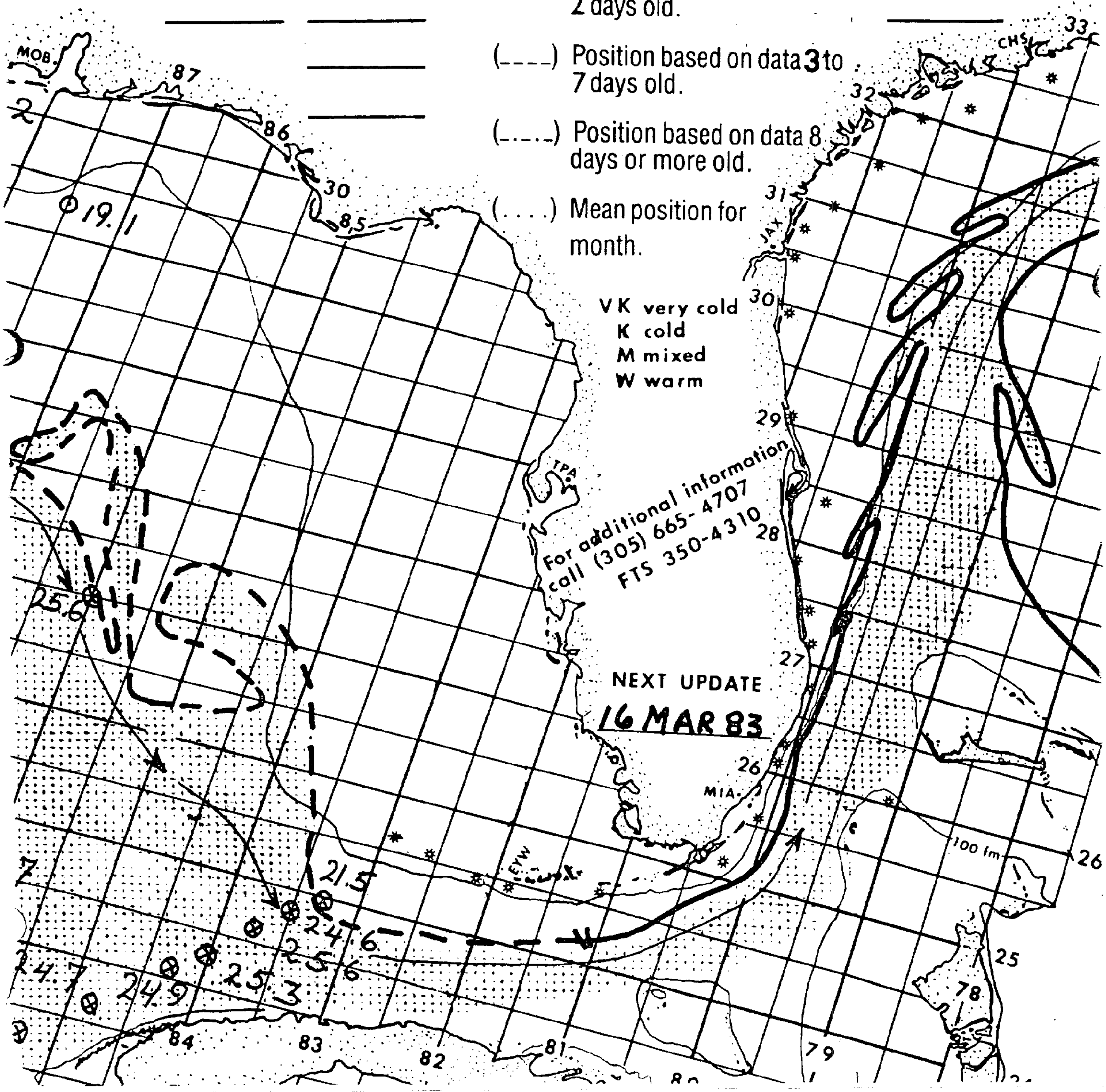
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(——) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(. . . .) Mean position for month.



TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 16 MAR 1983

235869	244876	252879	270799	2857
269870	265864	255856	317791	3227
249836	244835	241832	338763	3417
244810	251800	260799//	358739	3607

