OCS Study
MMS 94-0027

Louisiana/Texas Shelf Physical Oceanography Program: Eddy Circulation Study

Annual Report: Year 1

MMS
U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS Study
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Annual Report: Year 1

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EDDY CIRCULATION STUDY

First Annual Report

I. INTRODUCTION

This document describes progress in accomplishing the principal objectives of the Gulf of Mexico Eddy Circulation Study (Minerals Management Service (MMS) Contract 14-35-0001-30633) during the first field year, April 1, 1992 through April 30, 1993. The study is also known as the C component of the Louisiana/Texas Shelf Physical Oceanography Program (LATEX Program). Briefly stated, the study objectives are:

- monitoring and characterizing three classes of mesoscale circulation patterns important in the open sea and slope waters of the northwestern Gulf of Mexico (Tasks C-2, C-3, C-6, C-7);
- providing efficient, centralized logistics support, including Service ARGOS liaison for drifting buoys, air deployed expendable probes, and XBTs for a ship-of-opportunity program (Tasks C-1 through C-6 and C-8);
- disseminating information collected during this study to other investigators on a regular basis (Tasks C-9 through C-12).

Monitoring mesoscale features has been accomplished by a series of seven aerial surveys with AXBTs and AXCPs to examine the instantaneous hydrographic and velocity structures of selected features. Continuous monitoring of features has been done using air-deployed, satellite-tracked drifting buoys (Clearwater Instrumentation, Inc., model LSD2). Satellite altimetry has been used to provide an historical perspective of conditions in the Gulf of Mexico from early 1985 through 1990.

Aerial surveys (including photography) and drifting buoy deployments were executed by an experienced subcontractor, AeroMarine Surveys, Inc., under the direct supervision of an SAIC scientist. Eddy characterization will be accomplished by careful analysis of the data collected in this study along with selected data elements from the other two field components of the program and through synthesis of knowledge gained during this study with what is already known.

SAIC provided centralized storage and shipping of drifting buoys, and air and ship launched expendable probes from a facility in Plano, Texas, operated by Specialty Devices, Inc. The operator of the facility is responsible for checkout of the satellite uplink transmitter in each drifting buoy procured under this program. SAIC has made all necessary Service ARGOS arrangements, fee payments, and provides ongoing liaison with Service ARGOS and the NOAA Office of Global Programs.

Dissemination of quality controlled data and analyzed results has taken place through regular posting on the GULF.MEX bulletin board service of OMNET and through regular interaction among the investigators on this project.

Chapter II presents an overview and chronology of events accomplished under each task of the contract. Chapter III documents progress during the first field year under Tasks C-2, C-3, C-6, C-7, and C-9 in data collection and archiving, results of quality control exercises, data shared with other investigators, analytical methods employed, and standard computer graphics. Appendix A is a microfiche containing data products generated during Year 1.

II. OVERVIEW AND CHRONOLOGY OF INDIVIDUAL TASKS

2.1 Task C-1: Drifting Buoys Provided to Other Contractors

Seventeen drifters "drogued at the surface" were ordered for subsequent distribution: 16 to Texas A&M University (TAMU), prime contractor for the Louisiana/Texas Shelf Circulation and Transport Processes (LATEX A) Study; and one to Louisiana State University (LSU), prime contractor for the Mississippi River Plume Hydrography (LATEX B) Study. Discussions were first conducted among the MMS Contracting Officer's Technical Representative (COTR), SAIC, TAMU, and LSU as to the exact configuration desired for these drifters.

The chosen configuration was a Clearwater Instrumentation, Inc., WOCE/SVP type drifter with a 6x1 m holey sock drogue and approximate 3 m tether such that the bottom of the drogue was at 9 m. A schematic of the drifter is shown in Figure 2.1-1. According to the manufacturer's calculations, this arrangement provided a drogue to drag area ratio of 40:1.

The 17 surface configured drifters were received at the central logistics facility at Specialty Devices, Inc., Plano, Texas, in two shipments on April 14, 1992, and May 29, 1992. By the end of Year 1 all but three of the drifters (two for LATEX A and one for LATEX B) had been shipped. This same facility also accommodated twelve air-deployed drifters described in the following paragraphs. The air deployed drifters were received on April 22 and May 29, 1992 and were shipped to various locations during the year as directed by the Program Manager. Table 2.1-1 shows the disposition of drifters during Year 1.

2.2 Task C-2: Drifting Buoys in Loop Current Eddies

The drifter configuration for this task was a Clearwater Instrumentation, Inc., WOCE/SVP type drifter with a 12x1 m holey sock drogue and approximate 88 m tether such that the bottom of the drogue was at 100 m. The drifter was identical to the surface drifter illustrated in Figure 2.1-1 except the drogue and tether were longer. Each of the six drifters was provided with a small parachute and was packed in 1x1x⅓ m box sealed with water soluble tape. The size of this box necessitated dropping from a small cargo type aircraft equipped with a large side door. The air deployment capability was provide by attaching a small parachute to the cardboard box containing the drifter by means of a nylon web harness which was strapped to the box just before loading in the deployment aircraft. Separation of the parachute from the package was controlled by a pyrotechnic device (cutter) which cut the link between the parachute shrouds and the harness approximately 24 seconds after deployment from the aircraft.

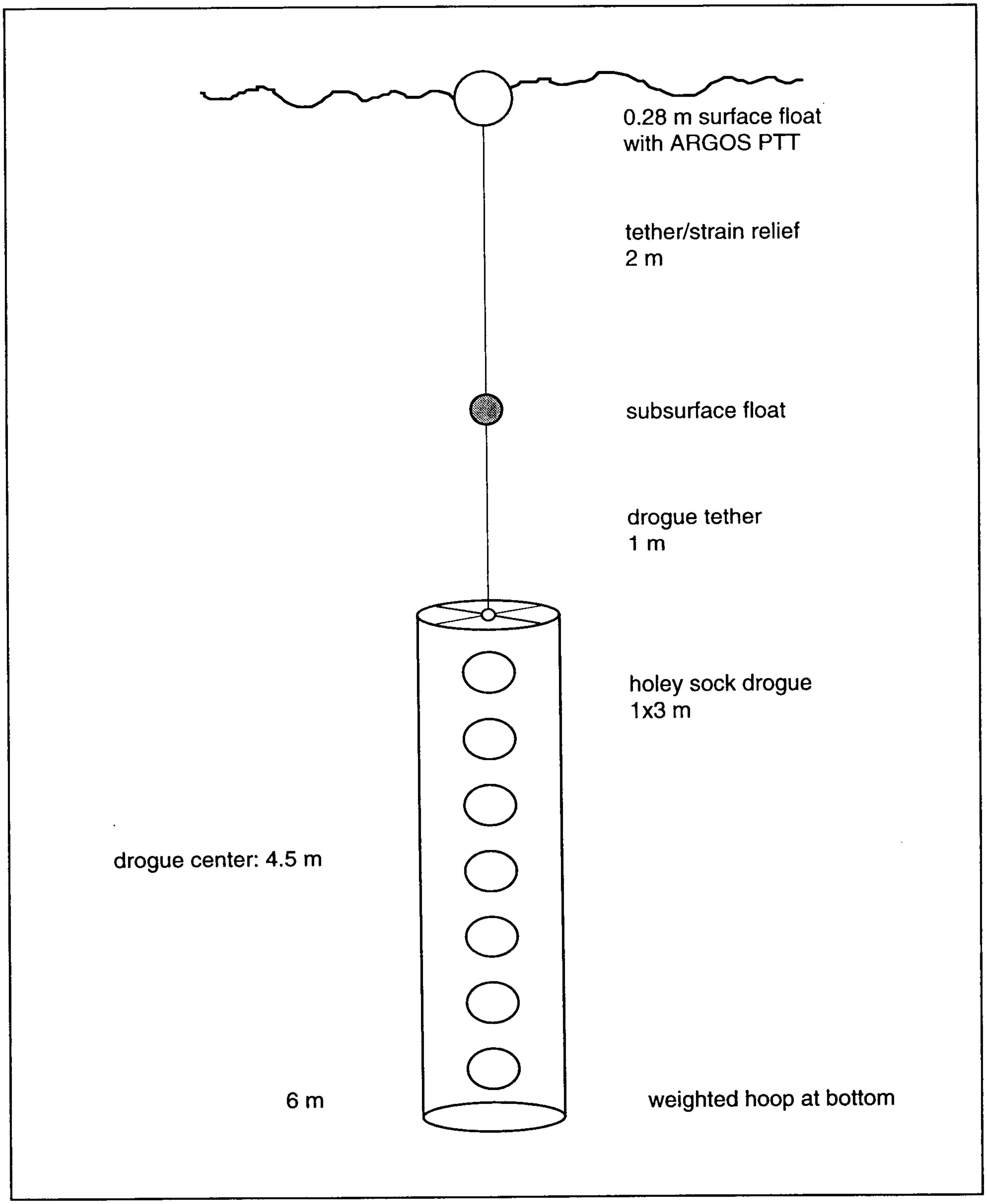

Figure 2.1-1. Schematic of Clearwater Instrumentation, Inc., WOCE/SVP Drifter 'drogued at the surface'.

Table 2.1-1. LATEX Drifter Inventory.

PTT ID	DEPTH (m)	RCVD	SHIPPED	TO	DEPLOY	YEAR END	REMARKS/PERFORMANCE
2445	200	04/22/92					
2446	6	04/14/92	04/20/92	TAMU	08/03/92	off	Recover 8/13/92; redeploy 10/8/92, fail 10/9/92
2447	6	04/14/92	07/22/92	TAMU	08/04/92	off	Data end 2/9/93 in Eddy V
2448	100	04/22/92					
2449	100	04/22/92	10/16/92	GYRE	10/30/92	on	Eddy U
2450	200	04/22/92					
2451	50	04/22/92	12/30/92	Galveston	01/09/93	on	Eddy V picked up by VN fishing vessel
3581	50	04/22/92	12/30/92	Galveston	01/09/93	off	Eddy V data end 1/12/93
3582	6	04/14/92	04/20/92	TAMU	08/03/92	off	Data end 9/4/92; recover 11/20/92 minus drogue
3583	6	04/14/92	04/20/92	TAMU	08/03/92	off	Recover 8/9/92; redeploy 11/8/92: not ON
3584	6	09/21/92		TAMU			
3585	6	04/14/92	04/20/92	TAMU	11/12/92	off	Not ON when deployed
6931	6	05/29/92	09/11/92	TAMU	11/12/92	off	Destroyed during deployment
6932	6	05/29/92	09/11/92	TAMU	11/08/92	off	Data end 12/2/92
6933	6	05/29/92	09/11/92	TAMU	11/10/92	off	Data end 1/8/93
6934	6	05/29/92	09/11/92	TAMU	11/10/92	on	Picked up UNK 11/15/92
6935	6	05/29/92	01/05/93	TAMU			
6936	6	05/29/92	01/05/93	TAMU			
6937	6	05/29/92	01/05/93	TAMU			
6938	6	05/29/92	01/05/93	TAMU			
6939	6	05/29/92	01/05/93	TAMU			
6940	6	05/29/92		TAMU			
6941	6	05/29/92		LSU			
7832	50	05/29/92	12/30/92	Galveston	01/09/93	off	Data end 1/12/93
7833	50	05/29/92					
7834	50	05/29/92					
7835	50	05/29/92	12/30/92	Galveston	01/09/93	on	Exit GOM 6/93; OFF 6/29/93
7836	100	05/29/92	10/08/92	Lafayette	10/12/92	off	No data - parachute failure
7837	200	05/29/92	07/30/92	Lafayette	08/13/92	off	Data end 9/30/92 - parachute failure/deployment

Drifter 7836 was air-deployed in Loop Current Eddy U on October 12, 1993, and failed almost immediately. The parachute detached from this unit almost immediately after being dropped from the aircraft. Drifter 2449 was deployed in Eddy V on October 30, 1992 from R/V GYRE by Dr. Douglas Biggs. This unit was still operating at the end of Year 1.

2.3 Task C-3: Drifting Buoys in Other Meso-Scale Features

Two different air-deployable configurations of the Clearwater Instrumentation, Inc., WOCE/SVP type drifter were chosen: one set of four with the bottom of the drogue at 200 m for deployment in slope eddies, and one set of 10 with the bottom of the drogue at 50 m for deployment in squirts. Except for drogue tether length, these drifters were identical to the Loop Current eddy drifters. Drifter 7837 was air-deployed in a small upper slope cyclone on August 13, 1992 and continued to operate until September 30, 1992. The parachute shroud cutter appeared to activate early and the package hit the water hard.

2.4 Task C-4: Returned Buoys

No buoys were recovered after deployment and returned to the manufacturer for refurbishment.

2.5 Task C-5: Buoy Quality Control

Each of the 29 drifters received by Specialty Devices, Inc., was turned ON, on receipt and again prior to shipment, and checked with a Telonics TSUR-B Satellite Uplink Receiver/Analyzer System to verify correct operation of the ARGOS platform terminal transmitter (PTT). Each unit's operation was also verified through receipt of the signal through Service ARGOS. No unit failed these tests.

Drifter 3584 was shipped to TAMU in April 1992, where it appeared in subsequent testing to be operating erratically in that the fixes determined through Service ARGOS were less accurate and stable than other similar units. This unit was returned to Clearwater Instrumentation, Inc., for examination and correction of defects, if any were found. No defects were detected and the unit was returned to TAMU.

2.6 Task C-6: Aerial Surveys

Five types of aerial survey were proposed to accomplish the objectives of the LATEX C program: Slope Surveys, Slope Eddy Surveys, Loop Current Eddy Surveys, Squirts and Jets Surveys, and Squirts and Jets Locator Surveys. These survey types are described below:

- Slope Survey - made over two days with 32 airborne expendable bathythermographs (AXBT) on a regular hydrographic grid of five or six lines covering a portion of the upper slope between the 200 m and 2000 m isobaths. Three surveys were planned during each program year. The area covered in Year 1 was between 90°30'W and 94°00'W.

- Slope Eddy Location Survey - made with 16 AXBTs and five airborne expendable current profilers (AXCP) on an as required basis if a slope eddy was discovered during a Slope Survey. Each survey was to be followed by aerial deployment of a drifter with a drogue at 200 m.

- Loop Current Eddy Survey - made with 16 AXBTs on an as required basis whenever the center of a Loop Current eddy was determined to have reached 90°W after separating from the Loop Current. Each survey was to be followed by aerial deployment of a drifter with a drogue at 100 m.

- Squirts and Jets Survey - made over two days with 32 AXBTs and nine AXCPs whenever a 'squirt' was detected in satellite imagery. This survey was to be followed by a Squirts and Jets Location Survey (16 AXBTs) and deployment of two drifters with drogues at 50 m. A sequence of two of these survey sets, separated by about one week, was planned in Year 1.

- Squirts and Jets Location Survey - made in one day with 16 AXBTs to determine the best locations in a 'squirt' for subsequent deployment of two drifters with drogues at 50 m.

Seven aerial surveys were actually conducted during Year 1: three Slope Surveys, one Slope Eddy Survey, two Loop Current Eddy Surveys, and a modified Squirts and Jets Survey/Squirts and Jets Location Survey. Table 2.6-1 shows the surveys in sequence along with the types of probes used in each survey and the number of probes in each survey which returned valid data. Reliability of AXBTs was 99.5% and of AXCPs was 80.0%.

All surveys, except the modified Squirts and Jets Survey which was flown out of Galveston, Texas, were conducted from the Paul Fournet Air Services facility at Lafayette Regional Airport in Lafayette, Louisiana. The support provided by this fixed base operator was exceptional and included shipping and receiving activities before each survey and storage of materials, at no cost to the program.

2.7 Task C-7: Altimetry

The goal of this task, which is being carried out by Drs. George Born and Robert Leben at Colorado Center for Astrodynamics Research

Table 2.6-1. Aerial Survey Dates and Probe Usage

Survey	Type	Dates	AXBT		AXCP		Drifters	Remarks
			used	good	used	good		
F01	Slope	5/5/92	34	34	-	-		
F02	Slope	8/6/92	35	35	-	-		
F03	Slope Eddy	8/10/92	17	17	5	4	7837	
F04	LCE	10/11/92	16	16	-	-	7836,2449	Eddy U
F05	LCE	12/18/92	16	16	-	-		Eddy V
F06	Squirt	1/4/93	44	40	10	9	2451,3581 7832,7837	Eddy V
F07	Slope	1/21/93	35	35	-	-		

(CCAR) at the University of Colorado, is to use all publicly available U.S. Navy Geodetic Satellite (GEOSAT) data to provide an altimeter climatology consisting of the following elements:

- charts of the mean sea surface and mean slope;
- charts of sea surface topographic variability and slope variability for each year and season;
- charts of sea surface topography anomalies for each exact repeat cycle (ERC);
- charts of eddy paths, eddy size and shape, eddy decay and Loop Current penetration derived form the above; and
- wave height and wind speed analyses.

Work progressed during Year 1 on the required GEOSAT Geodetic (GM) and Exact Repeat (ERM) mission data processing. The GM analysis with the NOAA computed crossovers was essentially completed. Orbit error corrections were applied and an initial optimal interpolation of the sea surface height anomaly fields was performed to check CCAR software for tracking Loop Current eddies. This software allows determination of individual eddy trajectories, amplitudes, translation speeds and physical dimensions. We have also performed an initial examination of the wind speed and wave height data included on the crossover archive. Toward the end of Year 1 CCAR received a crossover data set from Naval Oceanographic Office (Bill Rankine, personal communication), which used a more appropriate land mask for the Gulf of Mexico and has data extending all the way to the coast, unlike the NOAA crossovers which were edited using a one degree land mask. Discussion was underway at the end of Year 1 to determine how best to use this data set to augment the NOAA crossover analysis.

2.8 Task C-8: Ships-of-Opportunity

Support of the Ships-of Opportunity (SOOP) program during Year 1 involved procurement of 28 cases of T-7 expendable bathythermograph (XBT) probes from Sparton of Canada, and provision of varying number of probes, in case lots, to investigators designated by the MMS Contracting Officer's Technical Representative (COTR). One HP-85/Sippican Mk-9 Launch System and seven cases of XBTs were provided to Dr. Doug Biggs, at TAMU for use during various non-LATEX A cruises, four cases were provided to a NOAA sponsored program, five cases were provided to Dr. Giulietta Fargion and the MMS-funded Gulf Cetacean Program at the TAMU Galveston campus, and two cases were provided to the LATEX A program to augment data collection during a quarterly hydrographic survey.

2.9 Task C-9: Data Quality Control

The goals of this task are to eliminate spurious or doubtful vales in the data sets and to correct, where possible, values affected by identifiable and quantifiable sources of bias. Data collected or processed comprise three basic data types:

- Hydrographic Profile Data (XBTs/AXBTs/AXCPs),
- Lagrangian Data (Drifting Buoys), and
- Remotely Sensed Data (Altimetry).

Hydrographic profile data from AXBTs, AXCPs and drifter data are processed by SAIC, while quality control of altimetry data is performed by CCAR. Data from XBTs distributed under the SOOP Program are processed by the individuals receiving the probes.

Initial quality control of AXBTs and AXCPs occurred in the field and involved aural evaluation when the probe was dropped, to ensure 'normal' operation, and substantial effort to provide duplicate copies of the raw data on nine-track analog tape and on digital audio cassette tape. As noted in Section 2.6, data return from AXBTs was 97.9%, as the result of four data losses in 195 drops. Only one of these was an outright failure of the instrument while the remaining three were apparently result of high powered radar transmissions in the drop area. Similarly, data return from AXCPs was 80.0%, based on three instrument failures in 15 drops. Final quality assurance/quality control (QA/QC) of these data is described in Section 3.9.

