OCS Study
MMS 94-0029

Texas-Louisiana Shelf Circulation and Transport Processes Study: Year 1, Annual Report

Volume I: Executive Summary

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

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MMS 94-0029

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Volume I: Executive Summary

Editors

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1 INTRODUCTION

1.1 LATEX A Overview

The Minerals Management Service (MMS) of the U.S. Department of the Interior supports the Louisiana-Texas Shelf Physical Oceanography Program (LATEX). LATEX is divided into three study units. These are: Study Unit A, Texas-Louisiana Shelf Circulation and Transport Processes (LATEX A or LATEX Shelf); Study Unit B, Mississippi River Plume Hydrography (LATEX B or LATEX Plume); and Study Unit C, Gulf of Mexico Eddy Circulation (LATEX C or LATEX Eddy). LATEX A is the largest of the three studies and covers the middle and outer Texas-Louisiana continental shelf from the Mississippi River to the Rio Grande. This report focuses on the work of LATEX A from contract award in September 1991 through the end of the first field year, which was from April 1992 through March 1993. Per the contract, this report does not contain detailed analyses or interpretation of the data collected.

The contract for LATEX A was awarded to the Texas A&M Research Foundation on 30 September 1991. The Texas A&M University System, a combination of Texas institutions of higher learning and Texas state agencies dedicated to training, research, and extension, conducts the LATEX A Program. In addition to support from the MMS, financial backing for LATEX A is provided by the Texas Institute of Oceanography, the Texas Engineering Experiment Station, and Texas A&M University (TAMU), all components of the System. The System is assisted in this program by subcontracts with Evans-Hamilton, Inc. (EHI), Louisiana State University (LSU), and Maine Maritime Academy (MMA).

1.2 Program Objectives

In its original Request for Proposal (RFP), the MMS outlined four objectives for the LATEX A study:

1. To identify key dynamical processes governing circulation, transport, and cross-shelf mixing on the Texas-Louisiana shelf.

2. To upgrade existing empirical evidence on the same processes, fill in gaps in the evidence, synthesize the evidence into a scheme of circulation, and quantify transports and mixing rates.

3. To develop conceptual models of small- to large-scale processes and circulation features, from coastal plumes and fronts to shelf-edge eddy exchange, and large-scale shelf circulation, all on event- to seasonal scales.

4. To provide important physical and chemical information needed for synthesis with biological data into a broader ecological characterization of the region.

MMS modified this RFP to eliminate a coastal front array for the high resolution study of the coastal boundary layer and a dense array for study of the interactions between eddies and shelf circulation at high resolution. Elimination of these arrays reduced the range of scales of phenomena that could be studied in LATEX A to those with larger scales.

These objectives, as modified implicitly, will be met through the completion of a three-year field program of observations over the Texas-Louisiana continental shelf and the accomplishment of a series of 12 tasks, which are discussed in section 1.3. The observations will be synthesized, interpreted, and reported to provide a better understanding of the circulation and transports of properties over the shelf. This first annual report summarizes the progress that has been made on each of these tasks through 31 March 1993.

1.3 Program Tasks and Participants

There are 12 tasks in LATEX A in addition to program management and data management. Each task has a Principal Investigator who is responsible to the Program Manager for successful completion of that task.

Program Management: Program management is provided through the Program Management Office, under the direction of Dr. Worth D. Nowlin, Jr., Program Manager, and Dr. Ann E. Jochens, Deputy Program Manager.

Task A-1. Current Measurement Moorings: Mr. Robert C. Hamilton of EHI is the Principal Investigator of Task A-1. This task consists of the deployment and maintenance of 33 moorings with current meters, wave gauges, meteorological buoys, and inverted echo sounders. These moorings provide a shelf-wide network of current, temperature, and salinity time series with which to identify, characterize, and parameterize circulation processes. The moored array initially consisted of a boundary array along the shelf edge, cross-shelf arrays for study of along-shelf transports, a wild card array located in the southwestern portion of the study area to study the onshore migration of rings and small-scale phenomena, and two deep-water inverted echo sounders to monitor the westward passage of rings into the Texas-Louisiana shelf region. The wild card array is used to provide a source of spare instruments for the main array. Initially, the maintenance schedule called for cruises on 45-day intervals. After deployment of the array, the U. S. Coast Guard required the addition of lighted surface marker buoys on all moorings with equipment within 60.96 m (200 feet) of the sea surface and not within 30.48 m (100 feet) of a platform. As a result of this new requirement, the program was modified to provide cost savings that would enable the addition of lighted surface marker buoys to 14 moorings (numbers 4, 5, 6,7, 8, 9, 10, 11, 12, 13, 45, 47, 48, and 49). The modifications included a change in January 1993 to a maintenance schedule with cruises on 60-day intervals.