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

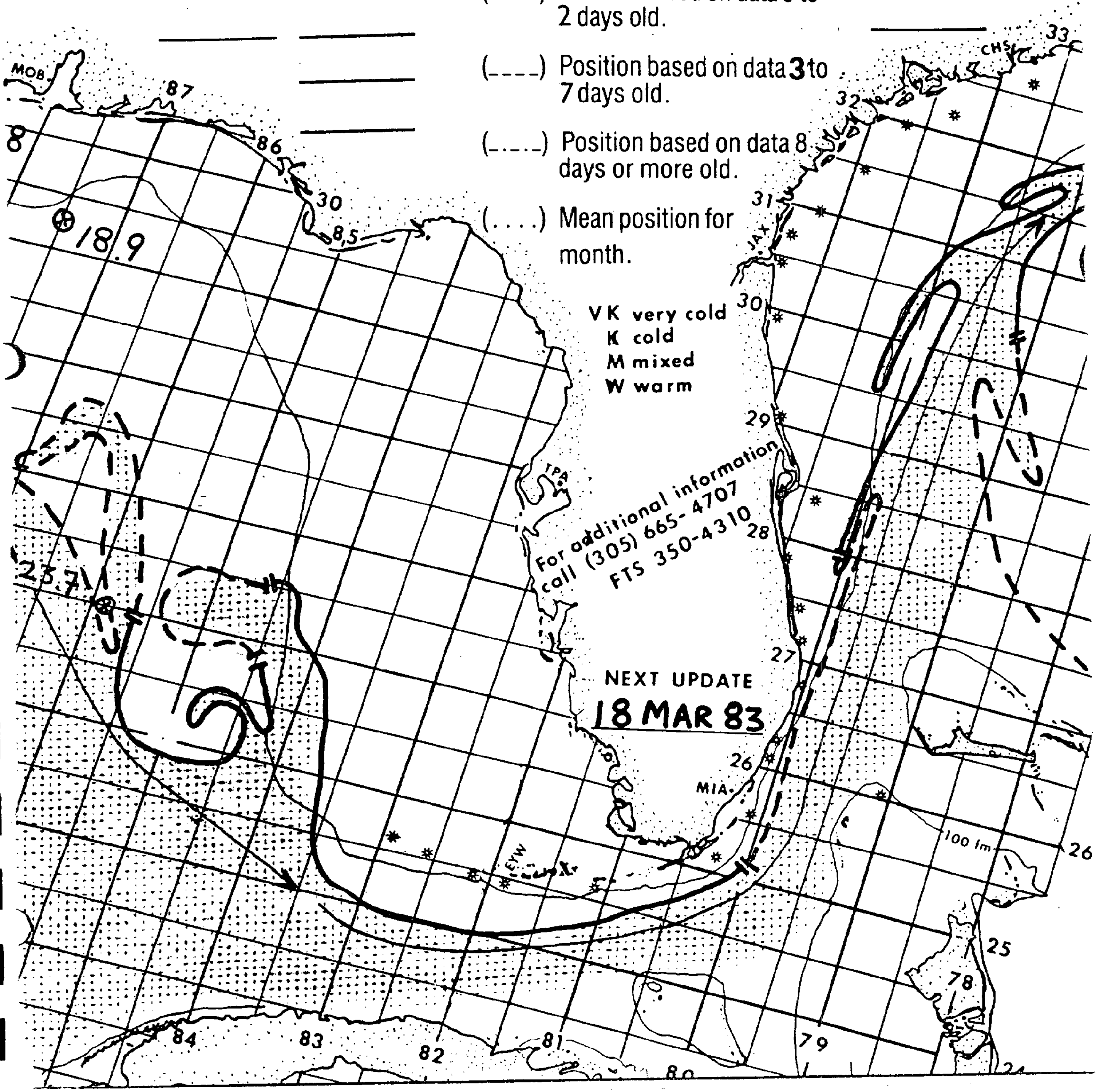
(_____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



EM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 18 MAR 1983

240874	247876	255880
270873	265865	260860
248847	248841	245835
240815	243810	249802