2.10 Task C-10: Analyses and Reports

There was no activity under this task in Year 1.

2.11 Task C-11: Information Transfer

This task has included posting to the GULF.MEX Electronic Bulletin Board on OMNET of the following types of messages:

- drifter tracks on a weekly basis, whenever a drifter has been operational,
- cruise plans and reports before and after each set of surveys,
- inflection points from AXBTs after each aerial survey, and
- program schedule changes.

2.12 Task C-12: Government Furnished Equipment/Capital Equipment

There has been no activity under this task, which is designated for the refurbishment and return to MMS of government owned property at the end of the project.

III. DETAILS OF DATA COLLECTION AND ANALYSIS

3.1 Aerial Surveys and Drifting Buoy Deployments

Throughout the following discussion reference is made to scheduled activities even in the case of clearly event driven activities like Loop Current Eddy Surveys. The schedule was developed initially as a means of cost estimating and as a means of keeping the scientific community informed of forthcoming events in case cooperative ventures could be developed. The schedule was continually refined and updated based on occurrence of various events and on recommendations of the LATEX Science Advisory Panel or individual members of the panel.

Each survey event was identified in the schedule, and in the following discussions, by a designator which noted it as an aircraft based survey (F), a two digit sequence number, and a five character nickname. Thus the first survey conducted was identified as F01SLOPE. This same identifier is used for all data files.

The plan for each survey flight included aerial photography using a 70 mm format camera and black and white film, with emphasis on fronts. After evaluating the results of the first series of 63 photographs, taken during the first Slope Survey, it was decided that the altitude requirement (~3,000 m) for useful photographs was incompatible with safety requirements imposed by dropping expendable probes from an aircraft. An opportunity for providing the photographs was developed during the last months of Year 1 and carried out successfully in May 1993.

3.1.1 Slope Surveys

Three Slope Surveys were scheduled during Year 1 at time to approximately coincide with the quarterly hydrographic surveys made on the shelf by TAMU in the LATEX A study. The 'missing' Slope Survey was staggered over the three years of field work so that no one season would be consistently unsampled. The three planned surveys were conducted as scheduled in early May and early August 1992 and early February 1993. The original grid planned for Year 1 is shown in Figure 3.1-1. This original plan was adjusted slightly to make the survey line mesh better with the LATEX A shelf surveys and to make an AXBT drops over the inverted echo sounders at 27°07.02'N 92°00.00'W (LATEX A Mooring Station 42) and 25°32.52'N 91°59.99'W (LATEX A Mooring Station 43). A Slope Eddy Location Survey was also scheduled in August and fortuitously a small cyclone was detected in the Slope Survey area.

Slope Survey 1 (F01SLOPE)

The first Slope Survey (F01SLOPE) was conducted May 6-8, 1992 as shown in Figure 3.1-2. The survey was flown in three legs with

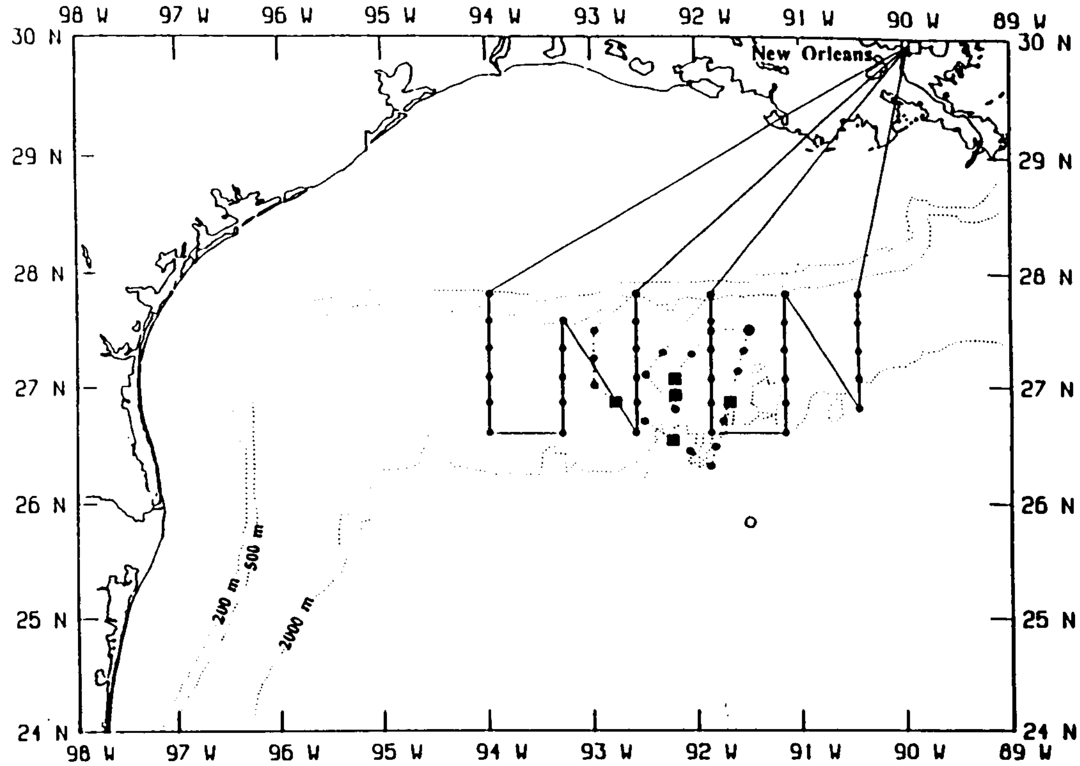

Figure 3.1-1. Plan for Year 1 Slope Surveys. AXBT stations are shown as small dots, AXCPs as solid squares, and IES as open circles. A schematic Slope Eddy Location Survey is nested within the Slope Survey grid.

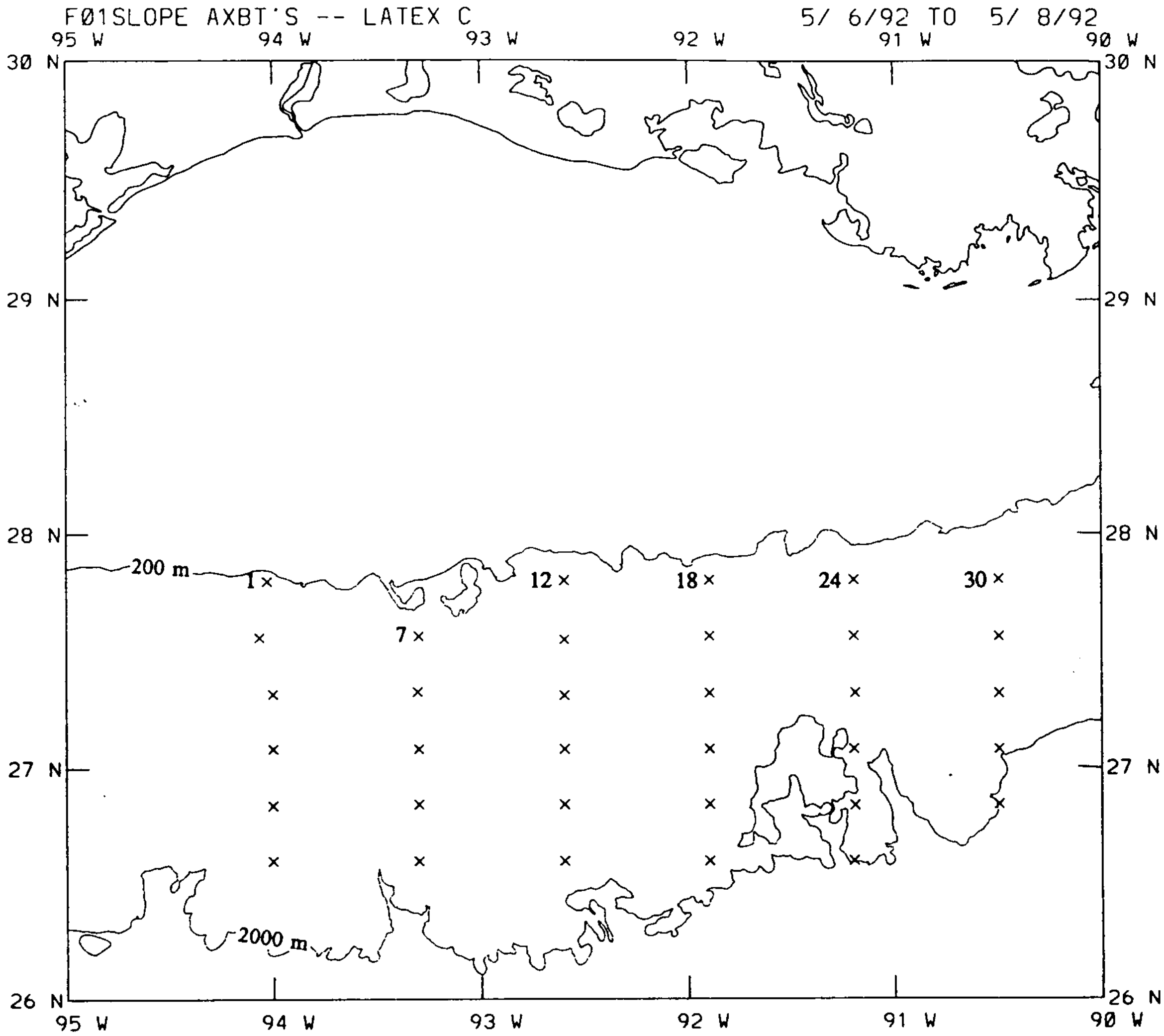

Figure 3.1-2. Station plot for survey F01SLOPE.

aerial photography completed on a fourth day devoted to refining survey plans and buoy deployment procedures. As this was the first survey event of the LATEX C study, considerable time was spent developing and refining all the necessary procedures, including determining aircraft load plans and alternate procedures.

Figure 3.1-3 plots the depth of the 8°C isotherm and shows a small cyclone near the center of the survey. Figure 3.1-4 shows the thermal structure in the upper 800 m along a section through the cyclone.

Slope Survey 2 (F02SLOPE and F03SEDDY)

The second Slope Survey (F02SLOPE) was conducted August 7-9, 1992 as shown in Figure 3.1-5. The cyclone detected in the center of the survey area during the first Slope Survey was detected in the southwest corner of the area in this survey. Figure 3.1-6 shows the depth of the 8°C determined from AXBT data. Similar plots of the 20°C and 15°C isotherms reveal a similar, though weaker, structure. Based on a quicklook at these data late on August 9, the plan shown in Figure 3.1-7 was developed for a eddy location survey (F03SEDDY) to be made on August 10 using 17 AXBTs and five AXCPs, and to be flown in two legs: afternoon of August 10 and morning of August 11. Weather caused the second leg to be flown on the afternoon of August 11. Evaluation of these data in the field was made to develop a drifter deployment location. Figure 3.1-8 shows the depth of the 8°C isotherm from AXBT data. Temperature data from the four (out of five) AXCPs which operated correctly were not available in the field.

Drifter 7837 was deployed at 36°50.4'N 93°29.2'W at 1134 CDT on August 13, 1992. The parachute shroud cutter appeared to operate prematurely and the launch container hit the water flat and fast. Drifter 7837 provided valuable data on the progress of the small cyclone until September 30, 1992 when the drifter abruptly ceased transmitting. The smoothed track of drifter 7837 is shown in Figure 3.1-9.

Slope Survey 3 (F07SLOPE)

The third Slope Survey (F07SLOPE) was completed in two legs on January 21 and 22, 1993, as shown in Figure 3.1-10. Figure 3.1-11 shows the depth of the 20°C isotherm. The edge of Eddy V is detectable along the western edge of the area in Figure 3.1-11, while a more complex structure is observed in Figure 3.1-12 which shows the depth of the 8°C isotherm. Figures 3.1-13 and 3.1-14 show the 20°C and 8°C isotherms, respectively, determined from AXBT data from the Squirts and Jets Survey (F06) and the third Slope Survey.

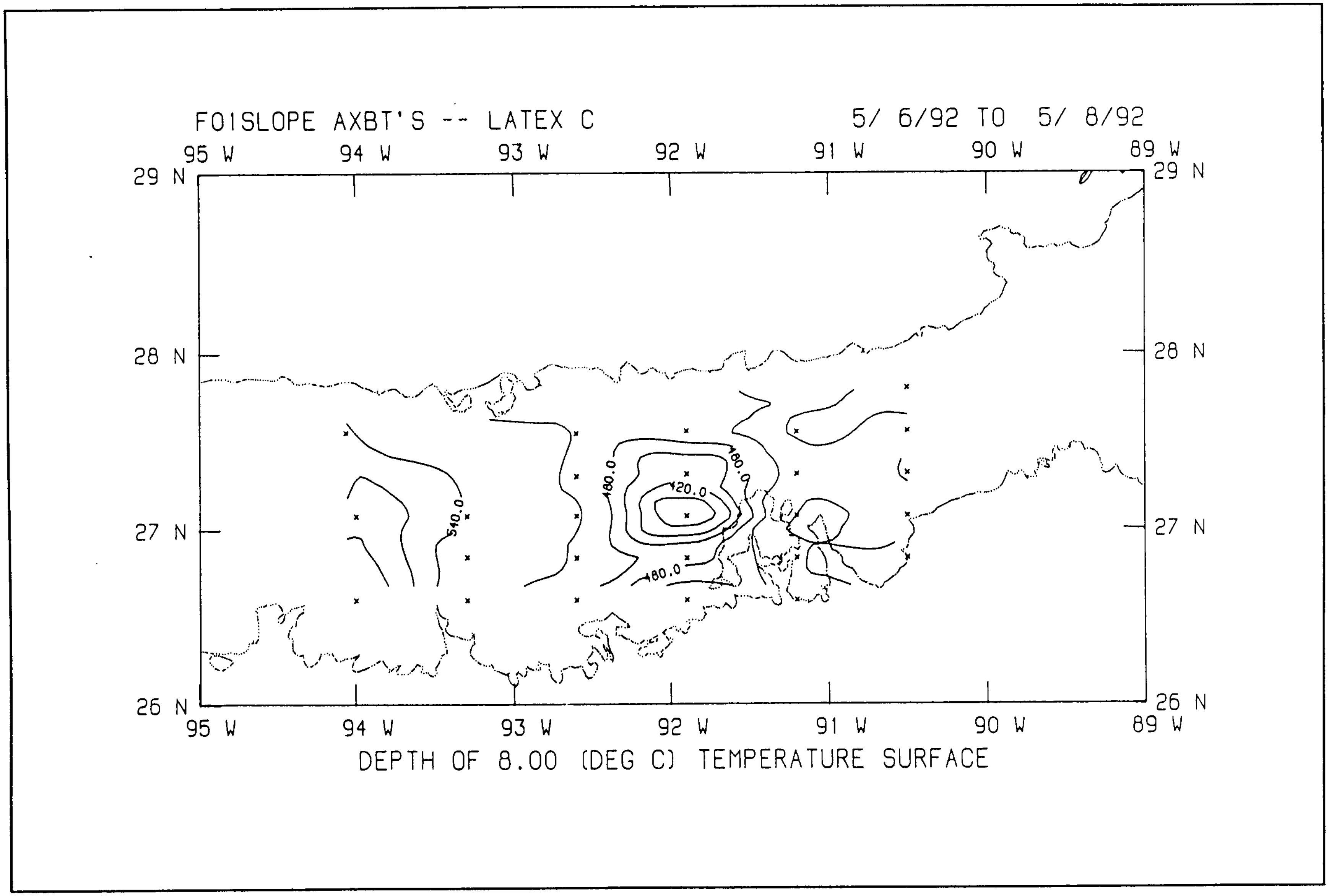

Figure 3.1-3. Depth of 8°C isotherm from F01SLOPE AXBT data.

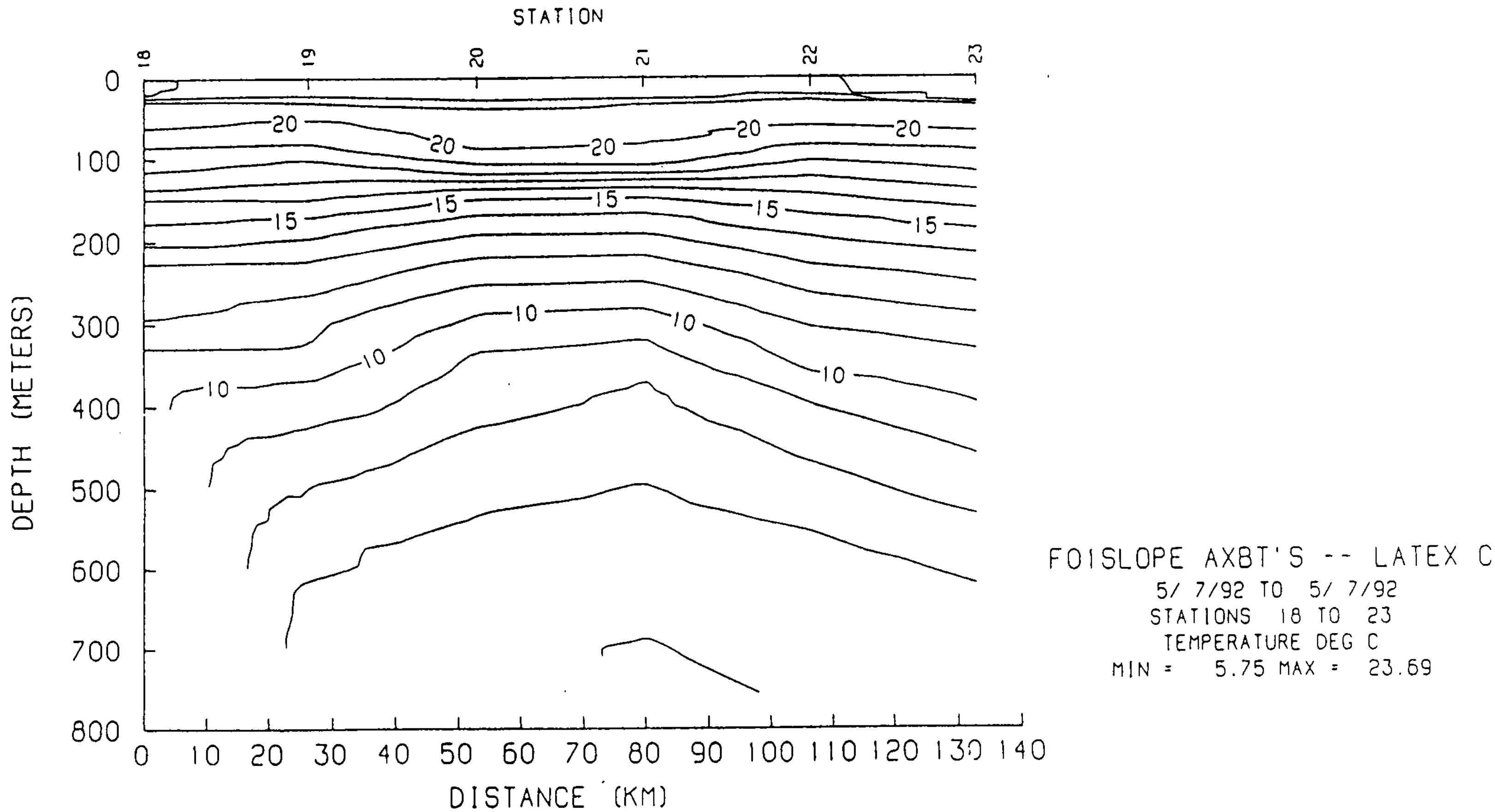

Figure 3.1-4. North-south section through F01SLOPE stations 18-23 to 800 m showing domed isotherms in the small cyclone.