Task A-2. ARGOS-Tracked Drifting Buoys: Dr. Worth D. Nowlin, Jr., of TAMU is the Principal Investigator of Task A-2. The initial plan for this task was to deploy four satellite-tracked drifting buoys in each of four seasons during field year one for study of the continuity of alongshore flow. Drifter tracks and sea surface temperature were monitored through Service ARGOS. Equipment failures resulted in postponement of the third and fourth deployments into the second field year.

Task A-3. Standard Grid Hydrography: Dr. Denis A. Wiesenburg of TAMU is the Principal Investigator of Task A-3. The original LATEX A hydrographic sampling strategy consisted of 13 surveys of the Texas-Louisiana shelf over three years. One survey was to be conducted in each calendar season: spring, summer, fall, and winter. Each survey was to cover only one half of the shelf, with the eastern half covered in year one, the middle two quadrants in year two, and the western half in year three. The hydrographic/acoustic Doppler current profiler (ADCP) survey work was planned to characterize the seasonal patterns of circulation and water mass characteristics and to allow initial assessment of interannual variability. The basic elements of this plan were completed for the first field year. The program was modified, however, to provide coverage of the full shelf in May 1993, late July 1993, November 1993, May 1994, late July 1994, and, if funding allows, November 1994.

Task A-4, Acoustic Doppler Current Surveys: Mr. Robert C. Hamilton of EHI was the Principal Investigator for the first three surveys conducted under Task A-4, and Dr. Douglas C. Biggs of TAMU is the Principal Investigator for the remaining Task A-4 surveys. During all hydrographic surveys, Task A-4 personnel collect ADCP measurements along the cruise tracks to provide vertical profiles of currents.

Task A-6, Winter Northers/Cyclogenesis: Dr. S.A. Hsu of LSU is the Principal Investigator for Task A-6. This task consists of the deployment and maintenance of four meteorological buoys during the winter season and the study of cyclogenesis resulting from cold air outbreaks over the Texas-Louisiana shelf.

Data Management: Data management is provided through the Data Management Office, under the direction of Dr. Norman L. Guinasso, Jr., Data Manager. Several tasks are the responsibility of the Data Management Office. Dr. Guinasso is also the Principal Investigator for these tasks. Task A-5, Collateral Data, consists of the assembly of data from concurrent programs in the LATEX region and from historical sources. Task A-7, Data Quality Control, processes all LATEX A data for quality control. Task A-10, Information Transfer, maintains the GULF.MEX electronic bulletin board on Omnet and posts LATEX A information to it. Under Task A-11, Public Notification, Cooperation, and Data Dissemination, the *LATEX Fortnightly* newsletter is published and information on LATEX A is provided to federal agencies and the public.

Task A-8, Analyses and Reports: Dr. Worth D. Nowlin, Jr., and Dr. Ann E. Jochens are the Co-Principal Investigators of Task A-8. Under this task, the scientific analyses and syntheses of the data are performed and the annual reports to MMS are prepared and finalized.

Task A-9, Field Measurements/Model Comparisons: Professor Robert O. Reid of TAMU is the Principal Investigator for Task A-9. Under this task, comparisons of observational data and model results are performed and the LATEX Science Advisory Panel is supported. To accommodate the addition of the surface marker buoys, the number of meetings to be held by the Panel was reduced to one per year.

Task A-12, Government Furnished Equipment/Capital Equipment: Mr. Robert C. Hamilton of EHI is the Principal Investigator of Task A-12. At the conclusion of the field program, the Government Furnished Equipment will be refurbished and returned to MMS by the personnel under this task. Because this task does not commence until the end of the field program, this report will not include any further information regarding this task.