270799	280
325772	3297
360731	3627

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

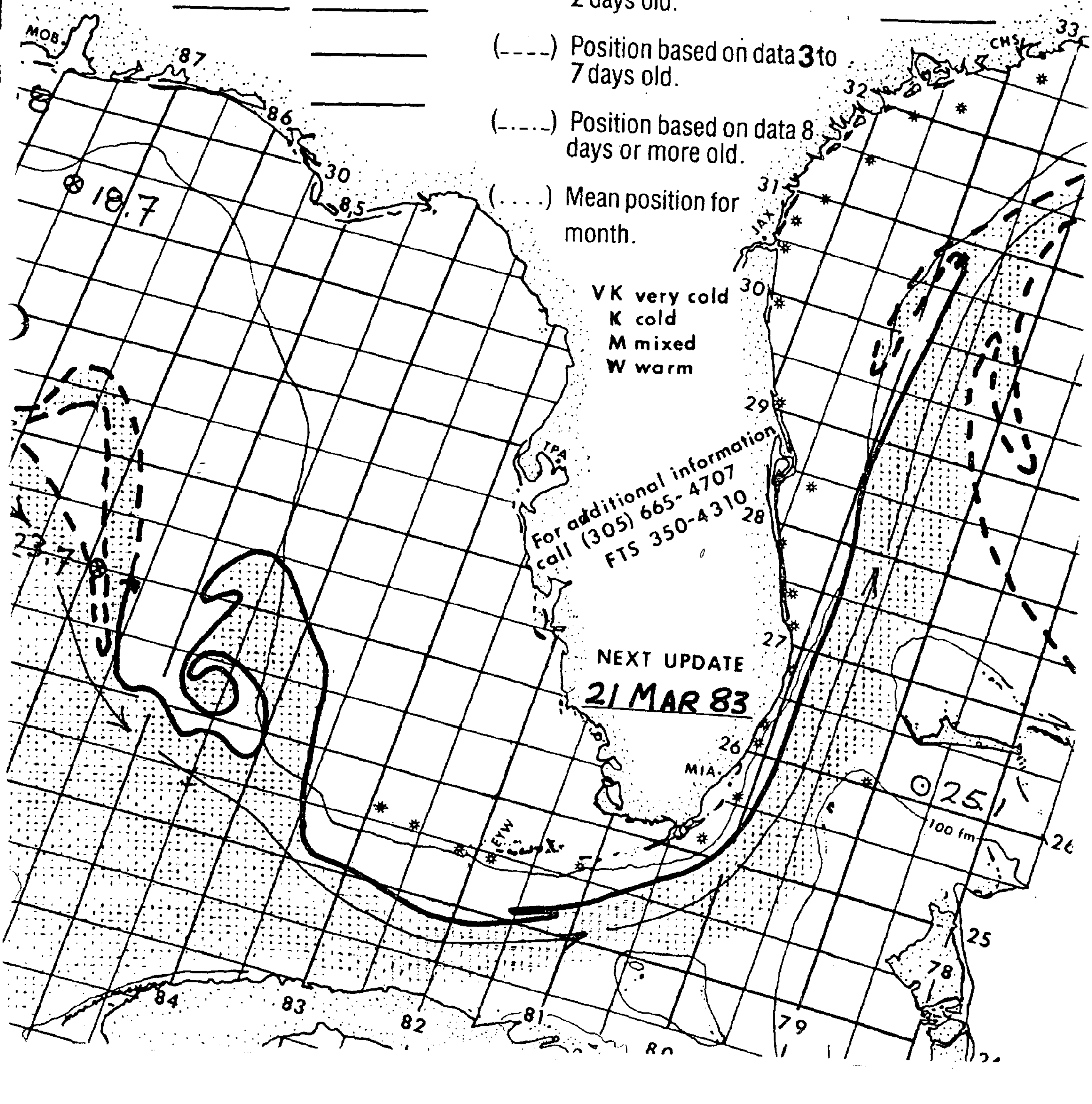
(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm

For additional information call (305) 665-4707 FTS 350-4310

NEXT UPDATE 21 MAR 83



STEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 21 MAR 1983

236874 241875 245876
267885 274875 271870
259857 256858 245855
240831 238825 239816
260800//