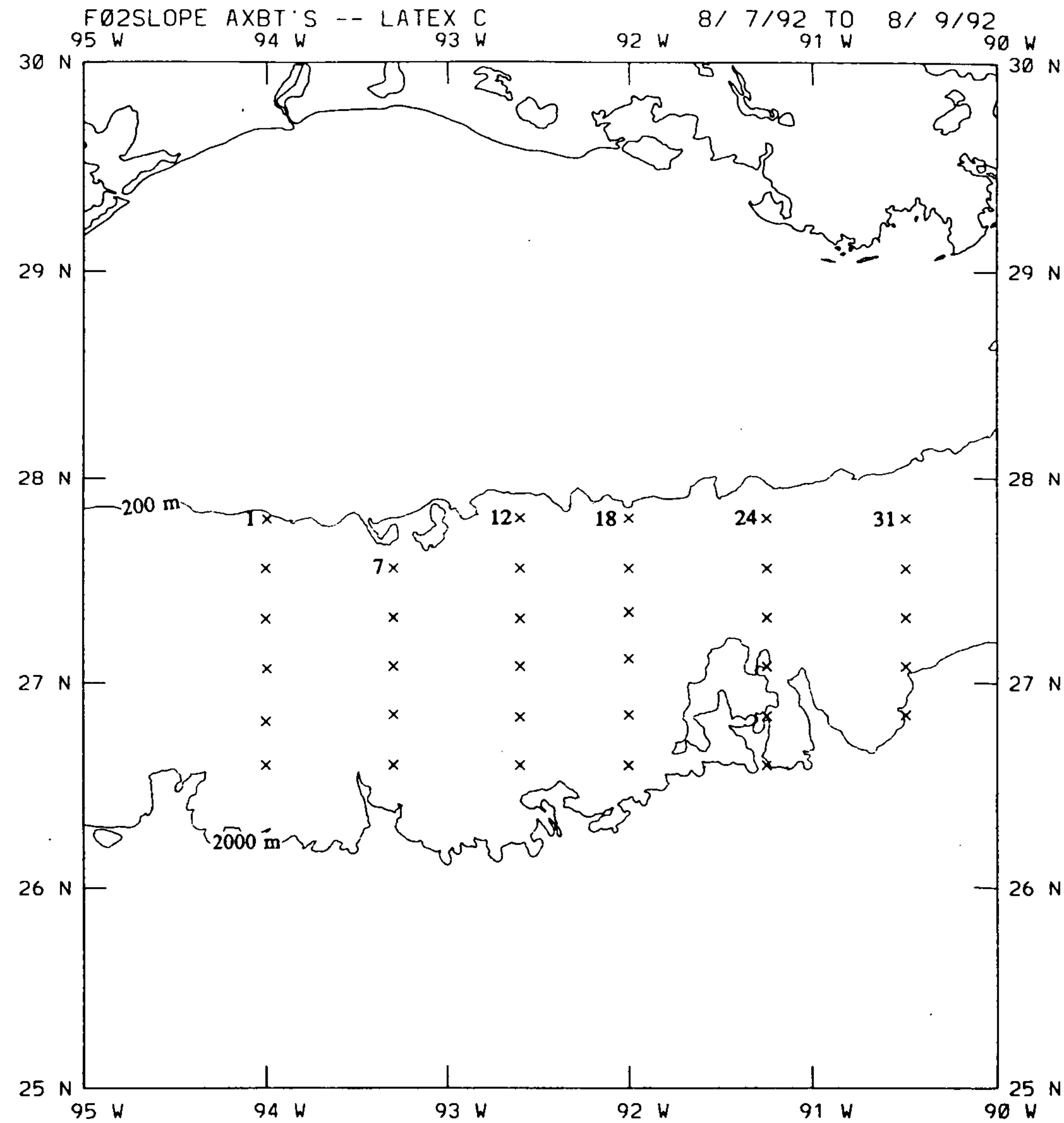

Figure 3.1-5. Station plot for survey F02SLOPE.

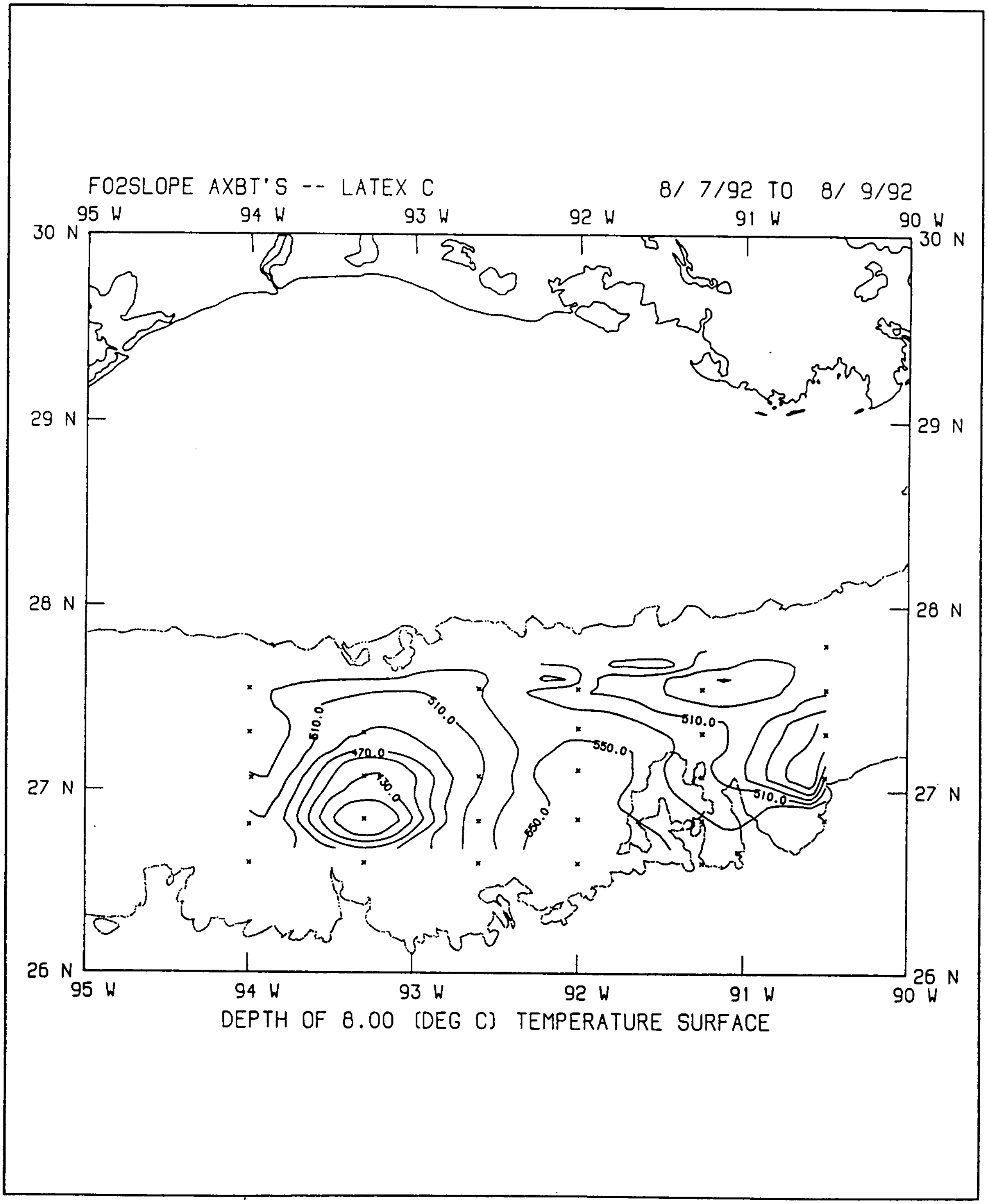

Figure 3.1-6. Depth of 8°C isotherm from F02SLOPE AXBT data.

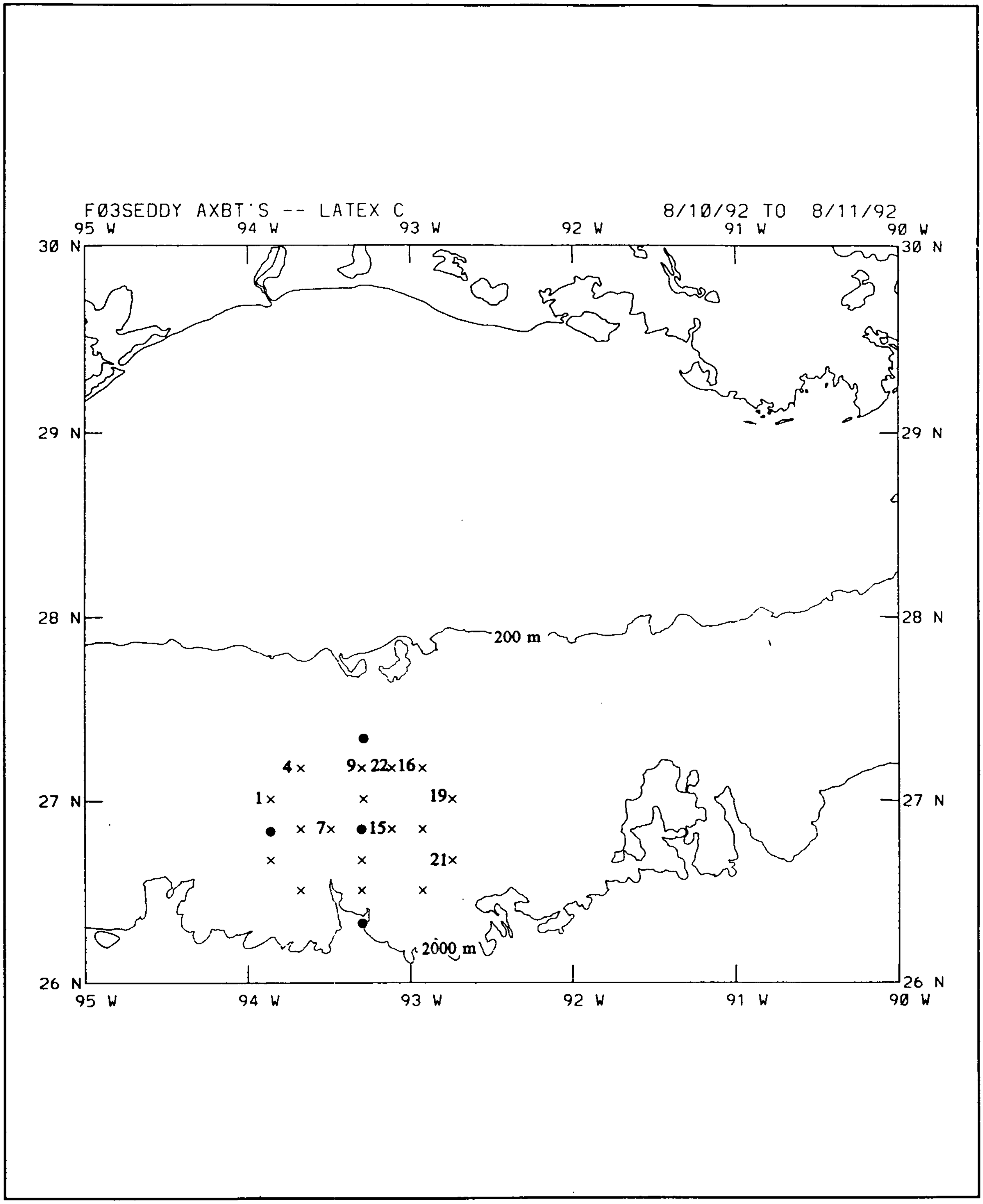

Figure 3.1-7. Station plot for eddy survey F03SEDDY showing AXBTs (x) and AXCPs (•).

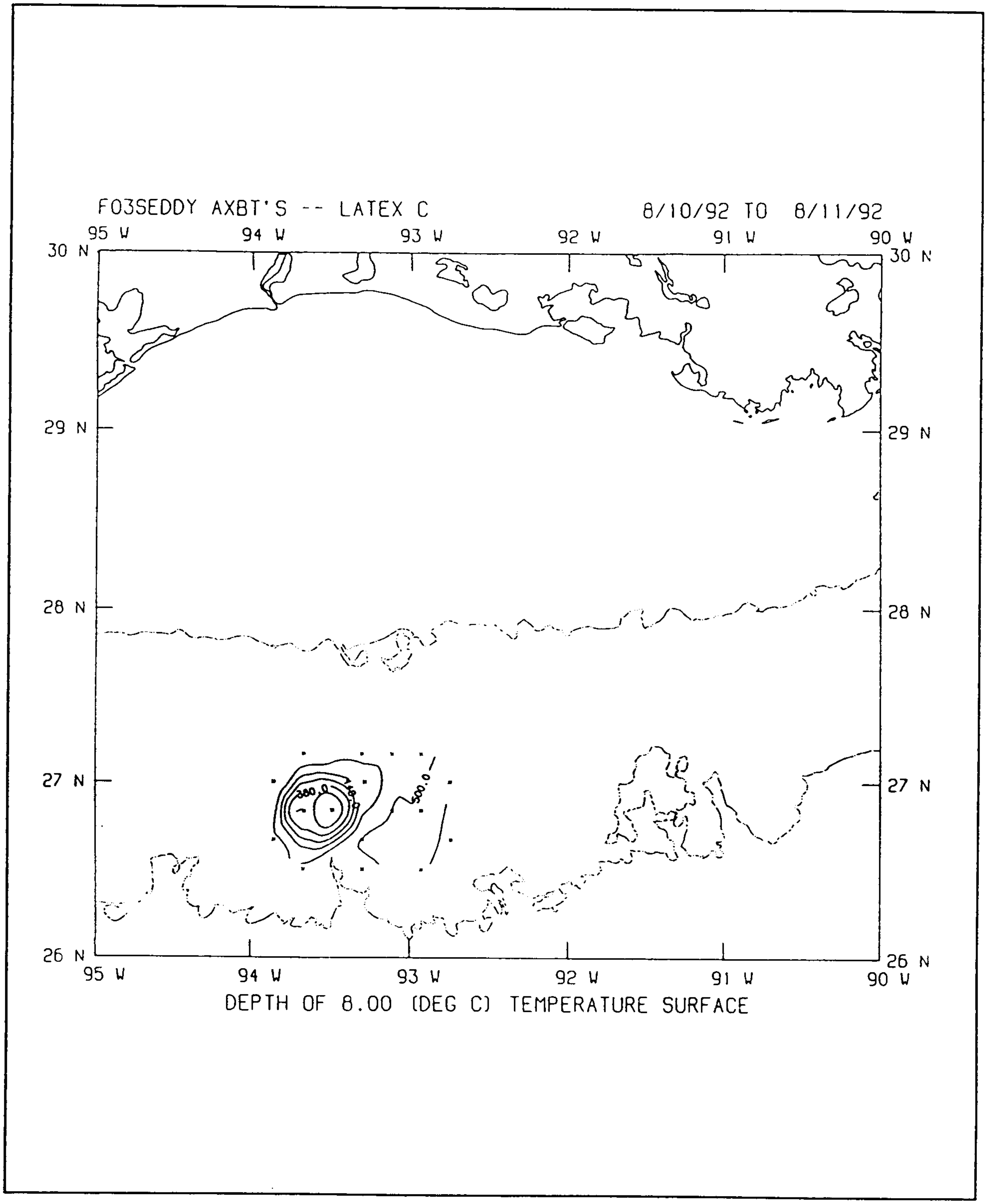

Figure 3.1-8. Depth of 8°C isotherm from F03SEDDY AXBT data.

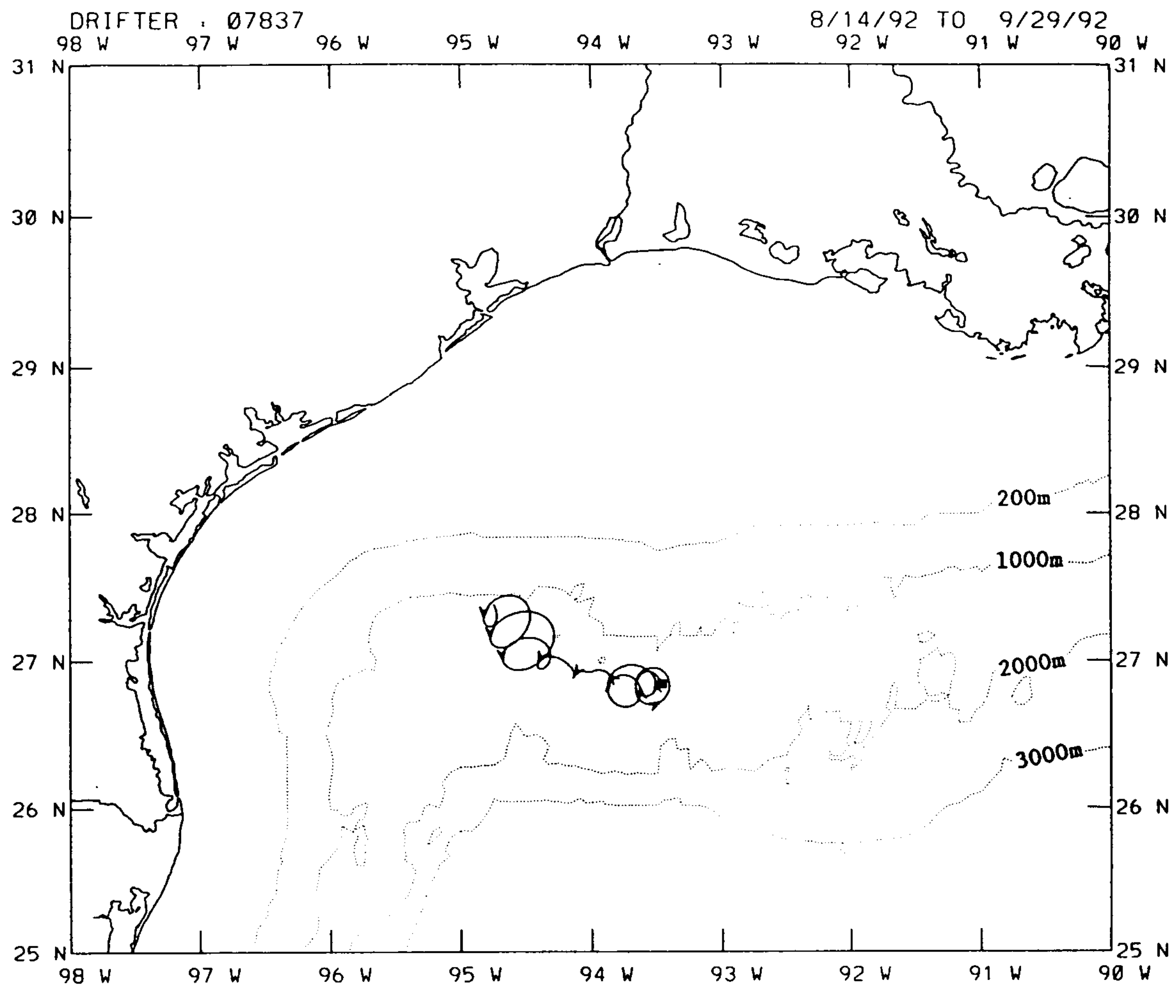

Figure 3.1-9. Track of Drifter 7837.

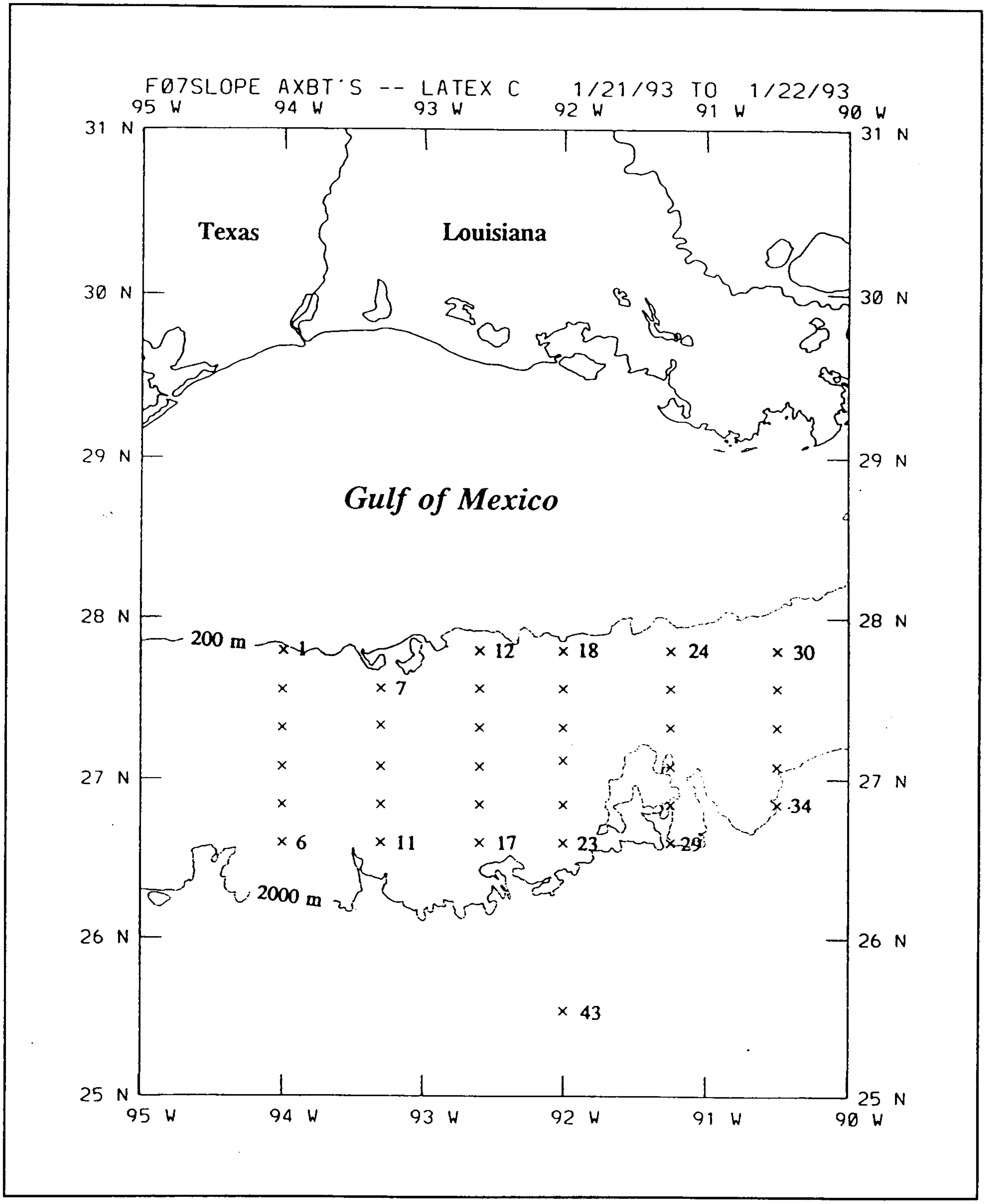

Figure 3.1-10. Station plot for F07SLOPE.

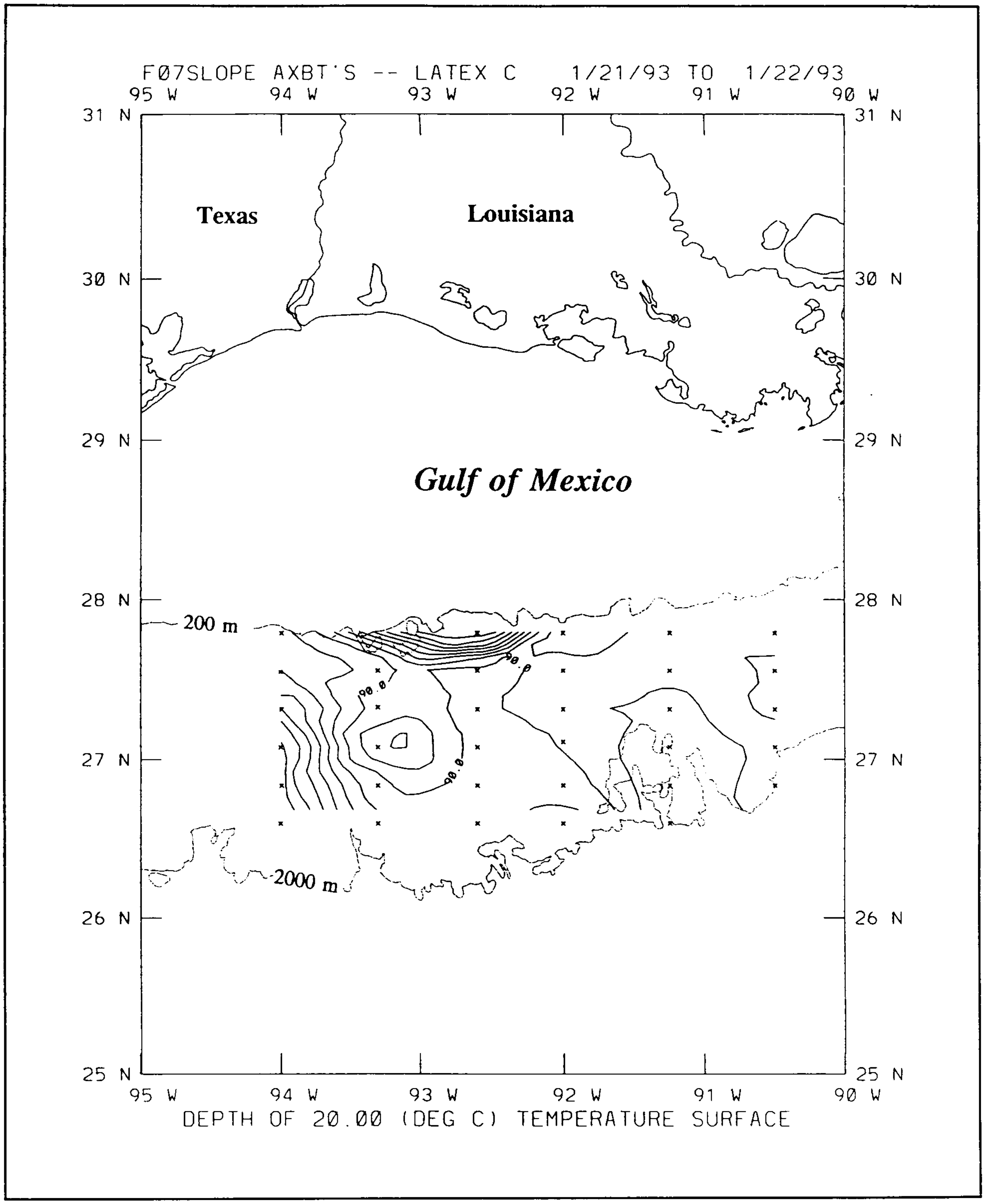

Figure 3.1-11. Depth of 20°C isotherm from F07SLOPE AXBT data.

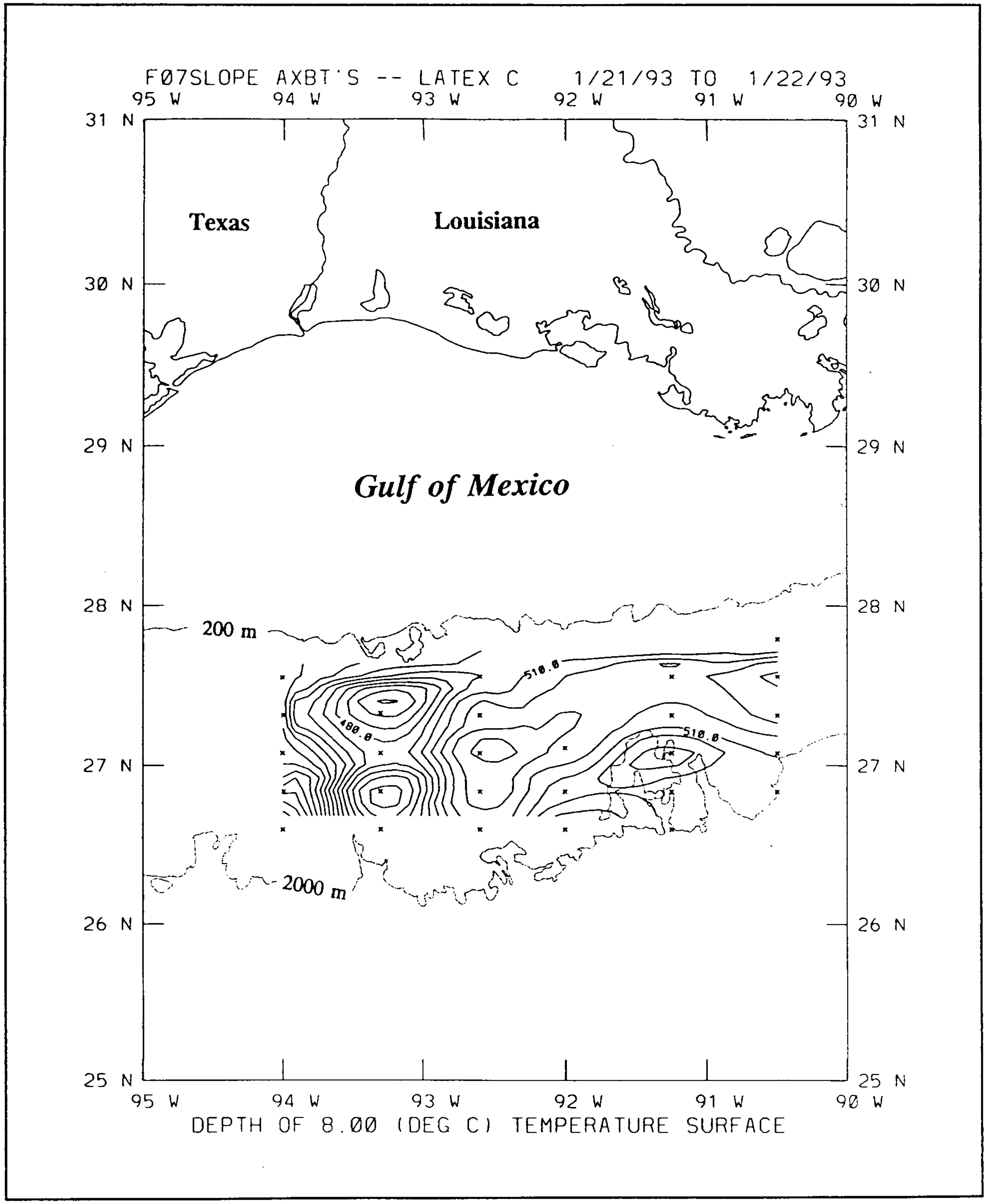

Figure 3.1-12. Depth of 8°C isotherm from F07SLOPE AXBT data.

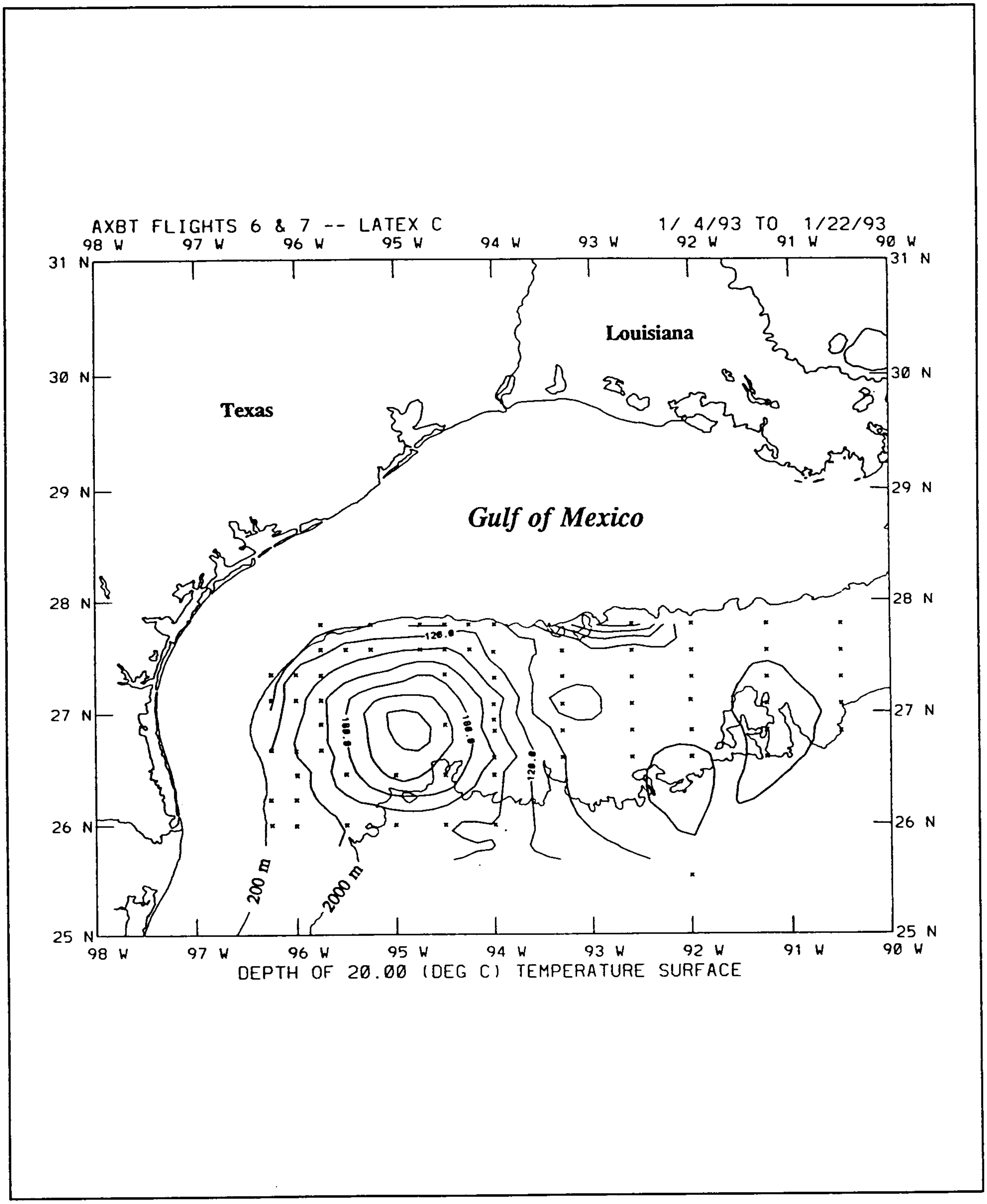

Figure 3.1-13. Depth of 20°C isotherm from merged F06 and F07 AXBT data.

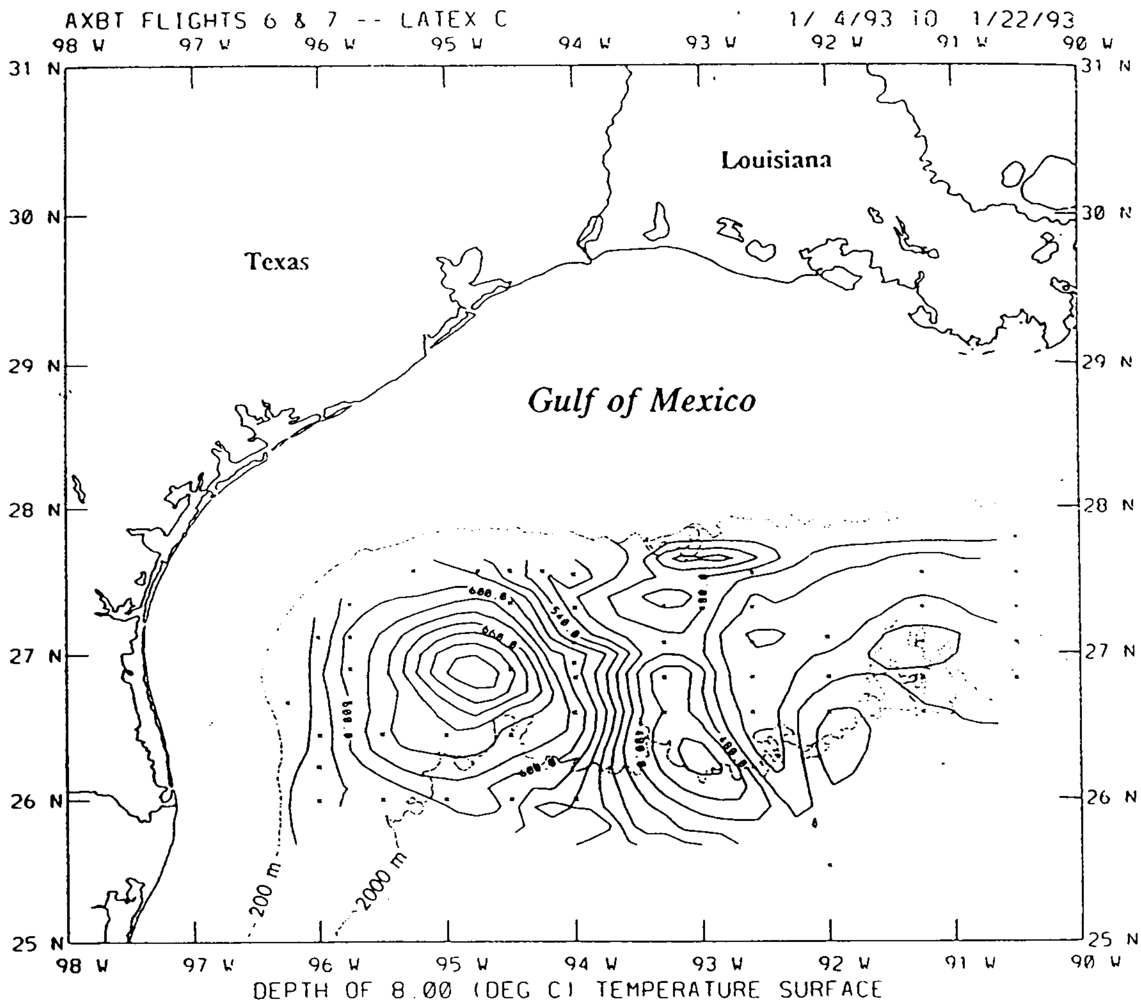

Figure 3.1-14. Depth of 8°C isotherm from merged F06 and F07 AXBT data.