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

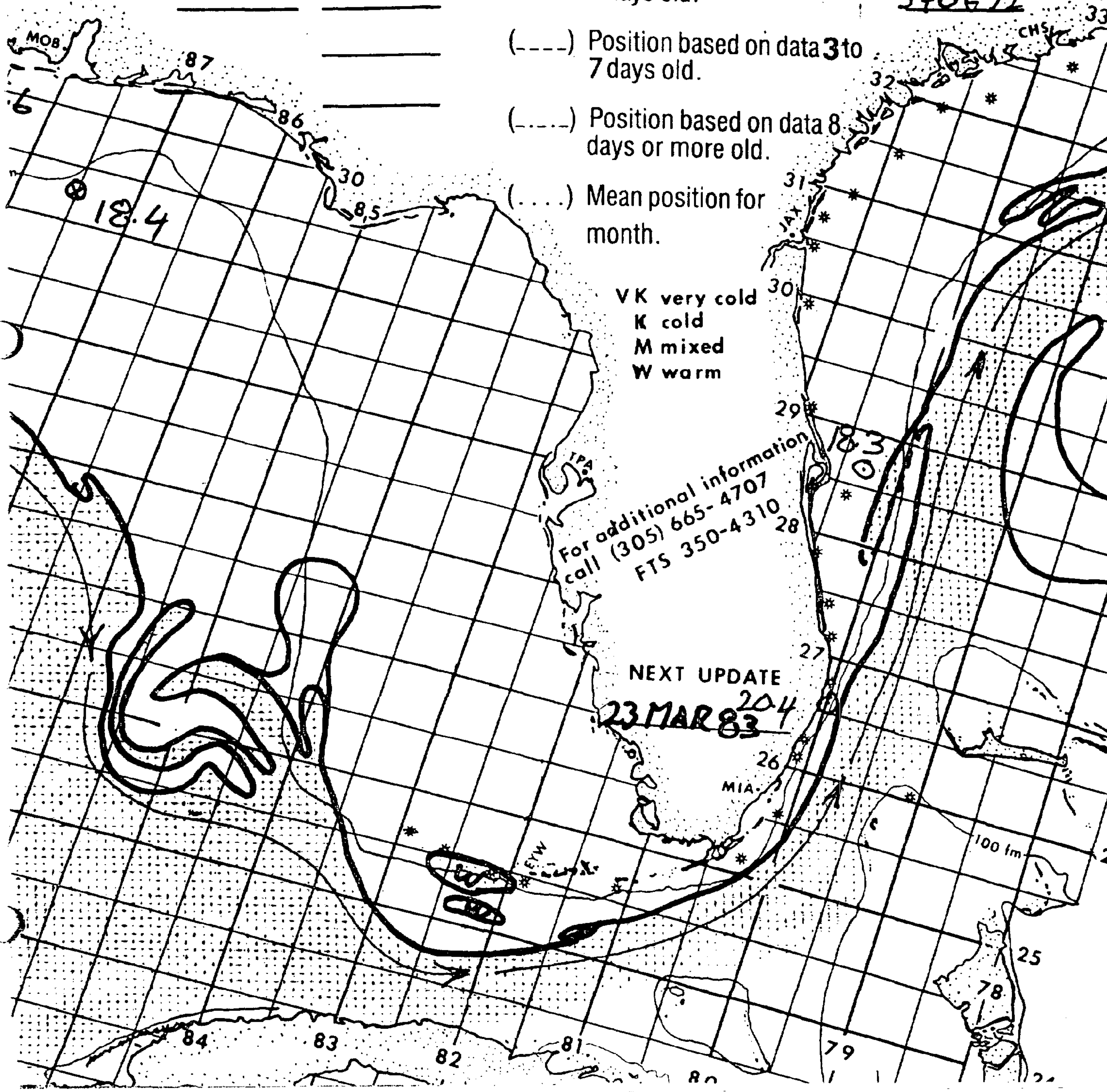
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

270799 273…
305798 3107…
328766 3357…
349749 3507…
365725 3627…
380705 380…
370692 —



TEM FLOW CHART #2450 | NOAA Miami SFSS | GULF STREAM

Date: 23 MAR 1983

236873	240878	244880	270797	273[illegible]
263883	268890	271885	307800	315[illegible]
262856	258855	250856	329770	334[illegible]
248847	248844	244840	350748	354[illegible]
236819	245808	248802	370716	370[illegible]
260798 //			380700	370[illegible]
			372685	—

Depicted land should not be used for navigation.

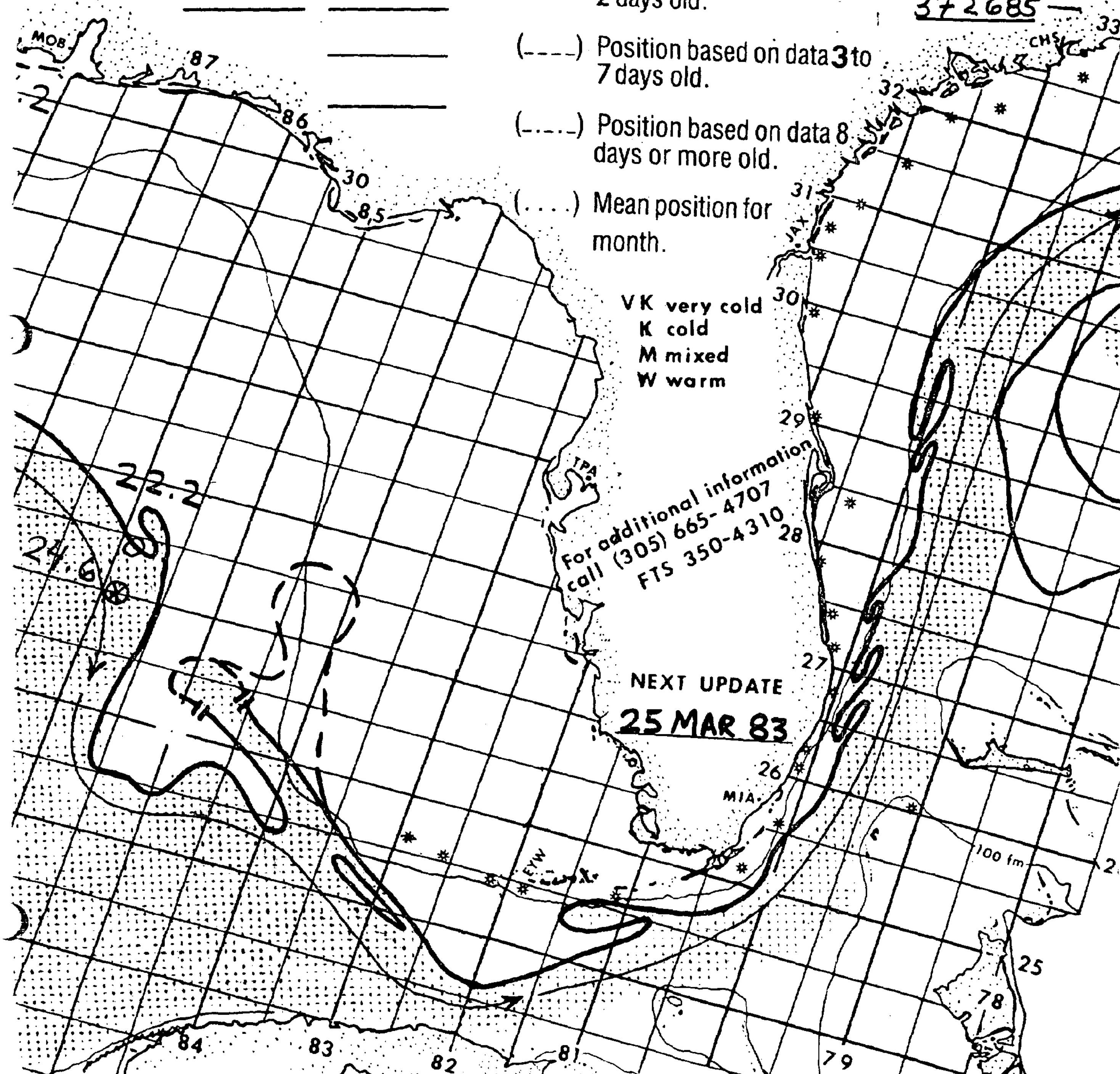
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(-.-.-.) Position based on data 8 days or more old.