3.1.2 Loop Current Eddies

Two Loop Current Eddy Surveys were planned during Year 1, in April and December 1992, based on an estimated nine month eddy shedding period for Loop Current eddies and the expectation that an eddy would have been shed early in 1992.

Eddy U (F04LEDDY)

One anticyclonic eddy separated from the Loop Current at the beginning of the field work in Year 1 while another was in the process of separating at the end of Year 1. The first eddy was designated Eddy U in the LATEX Program and Unchained Eddy by the Horizon Marine, Inc., Eddy Watch Program, which provides data on events which might impact offshore industry drilling activities. This eddy probably separated from the Loop Current during the summer. The edge of a large anticyclonic feature was detectable in the southeastern portion of the second Slope Survey as shown in Figure 3.1-15. By early fall the eddy was being detected in satellite SST imagery.

Drifter 2447, which had been deployed by LATEX A on the continental shelf on August 4, 1992, moved off the shelf in mid August and began a circuit of a large, elliptical feature centered at about 25°N 89°W on September 10. Shortly after September 10, drifter 2447 appeared to exit the large eddy and began anticyclonic loops around a smaller feature just to the west as shown in Figure 3.1-16. Two eddies were detectable in imagery in early October. the second smaller feature was designated Eddy V (Eddy Vasquez).

Based on the path of drifter 2447, ERS-1 altimetry data, imagery, and other sources, a Loop Current Eddy Survey (F04LEDDY) was completed on October 11, 1992, as shown in Figure 3.1-17. Figure 3.1-18 shows the temperature structure to about 800 m along the long axis of this survey. The survey track was designed to determine the major dimensions of Eddy U (on the right in figure 3.1-18) and to verify the separation of Eddy V (on the left in Figure 3.1-18).

Preliminary evaluation of the AXBT data confirmed the presence of Eddy U and the decision was made to deploy drifter 7836 on October 12. Drifter 7836 was deployed in Eddy U at 25°30'N 90°23.4'W at 1621 CDT on October 12, 1992. The parachute apparently separated from the launch package almost immediately after launch and the package made a hard landing. The drifter failed after the first ARGOS fix at 1736 CDT on October 12, 1992.

After the failure of drifter 7836, it was decided to take advantage of a scheduled trip by R/V GYRE from Key West, Florida to her homeport in Galveston, Texas, and have a backup drifter deployed in Eddy U. Thus was drifter 2449 was deployed at 24°36.8'N 90°17.3'W at 0100 CDT on October 30, 1992. Data from the October 11, 1992

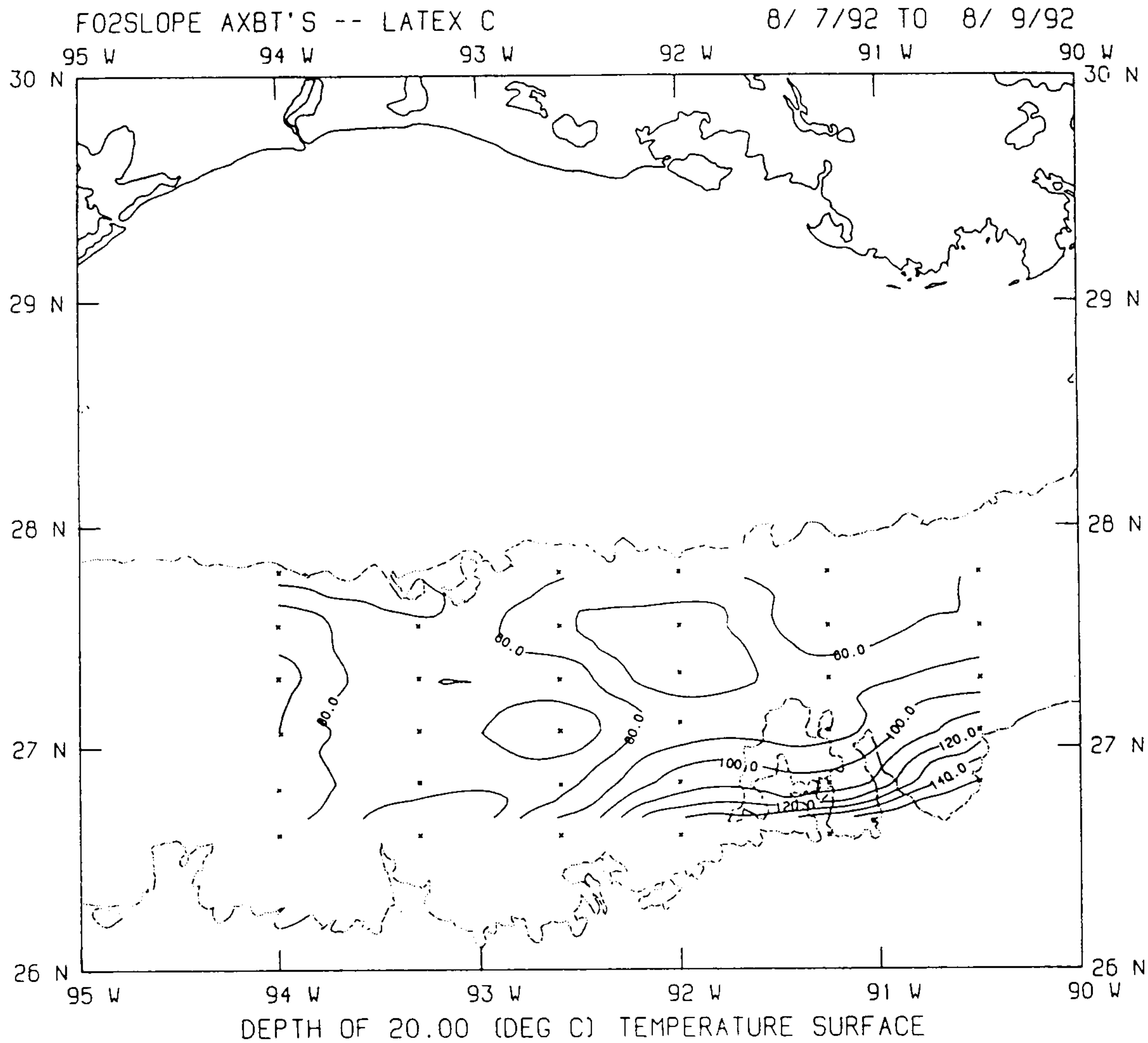

Figure 3.1-15. Depth of 20°C isotherm from F02SLOPE AXBT data.

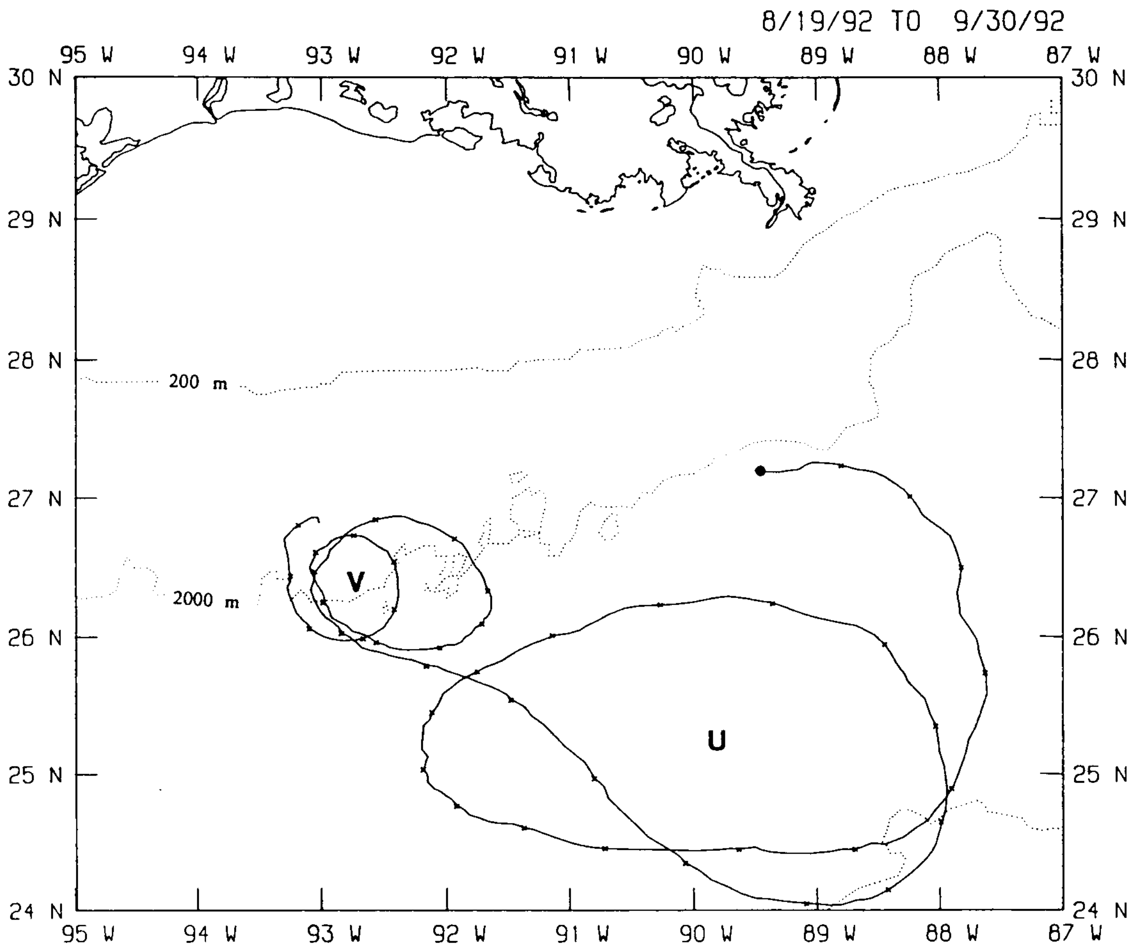

Figure 3.1-16. Track of Drifter 2447 after leaving the continental shelf. Path shows transition from Eddy U to Eddy V. Start is at dot, tick marks are at one day intervals.

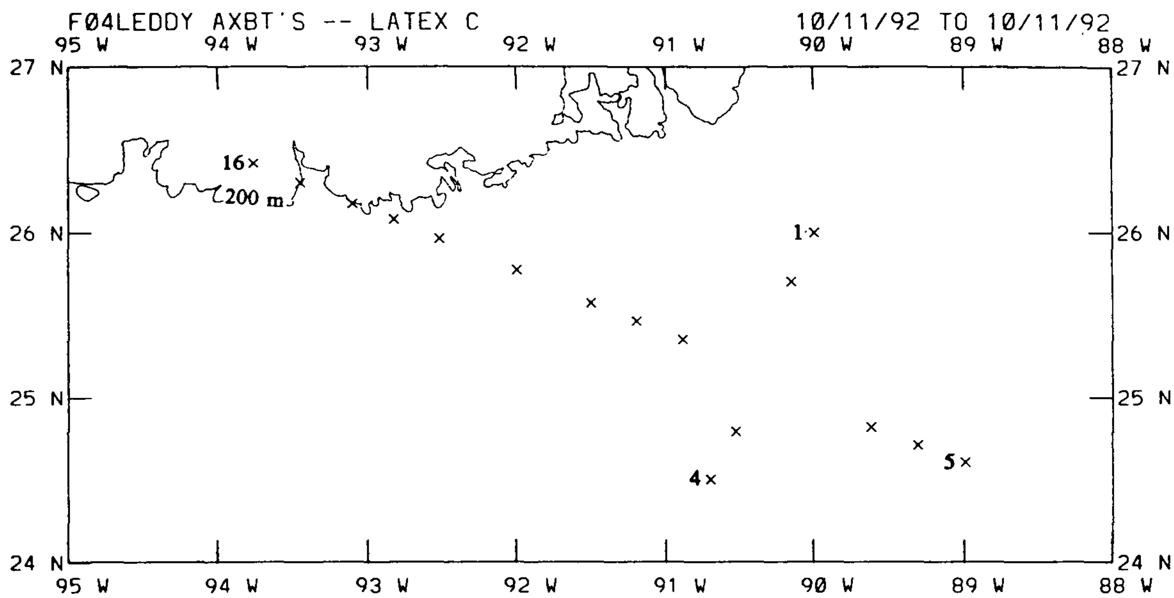

Figure 3.1-17. Station plot for survey F04LEDDY.

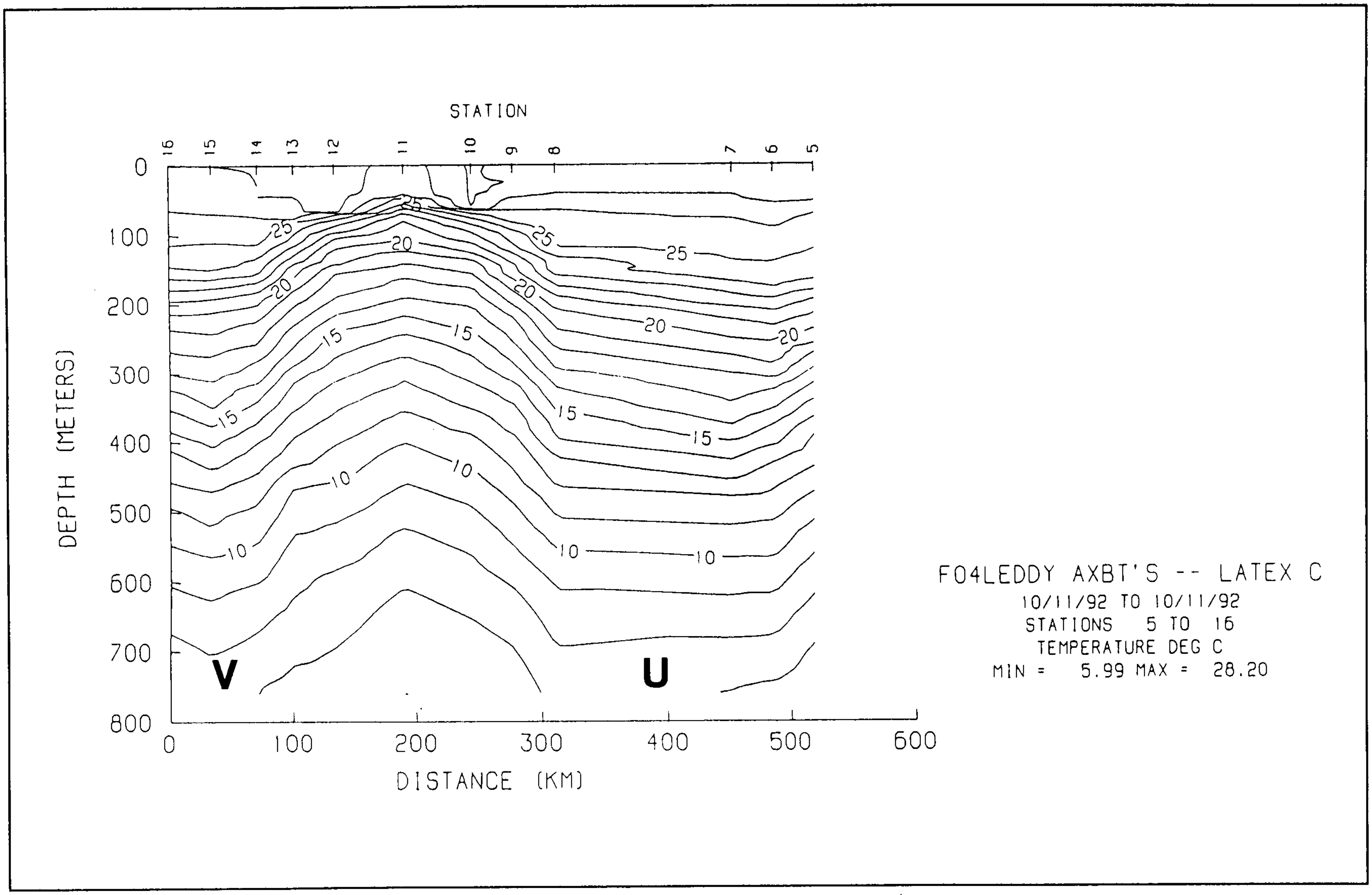

Figure 3.1-18. Northwest-southeast section through F04LEDDY long axis (stations 5-16) to 800 m showing depressed isotherms in Eddy U (right) and Eddy V (left).

survey were provided to the scientific party on R/V GYRE to aid them in placement of the drifter. Drifter 2449 provided useful data on the path of Eddy U as shown in Figure 3.1-19 and continued to operate past the end of Year 1.

Eddy V (F05SPEC and F06)

A survey of Eddy V (F05SPEC) was undertaken December 19, 1992 as shown in Figure 3.1-20, at the recommendation of the LATEX Science Advisory Panel during a meeting in New Orleans, Louisiana, November 17-20, 1992. The survey was recommended because Eddy V had been tracked from its origins and appeared to be nearly stationary in the northwestern corner of the Gulf of Mexico. The Science Advisory Panel also recommended that a detailed, high resolution survey of Eddy V be conducted at the earliest opportunity and that the assets intended for a Squirts and Jets Survey/Squirts and Jets Location Survey be used for this purpose. No drifter was deployed as drifter 2447 was still in Eddy V at the time. Figure 3.1.21 shows the depth of the 15°C isotherm determined from this survey.

A second, detailed survey (F06) of Eddy V, in response to the recommendations made by the LATEX Science Advisory Panel, was undertaken January 4-6, 1993 as shown in Figure 3.1-22. This survey was conducted over three days using 44 AXBTs and 10 AXCPs. One AXBT and two AXCPs failed to operate. Two AXBT stations were not made because of weather interference.

Figure 3.1-23 shows the depth of the 15°C isotherm. The presence of a large anticyclonic feature (Eddy V) is clear. Identification as Eddy V was based on continuity of observations including drifter tracks and hydrographic observations by this program, the MMS funded Gulf Cetacean Program at TAMU Galveston, and various TAMU SOOP cruises made by Dr. Doug Biggs. After evaluating data from the December survey (F05SPEC) and a portion of the data from this survey in the field, the decision was made to deploy four drifters with drogues at 50 m in a square array around the center of the eddy. These drifters were deployed between 1437 and 1532 CST on January 9, 1993. The first two days of drifter data are shown in Figure 3.1-24 which also shows the apparent movement of the center of the eddy between the mid December survey and this survey.

Drifters 3581 and 7832 ceased transmitting on January 12, 1993 possibly as the result of the air deployment process. Drifter 2451 was picked up at sea on February 5 but continued to operate. It was not recovered. Drifter 7835 operated until mid June 1993 after it had departed the Gulf of Mexico through the Straits of Florida. The useful track of drifter 2451 and the track of drifter 7835 through the end of Year 1 are shown in Figure 3.1-25.