(. . . .) Mean position for month.



EM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 25 MAR 1983

240876	247879	251886	270798	29079[illegible]
271886	273878	271868	323780	33176
246856	245851	249840	369719	3707[illegible]
249801	255799	260798//	371684	3886[illegible]
			385640	38963

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

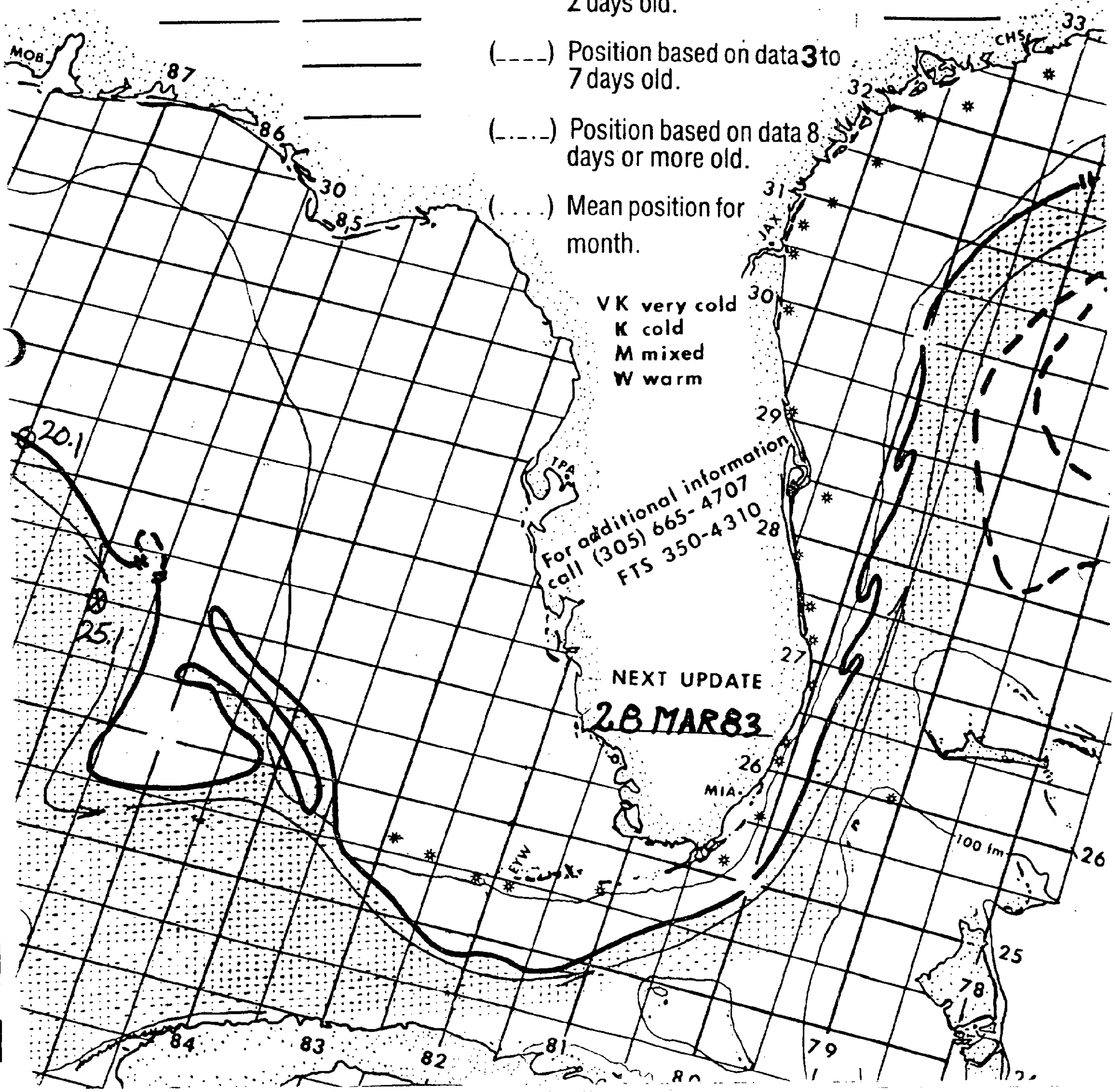
(____) Position based on data 0 to 2 days old.

(_ _ _ _) Position based on data 3 to 7 days old.

(_ . _ . _) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



STEM FLOW CHART "2450 NOAA Miami SFSS GULF STREAM

Date: 28 MAR 1983

3	224867	228872	239875	270798	305
4	258889	268880	270870	332767	3407
5	246857	243856	243854	361729	365
5	241830	238820	238813	375713	374
8	260798			387672	387
				378646	388

Depicted land should not be used for navigation.

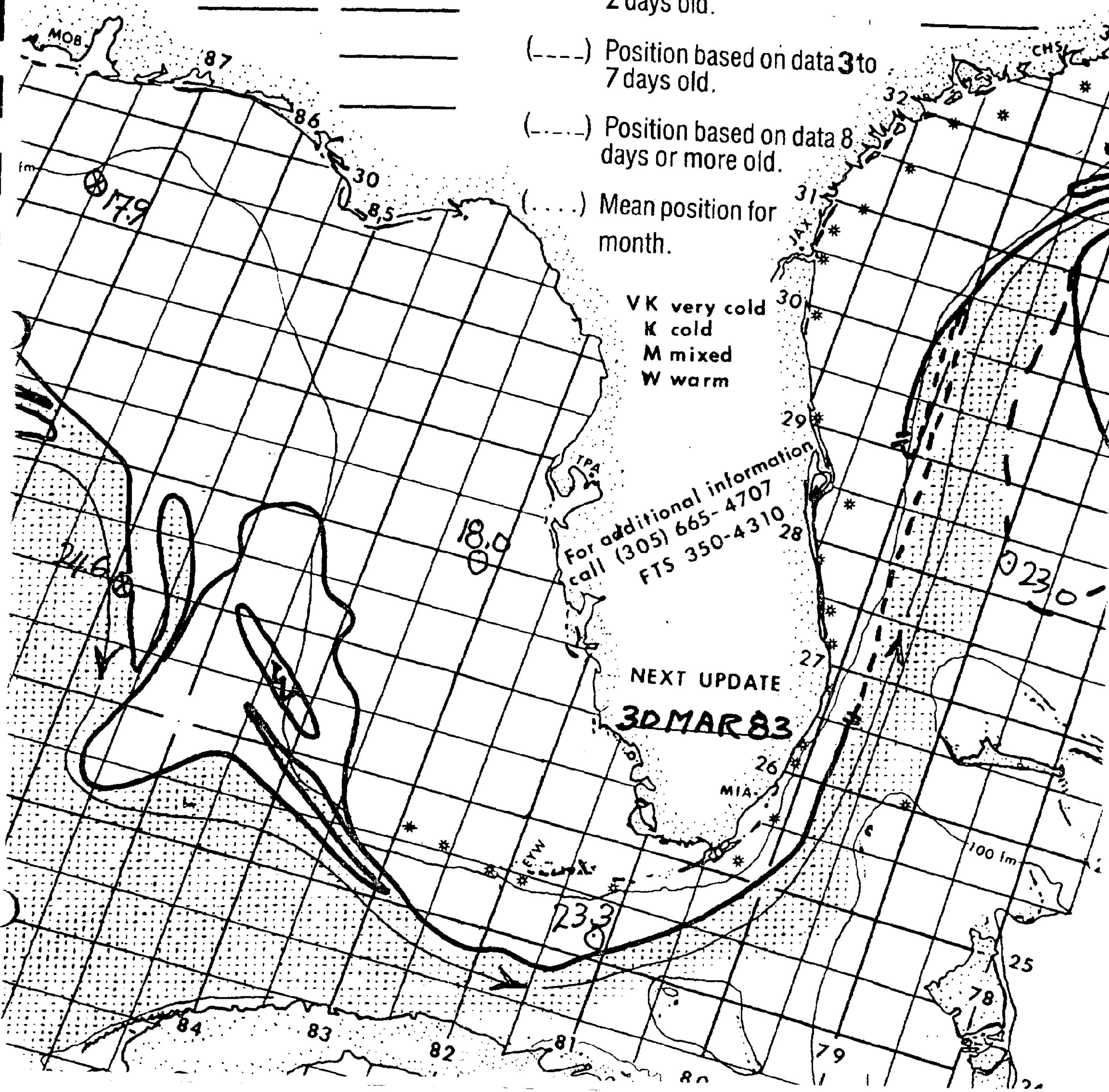
Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