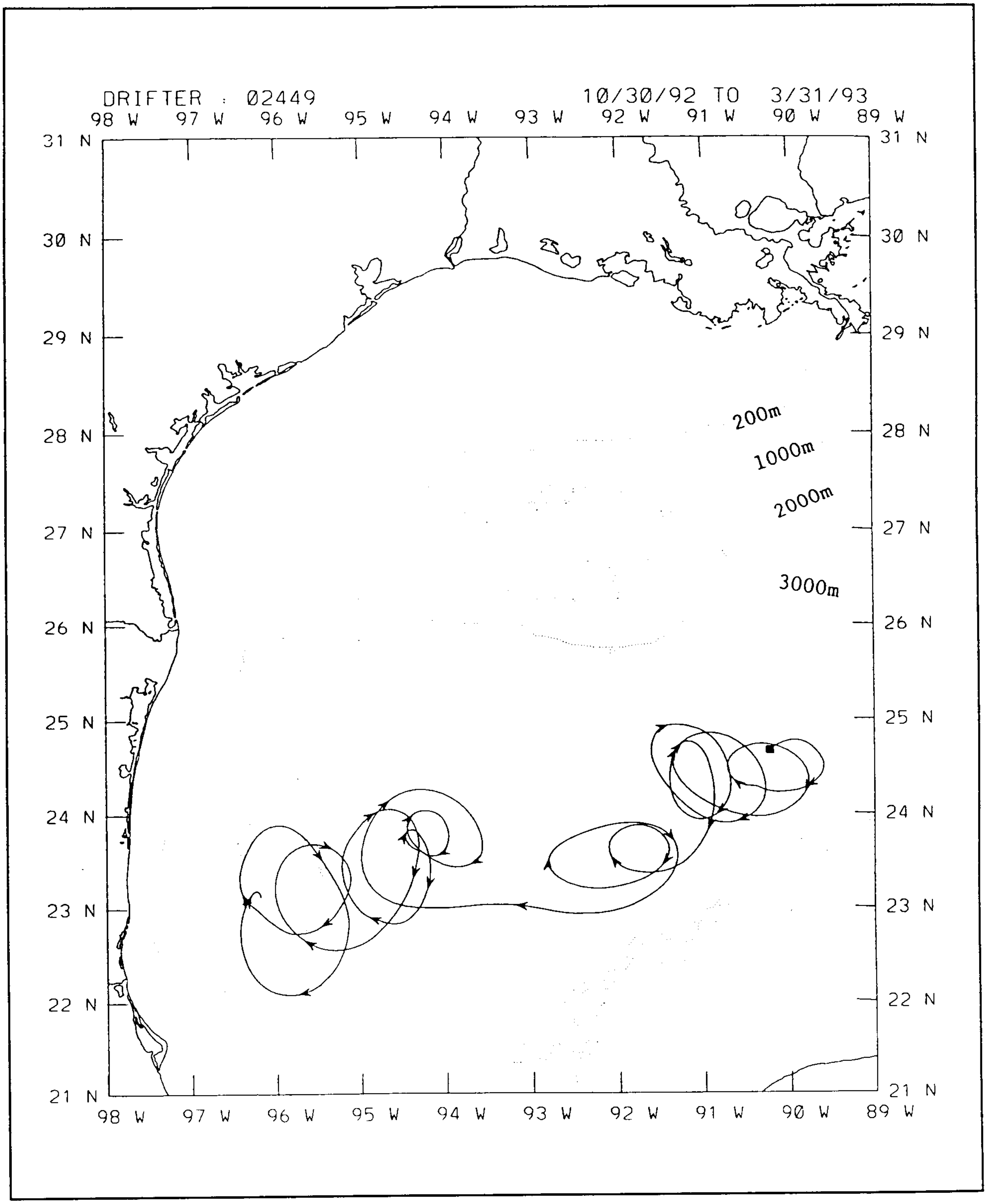

Figure 3.1-19. Track of Drifter 2449 deployed in Eddy U.

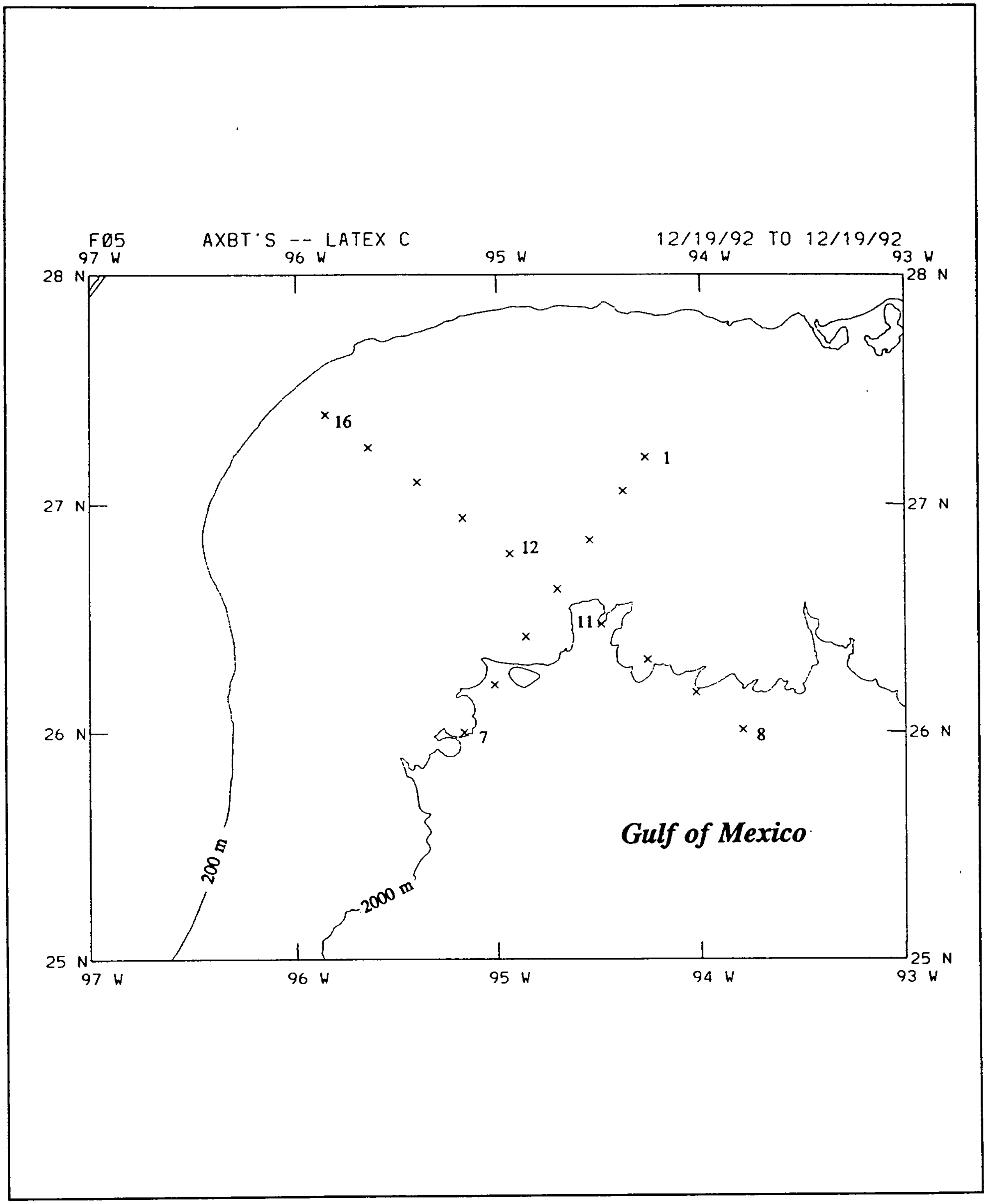

Figure 3.1-20. Station plot for survey F05SPEC.

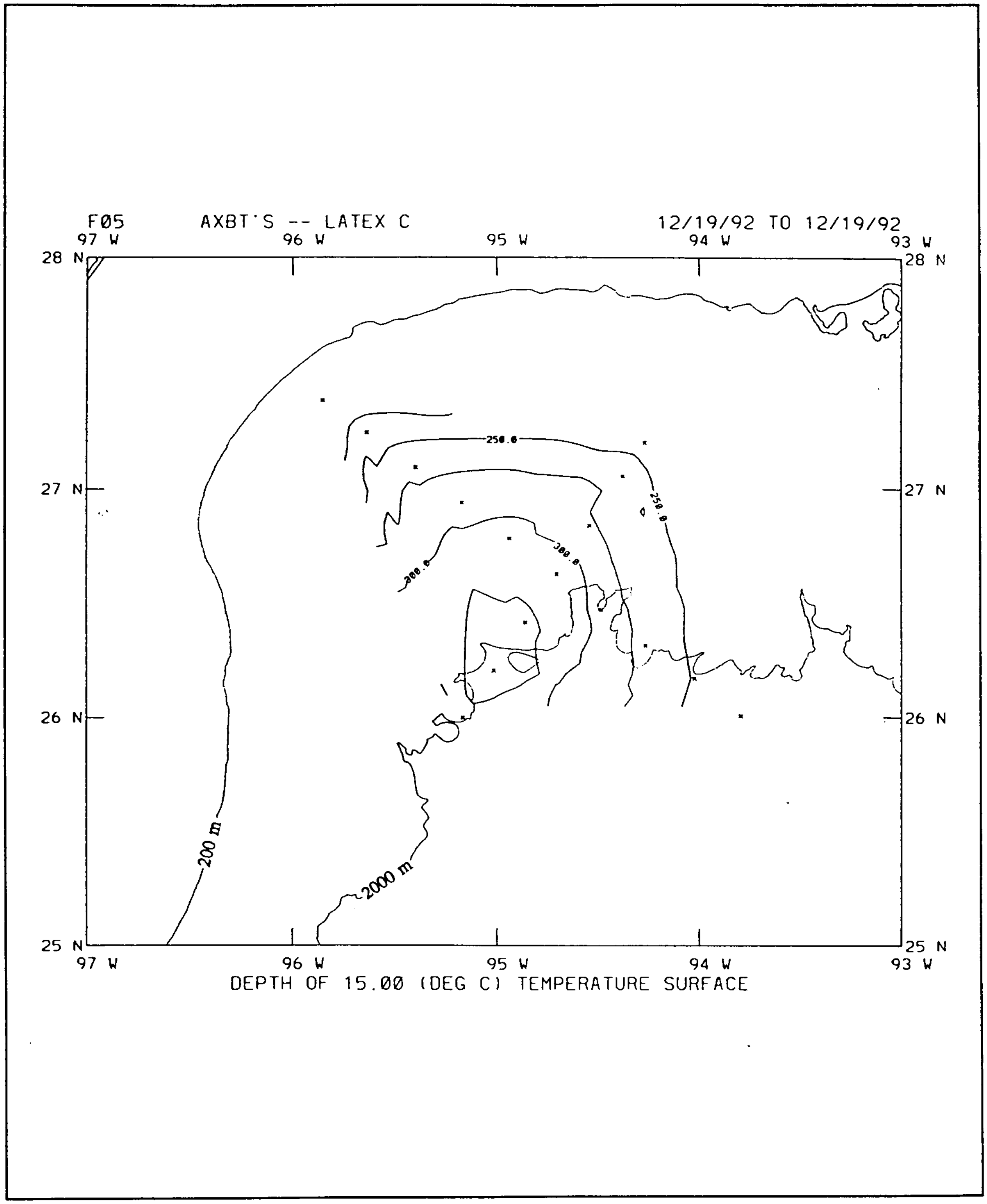

Figure 3.1-21. Depth of 15°C isotherm from F05SPEC AXBT data.

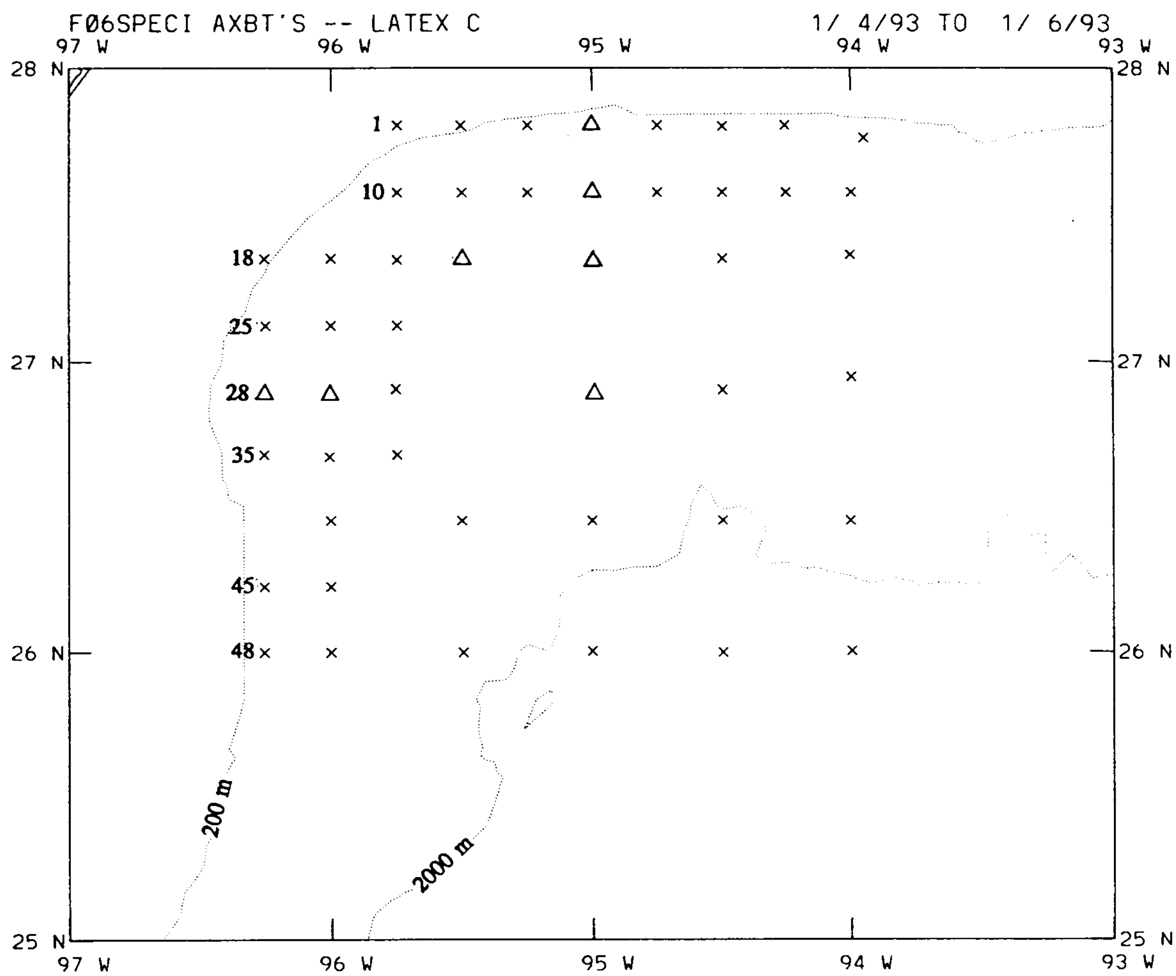

Figure 3.1-22. Station plot for survey F06 showing AXBTs (×) and AXCPs (△).

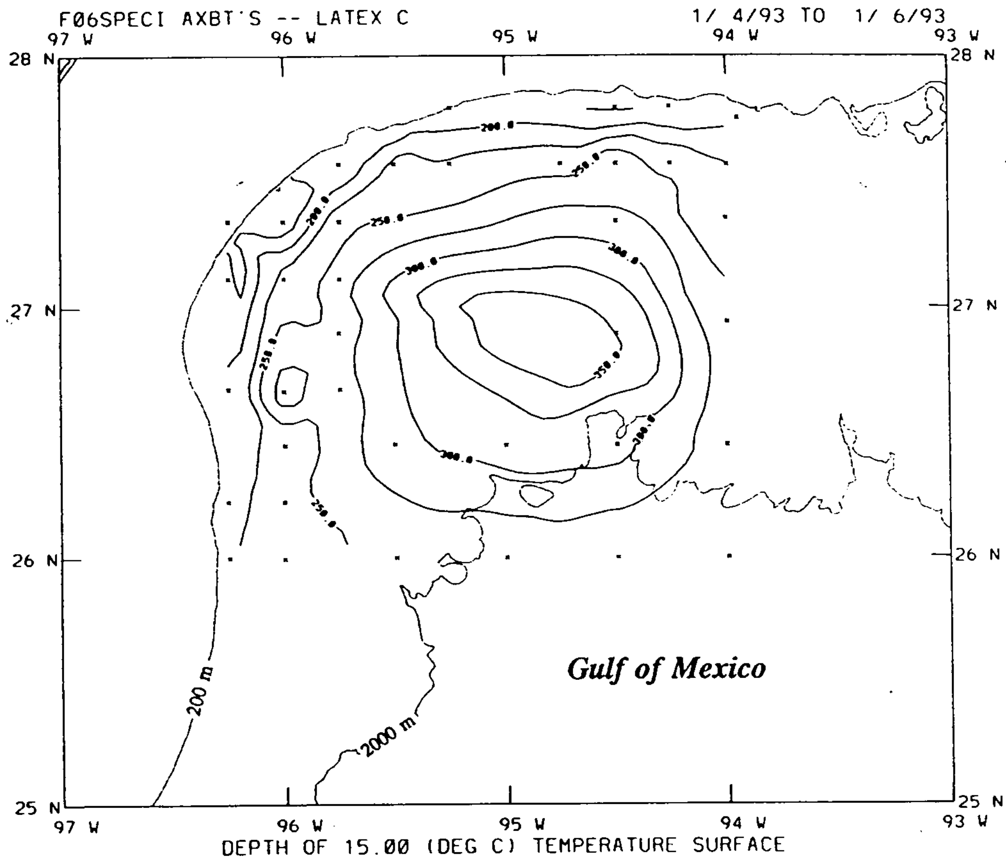

Figure 3.1-23. Depth of the 15°C isotherm from F06 AXBT data.

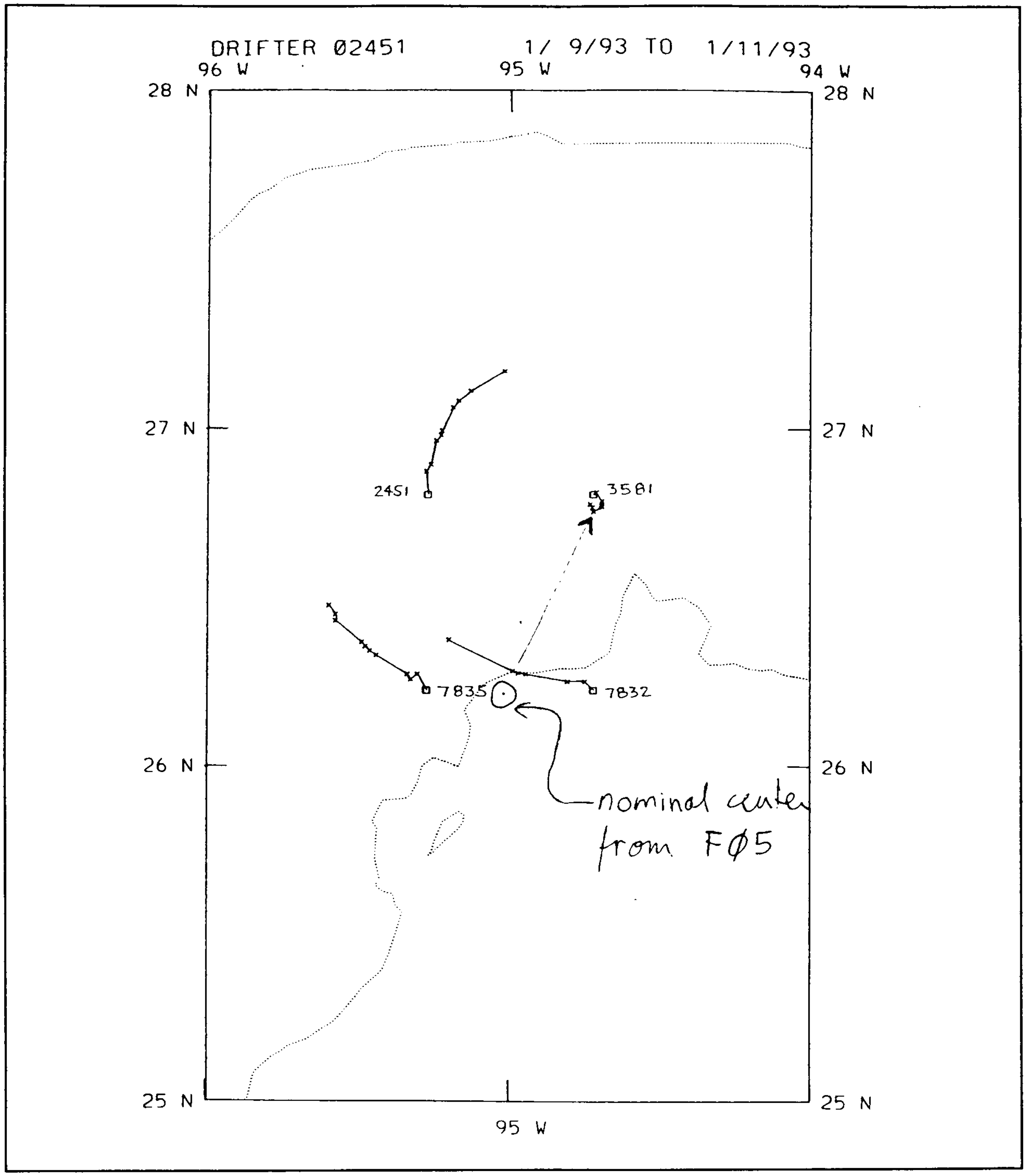

Figure 3.1-24. Annotated tracks of drifters 2451, 3581, 7832, and 7835 during first two days after deployment in Eddy V. Possible movement of eddy center is indicated.