(——) Position based on data 0 to 2 days old.

(----) Position based on data 3 to 7 days old.

(-.-.-) Position based on data 8 days or more old.

(....) Mean position for month.



.TEM FLOW CHART #2450 NOAA Miami SFSS GULF STREAM

Date: 30 MAR 1983

227864	236870	242875
260889	265885	269876
257856	241852	241850
241828	239822	240815
260799//		

270799	285…
328772	3347…
364722	3777…
370680	3776…
387652	3776…
387635//	SM…

Depicted land should not be used for navigation.

Position lines are for the edges of warmer water. The thin streamline is an estimated location for the maximum current. Measured current speeds may be shown.

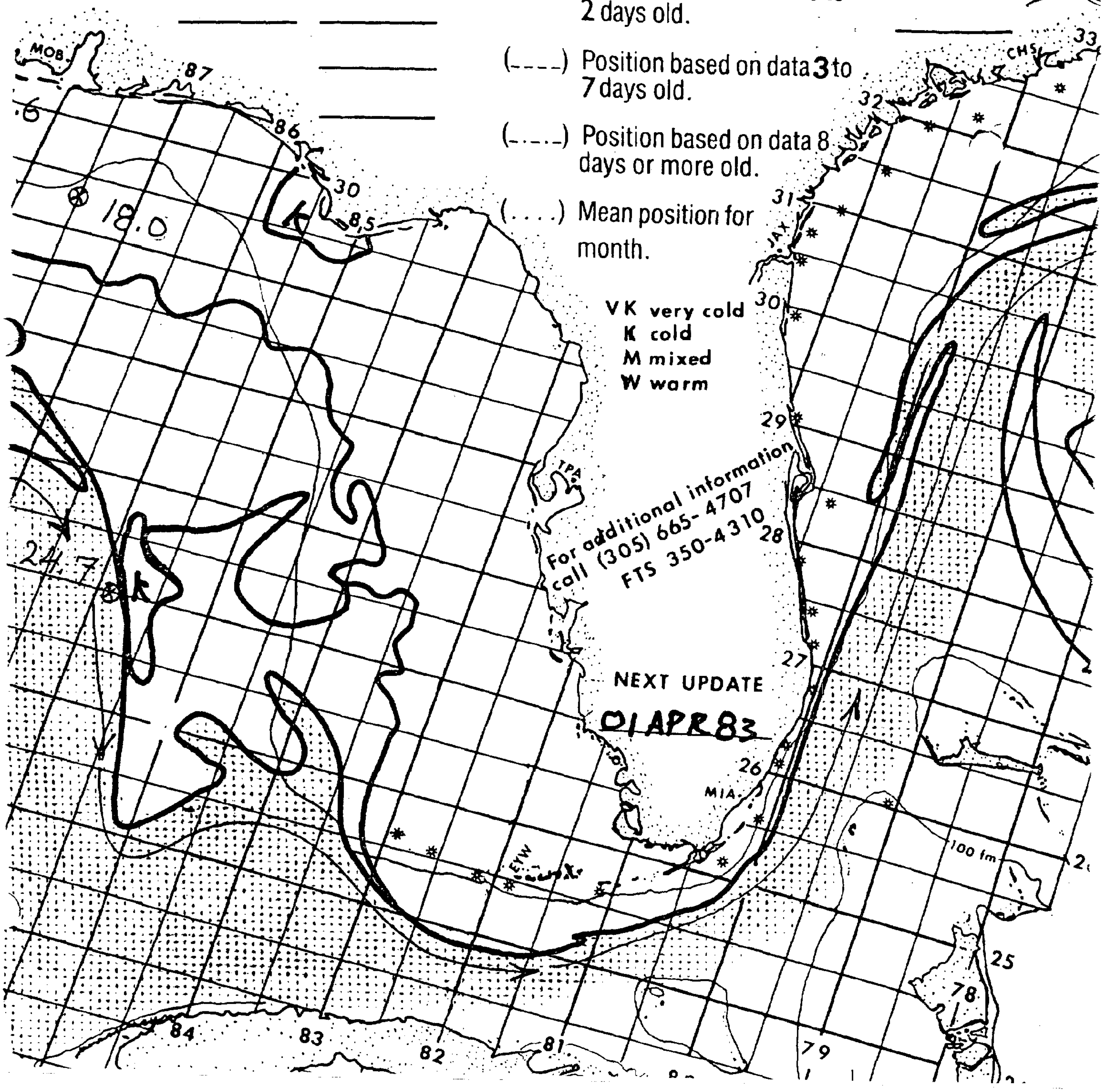
(____) Position based on data 0 to 2 days old.

(- - - -) Position based on data 3 to 7 days old.

(- . - . -) Position based on data 8 days or more old.

(. . . .) Mean position for month.

VK very cold
K cold
M mixed
W warm



6) Discussion of FOTEC Data

From the historical data we expect that there will be variance in the current and temperature on three time scales. Annual cycle time scale variability would require several to ten years of data to resolve. Our much shorter time series of profiles will not resolve these questions although the STACS data from the Palm Beach area will give us a good idea of the variability to expect. Also we can extract a part of the signal from satellite IR which can give us estimates of the position of the Gulf Stream edge and surface temperature which could be used with a current model. At present however our best estimates come from the historical data which suggests a transport variation of about $\pm 3 \times 10^6 m^3 s^{-1}$ which account for about 45% of the current variance. Long term current observations are the only method of accurately estimating these effects at the proposed FOTEC sites. Since the deep water temperatures are quite stable over the long term surface temperatures derived from satellite data are quite satisfactory to estimate the thermal resource. For this purpose the data would need to be worked up on an image by image basis taking into rejecting cloud contaminated data.

The second band of variability is the 2-10 day period fluctuations. These periods are known to be associated with the meanders of the Gulf Stream and include the dynamics of shelf waves and spin off eddies. Had this work been funded on the originally proposed schedule we would have been able to observe two to ten cycles in these period bands by alternating between stations barring an interpretation by hurricane. However late funding forced a winter experiment which was repeatedly interrupted by cold fronts. From the satellite data on 19, 21, and 24

January 1983 we can see that the Gulf Stream edge is south of both stations explaining the relatively moderate currents. On the 19th of January there is an indication of a warm water intrusion from the east at the easternmost station given by cross-section 1 which is confirmed from the in-situ temperature data. These data most likely are explained by the presence of a spin off eddy.

7) Conclusions and Recommendations

From the data above we have a good idea of the variability to be expected at the two possible FOTEC sites near Key West. By comparison of our mean profiles of temperature and velocity with those in Figure 3 we can clearly see that the currents we observed were far from the maximum or minimum currents to be expected at this site although our mean values are close to the longer term mean. The remotely sensed temperature data also shows that during our observation period that the Gulf Stream axis lies consistently south of our anchor stations. The temperature section data also shows the edge of the stream farther south than our anchor stations. However, the remotely sensed temperature suggests that during other periods that the stream lies farther north at times brushing against the Florida keys. Both remote and in-situ temperature data shows the clear presence of spin-off eddies near the FOTEC sites as we would expect from the historical data in Figure 5 and 6.

All of our historical data and the data recorded in this program fall short of the level of coverage required for a thorough engineering study required for the cost effective design of such a costly project as an OTEC plant. What is needed for the surface temperature and temperature gradient information can be extracted from a satellite remote sensing program which concentrates on measuring temperature at the proposed sites and rejects those images which contain significant cloud cover. The current data needed for the design process will be more difficult to obtain. The current meter group at RSMAS can maintain current meter moorings in this region for 6 month deployments. Our past experience tells us that at least one year of data is needed to define the seasonal cycle. However a mooring extending all the way to the surface is not practical for these lengths of time. We must settle for current data up to 150 meters from the surface which will often omit the strongest currents. One possible solution to the near surface current problem would be the use of a CODAR (Coastal Ocean Dynamics Radar) which relies upon remote land based radar transmitters and on site computer analysis to interpret the scattered returns in terms of surface currents. Such a system is now in use in the STACS experiment off Palm Beach on an experimental basis. Since the worst case currents are likely under storm conditions a remote sensing current system may be the only practical solution. Another approach which might work is to use an acoustic Doppler current profiler to measure the currents remotely from bottom mounted acoustic transducers. These systems like the current meters are restricted from measuring the upper 10% of the water column but do give much better spatial resolution than a typical current meter mooring. These acoustic systems are still in the experimental phase of their development but do offer potential savings compared to moorings. Because a potentially vulnerable mooring does not exist, these systems may be more reliable in the long run permitting longer term or even permanent installations with cables to shore for power and signal transmission.

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