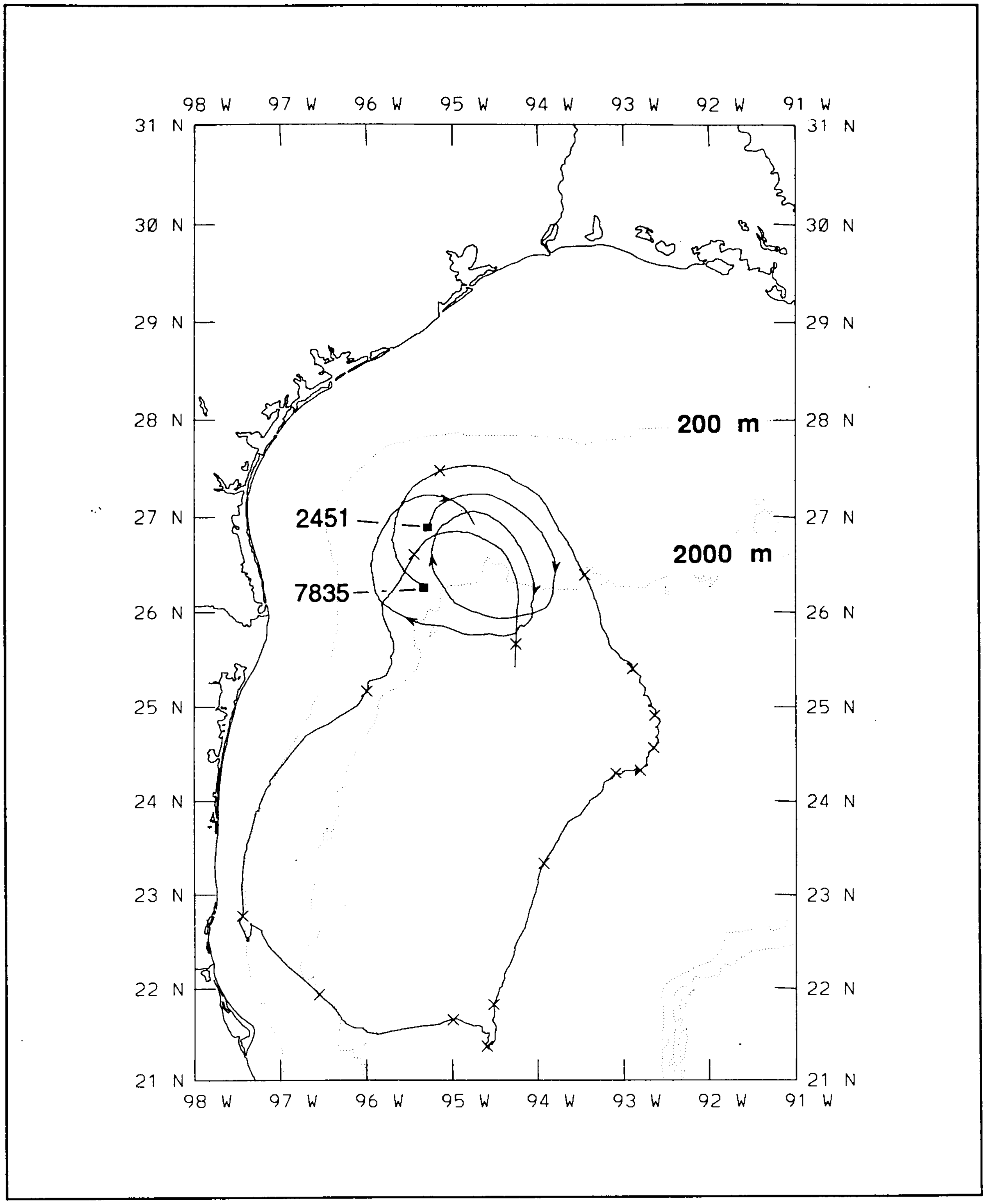

Figure 3.1-25. Tracks of Drifters 2451 and 7835. Arrows (2451) and crosses (7835) indicate five day intervals.

3.2 Task C-7: Altimetry

To perform retrospective analysis of the GEOSAT ERM data, CCAR felt it necessary to reprocess the National Oceanic and Atmospheric Agency (NOAA) supplied Geophysical Data Records (GDR) using the more accurate orbits computed using the GEM-T2 gravity model. CCAR completed gridding of the NOAA GDR GEM-T2 archive and produced a global gridded data set spanning the entire GEOSAT Exact Repeat Mission time period. The archive now includes the 62 cycles of data that were obtained before the GEOSAT tape recorder failed in September 1989 and the line of sight data stream collected over the Gulf of Mexico by The Johns Hopkins University Applied Physics Laboratory until the ultimate failure of the satellite in January 1990.

All GEOSAT ERM GDR data and corrections were interpolated to a 17 day reference orbit using linear interpolation in the along track direction. This provided an accurate and easily manipulated data set for analysis. The reference orbit was based on the ground track of the second exact repeat cycle, since no satellite maneuvers occurred during this time period. A statistical orbit propagation program (UTOPIA) was used to perform a least squares fit the reference orbit to the cycle 2 ground track. This resulted in a reference orbit which comes within 100 m cross track of the actual Cycle 2 data. The reference orbit for the interpolation consisted of points along the orbit solution ground track spaced at one second intervals.

The major advantage of this regridding of the GEOSAT data is that we now have an complete archive of the ERM data for the final processing of the Gulf of Mexico retrospective study. A systematic study of the corrections will be performed to provide the best estimate of the sea surface height time series over the ERM. Several corrections will pose some difficulty. For example, the west tropospheric delay correction may be either made using either the Fleet Numerical Oceanography Center model or TIROS Operational Vertical Sounder/Special Sensor Microwave Imager (TOVS/SSMI) fields, with the TOVS/SSMI correction preferred. Unfortunately, the TOVS/SSMI fields are limited in coverage near land and these data outages adversely affect the basin scale study over the coastal regions such as the LATEX shelf. To minimize these impacts CCAR plans to perform basin scale analyses using both corrections and then compare the results. Similarly, CCAR will investigate the sea state bias and inverted barometer corrections.

The archive can also be easily updated as better orbits and corrections become available. More accurate GEOSAT ERM orbits computed by NASA Goddard Space Center using the JGM gravity model are planned for release in the very near future. The gridded data archive will be updated from these orbits using blank fields in the archive reserved such updates. In addition, an accurate mean field (provided by Dick Rapp, Ohio State University)and along and cross track geoid gradient corrections have become available from the joint U.S. Ocean Topography Experiment (TOPEX)/French Poseidon mission. These have been incorporated into the archive and will be used to correct from cross track geoid gradient errors which appear in sea surface height variability as a result of the gridding process.

CCAR also explored the use of the Rapp mean as the reference surface for climatology. This mean surface is the best available surface in the Gulf of Mexico region and was derived using all the available altimeter and gravimetric data. We are in the process of comparing the along track GEOSAT mean with the Rapp surface. The advantage of using the Rapp surface is that current European Research Satellite (ERS-1) and TOPEX and future (GEOSAT Follow On) altimeter missions can be referenced to this surface, extending the climatology in a consistent manner. CCAR has developed a technique to correct the Rapp mean so that both TOPEX and ERS-1 data can be referenced to this mean surface. Figures 3.2-1 and 3.2-2 show, as examples of the analysis, plots from ERS-1 cycles 6 and 7 (Oct and Nov 1992), respectively. The plots show dynamic height relative to the mean, with white and black representing positive and negative anomalies, respectively. The width of the stripe is proportional to the height with a scaling of one meter dynamic height per degree. Three eddies are easily seen in the western Gulf of Mexico.

3.3 <u>Data Quality Control</u>

This section addresses data quality control performed after the data have been collected and reviewed in the field. The procedures described are largely interactive steps undertaken on an ENCORE Series 91 Dual Processor machine running under AT&T UNIX V Release 4 in an X-Windows environment. The processing steps were largely developed over more than a decade using FORTRAN 77 and NCAR graphics and analysis routines. These routines are completely linked to a relational data base management system tailored in-house to support physical oceanographic work.

3.3.1 Hydrographic Profile Data

Detailed interactive computer procedures for QA/QC of profile data are online and are an integral part of entering data into the SAIC Physical Oceanographic Data Base Management System (PODBMS). These procedures provide specific checks at key junction points to insure a high-quality data product as diagrammed in Figure 3.3-1. The following summarizes the processing steps for XBT/AXBT and AXCP profile data:

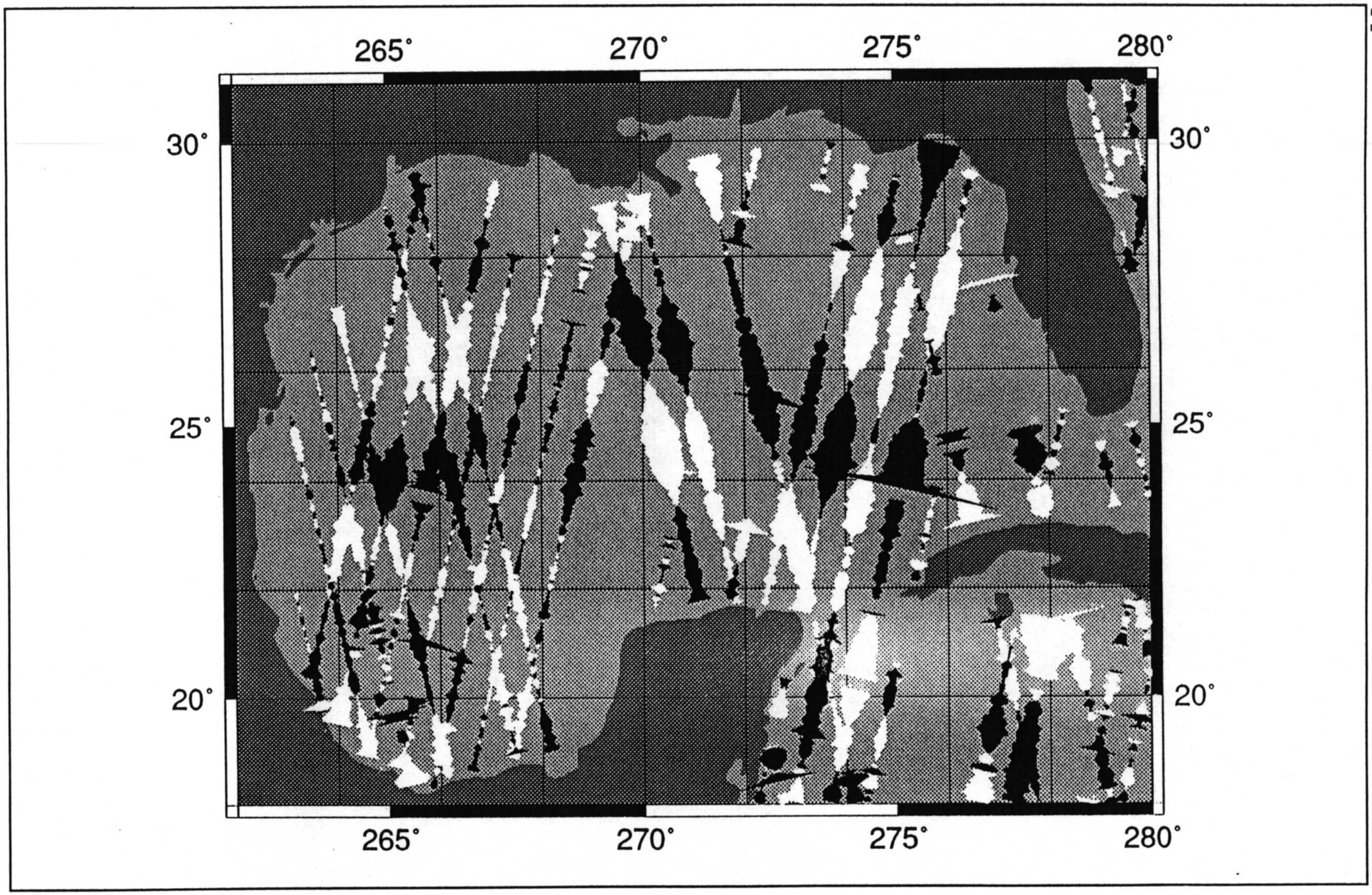

Figure 3.2-1. Altimetry data over the Gulf of Mexico from ERS-1 satellite's Exact Repeat Cycle 6.

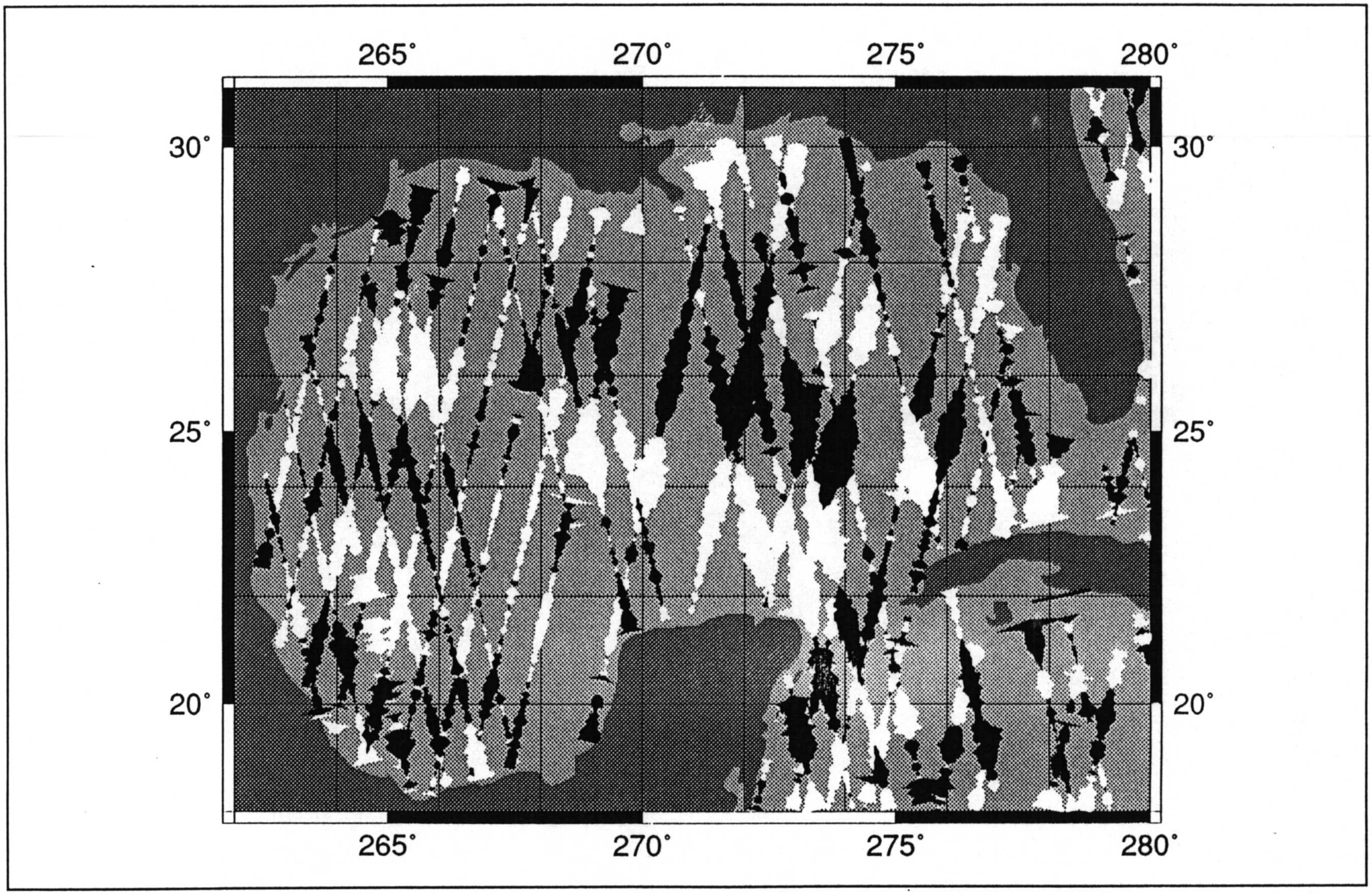

Figure 3.2-2. Altimetry data over the Gulf of Mexico from ERS-1 satellite's Exact Repeat Cycle 7.

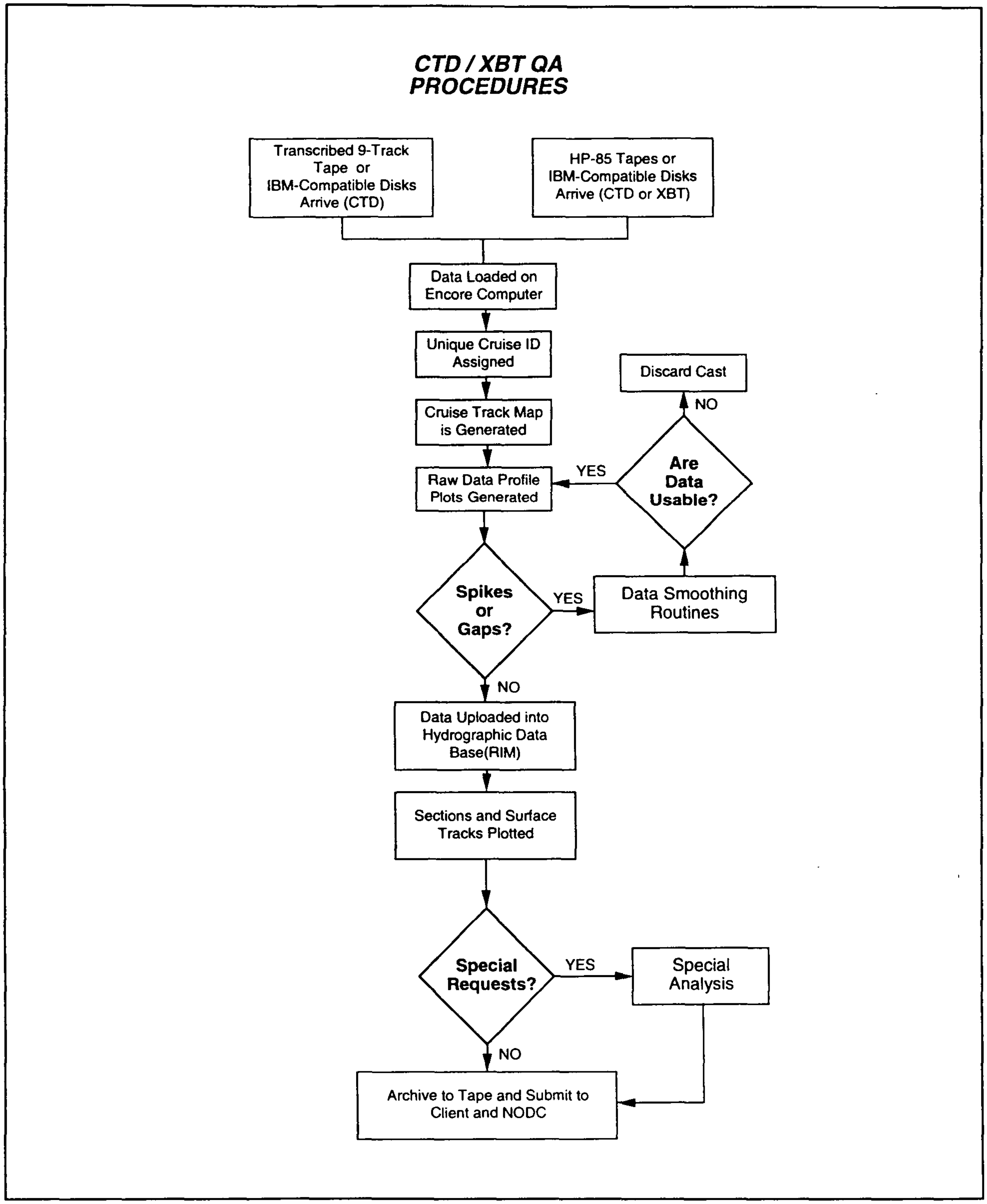

Figure 3.3-1. Schematic diagram of AXBT/XBT QA/QC procedures.

XBT/AXBT Processing Procedures

One hundred ninety four AXBTs were processed in Year 1. The data were recorded on both nine-track analog tape and on DAT cassettes from separate channels of the receiver in the aircraft. These data were then processed after the flight through a Sippican Mk12 Oceanographic Data Acquisition System which converts the data to an ASCII file containing a header with information about the drop and depth temperature pairs at approximately 0.15 m increments to a maximum depth of 760 m. The depth is computed from the fall time of the thermistor probe through the water column. The coefficients of the drop equation have been determined experimentally during the development of the probes. Calibration of the thermistor is accomplished during manufacture and is not duplicated in the field. The AXBT data are received from AeroMarine Surveys on 3½" IBM PC compatible diskettes.

- XBT/AXBT data are transferred into the PODBMS and a unique identifier (ID) is assigned to the data. The survey sequence number is part of the individual data file name, for example, file AB$01010.EDF is the AXBT deployed at station 10 in the first survey (F01SLOPE). Section 3.1 described the formation of the IDs used in this program. The data are then checked for spikes, large data gaps and total number of points through an interactive digital processing routine. The corrected data are archived to tape (nine-track, EXABYTE, or ¼" cassette) and stored in the Tapes Facility.

- Vertical temperature profiles are then checked individually, using an interactive graphics editor, for accuracy and smoothness. The routine allows the user to clip bad/noisy casts and to apply a spline to noisy or gappy data (a common problem of AXBT data, see Figure 3.3-2) in an attempt to smooth the data or supply missing data. The smoothing can be applied to an entire cast or to only a portion of the cast. Bad casts are deleted from the PODBMS.

- One-meter increment data are used to produce vertical sections along and across isobaths (see Figure 3.1-4) or along major survey axes and horizontal contour maps of selected temperature surfaces (see Figure 3.1-3) or temperature at a selected depth. Surface tracks are also generated for each survey.

AXCP Processing Procedure

Twelve AXCPs were available for processing during Year 1. Data acquisition for these probes was essentially similar to data acquisition for the AXBTs. Processing of these data was completed by AeroMarine Surveys, Inc., at their facility in Gales Ferry, Connecticut, using a Sippican Mk 10 XCP Digital Data Acquisition System which converts the data to an ASCII file containing a header

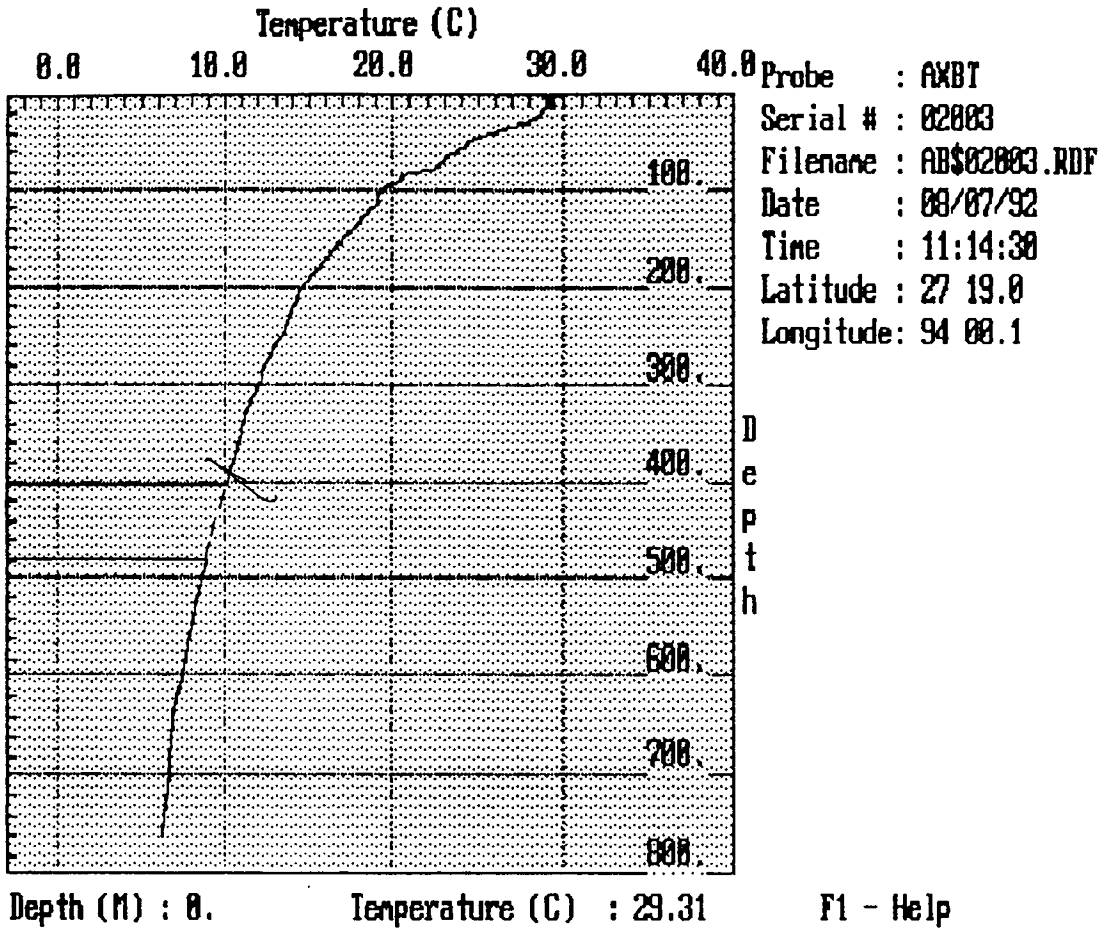

Figure 3.3-2. Plot of raw AXBT data from survey F02 station 3 showing data dropout.

with information about the drop, and depth, temperature, and velocity information at approximately 11 m increments to a maximum depth of 1500 m. Figure 3.3-3 shows the header and first three data lines generated by the Mk 10 system. Computations of depth and temperature are made in the same manner as for AXBTs.

Computation of velocity components from AXCP data uses a set of five 'standard' coefficients or five coefficients unique to each probe. Normally the unique coefficients are provided on a sheet accompanying each probe, however this was not the case with probes used during F03 and F06. Searches for the data sheets revealed they had been provided separate from the probes. No serial numbers could be found on any of the probes used in the two surveys and the coefficients provided thus could not be referenced to the appropriate probe. The remaining probes purchased for Year 1 were returned to Sippican, Inc., to determine if serial numbers could be found internally. None could and the remainder of the Year 1 lot were replaced by Sippican. Apparently an error during manufacture had allowed the batch to leave the factory without visible serial numbers. The data from these probes were processed with 'standard' coefficients.

Data processing procedures after receipt of the AXCP data on 3½" diskettes by SAIC are described below.

- Current Profiler data are transferred into the PODBMS from computer diskettes and the data set is assigned a unique ID as described above. The data are checked for spikes, large data gaps and the total number of points through an interactive digital processing routine. The corrected data are then archived to tape and stored in the Tapes Facility.

- Individual 'u' and 'v' components and temperature profiles are plotted and edited in a manner similar to XBT/AXBT data as shown in Figure 3.3-4. The three data components can be clipped or smoothed individually, depending on the quality of the data. Once again, the bad casts are deleted from the PODBMS.

- Ten-meter increment data are used to produce both vertical and horizontal contour sections. Cruise tracks and surface tracks are also generated for each flight. In addition, temperature data from adjacent AXBT stations can be merged with the AXCP data to provide a more detailed analysis of the vertical thermal structure of the water column.

- An NODC format tape is produced for data submission within three months of data receipt, and again at the end of the program.

MK10 Post Processing Application
Version V1.0 August, 1989
Sippican, Inc

Probe Header Information
Filename: C:\MK10\XCP$0604.PRO

S/N	: 9999	Depth(m)	: 1500
Gcca	: 1813	Latitude	: 27,48.0,N
Gcora	: 918	Longitude	: 095,00.0,W
Gefa	: 25260	Cruise	: LATEX C 06
Gevfa	: 500	Ship	: N900AM
Gcvfa	: 500	Speed	: 120 KNOTS
Fh	: .2659872	Heading	: 270 TRUE
Fz	: -.4115371	Memo	: xcp$0604
FltrSz	: 22	Date	: 01-04-1993
StepSz	: 11	Time	: 14:57:46

Depth(m)	Temp(C)	U	V	Area	Rotf	Fefb	Fccb	Velerr
9.08	18.10	38.11	-12.39	545	14.39	1293	2229	20.78
12.02	22.08	42.45	-20.94	587	15.98	1267	2255	3.23
14.85	22.08	50.96	-24.72	591	16.57	1262	2255	3.10

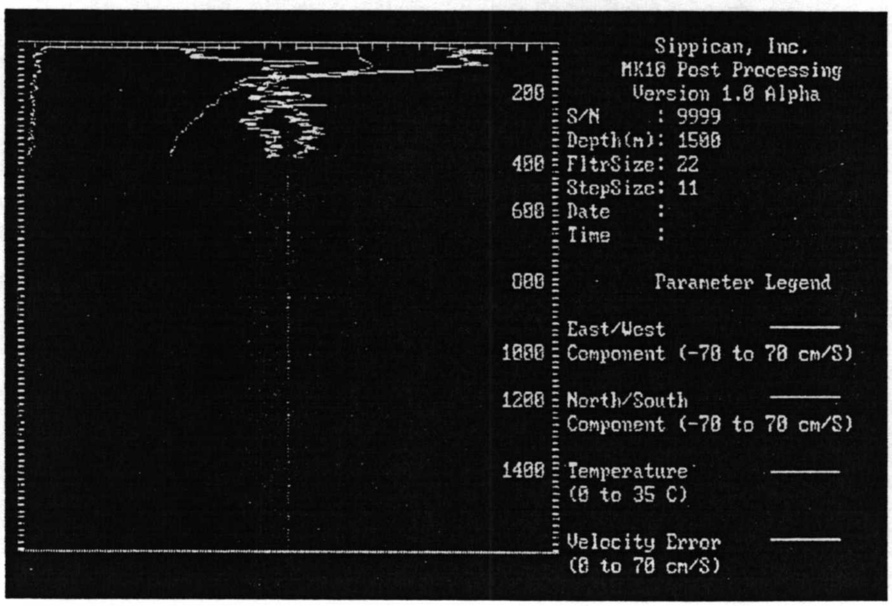

Figure 3.3-3. AXCP data file format and raw data plot from F06 station 4.

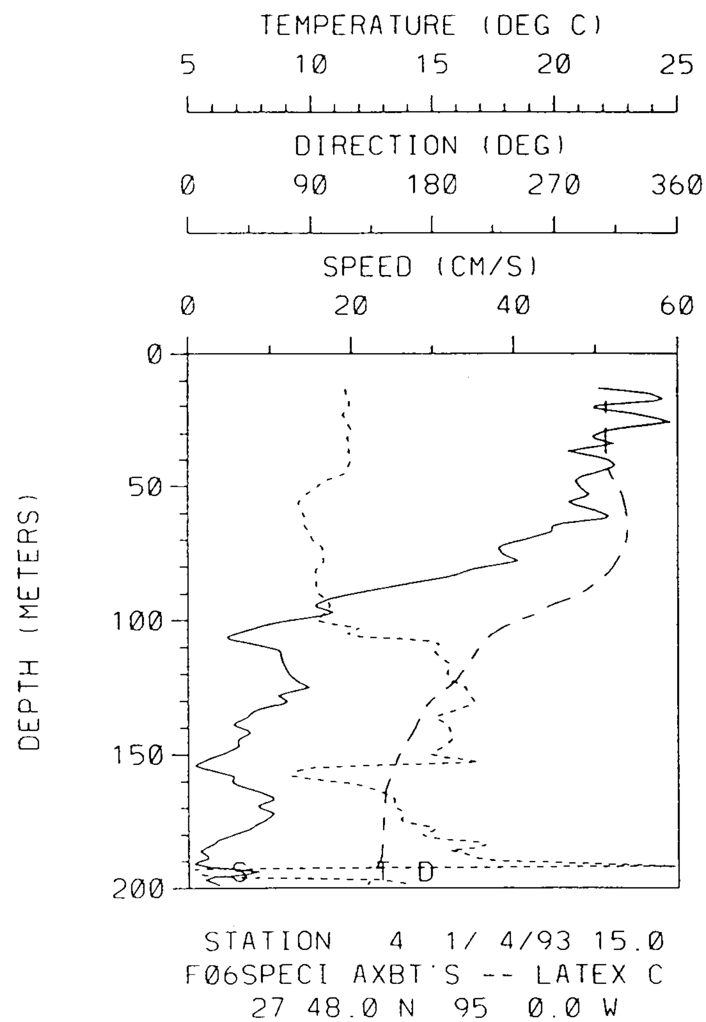

Figure 3.3-4. Plot of AXCP data from F06 station 4 after QA/QC.

3.3.2 Lagrangian Data

LATEX drifter data are received daily from the Service ARGOS U.S. Global Processing Center (USGPC) over the INTERNET. Drifter data for the shelf drifters deployed in LATEX A are also delivered daily to the LATEX A Data Office on INTERNET. The drifter data are also available through a dialup service (TYMNET) to the USGPC computer, and are thus available essentially in real time for use in the field to verify correct operation. These data include all transmissions received from each drifter and each position of the drifter determined by Service ARGOS. The files are edited to separate the position data for processing in the PODBMS, while the transmissions from the drifters are reviewed to evaluate qualitatively battery condition, drogue presence, and sea water temperature.

Interactive procedures remove all duplicate positions, verify the validity of each position fix, sort the data into a time-ordered sequence and archive the data into the PODBMS. Once loaded into the system, a final visual check is made on the data by plotting the individual buoy trajectories on a high-resolution map of the study area, which contains detailed bathymetry and coastline, and looking for spurious changes in the buoy's movement (see Figure 3-16, for example). The data are also written in *opcplot* format for placement on the GULF.MEX electronic bulletin board as shown in Figure 3.3-5.

```
07835,9301092100,-95.2733,26.2250,D
  009,9301092312,-95.3033,26.2750,B
  010,9301100030,-95.3267,26.2567,B
07835,9301100212,-95.3367,26.2733,L
07835,9301101000,-95.4383,26.3283,L
07835,9301101142,-95.4600,26.3417,L
07835,9301101254,-95.4733,26.3567,L
07835,9301101436,-95.4867,26.3667,L
07835,9301102118,-95.5717,26.4300,L
07835,9301102300,-95.5717,26.4483,L
  011,9301110154,-95.5950,26.4767,B
07835,9301110948,-95.6450,26.5617,L
07835,9301111130,-95.6550,26.5767,L
07835,9301111236,-95.6467,26.5883,L
07835,9301112106,-95.6850,26.6917,L
07835,9301112248,-95.6767,26.7067,L
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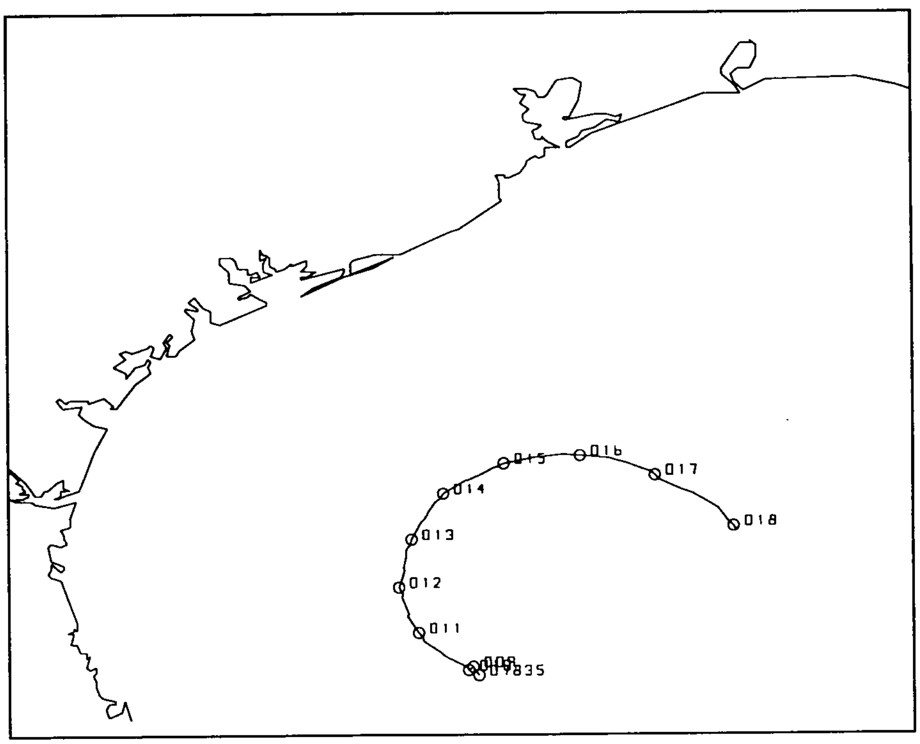
(a) Data file



(b) Graphic

Figure 3.3-5. Track of Drifter 7835 in *opcplot* format. (a) Portion of data file. (b) Graphic from *opcplot*.

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.