2 FIELD ACTIVITIES

2.1 Introduction

The first field year of LATEX A was conducted from April 1992 through March 1993. Data were collected from an array of current meter moorings, meteorological buoys, drifting buoys, and hydrographic/ADCP surveys on the Texas-Louisiana continental shelf in the Gulf of Mexico. Table 1 lists the LATEX A cruises and dates for the first field year. After collection, the data sets were processed for quality assurance and quality control. Historical and concurrent data from other programs in this region also were collected.

Table 1. Current mooring maintenance cruises and hydrographic surveys.

Current Mooring Maintenance Cruises

Cruise	Description	MMS I.D.	Start Date	End Date	LATEX ID	Cruise ID
1	Initial Deployment	M01CPW9203	04/07/92	04/16/92	M01	92P03
2	I-45 Day Maintenance	M02CPW9205	05/26/92	06/04/92	M02	92P05
3	I-90 Day Maintenance	M03CPW9206	07/13/92	07/27/92	M03	92P06
4	II-45 Day Maintenance	M04CPW9208	08/28/92	09/06/92	M04	92P08
5	I-180 Day Maintenance	M05CPW9209	10/13/92	10/23/92	M05	92P09
6A	III-45 Day ROV Work	M06CPW9212	11/28/92	12/06/92	M06A	*M/VAloha*
6B	III-45 Day Maintenance	M06CPW9212	12/08/92	12/18/92	M06B	92P12
7	Reinstallation	M07CPW9301	01/09/93	01/21/93	M07	93P01
8	I-60 Day Maintenance	M08CPW9304	03/16/93	03/24/93	M08	93P04

Hydrographic Surveys

Survey	Description	MMS ID	Start Date	End Date	LATEX ID	Cruise ID
1	Eastern Half Shelf	H01CGY9205	04/30/92	05/09/92	H01	92G05
2	Eastern Half Shelf	H02CGY9208	07/31/92	08/09/92	H02	92G08
3	Eastern Half Shelf	H03CPW9210	11/04/92	11/13/92	H03	92P10
4	Eastern Half Shelf	H04CGY9302	02/04/93	02/14/93	H04	93G02

2.2 Moored Measurements

The current meter array consisted of 75 current meters measuring current speed and direction, temperature, and conductivity on 31 moorings, five directional wave gauges measuring current speed and direction, temperature, and pressure near the sea floor; and two Inverted Echo Sounders measuring acoustic travel time and bottom temperature and pressure. Eight meteorological buoys, including the four Task A-6 buoys, were installed on the shelf to measure wind speed and direction, air and sea surface temperature, and barometric pressure. Table 2 lists the instrumentation that typically is installed on each mooring. Because of biofouling and losses from fishing activity, the moorings closer to the shore required maintenance on a more frequent basis than those located farther offshore. Table 2 also lists the maintenance schedule for each individual mooring, with the first value being the schedule under the 45-day cruise interval and the second under the 60-day cruise interval. Figure 1 shows the locations of the moorings and buoys.

Table 2. Typical mooring configurations.

Mooring No.	Water Depth (m)	Latitude (°N)	Longitude (°W)	Comments	Top Meter Depth	Middle Meter Depth	Bottom Meter Depth	Maintenance Interval (Day)
1	21	27°15.38'	97°14.74'	Platform	10m		19m	45/120
2	37	27°17.03'	96°58.81'	Platform	10m		30m	45/120
3	66	27°17.38'	96°44.17'	Platform	10m	30m	61m	90/120
4	201	27°07.57'	96°21.51'	MarkerBuoy	12m	100m	190m	90/120
5	199	27°28.10'	96°04.40'	MarkerBuoy	12m	100m	190m	90/120
6	201	27°42.51'	95°39.84'	MarkerBuoy	12m	100m	190m	90/120
7	199	27°50.04'	95°04.17'	MarkerBuoy	12m	100m	190m	90/120
8	201	27°49.47'	94°10.77'	MarkerBuoy	14m	100m	190m	90/120
9	200	27°48.50'	93°30.18'	MarkerBuoy	12m	100m	190m	90/120
10	200	27°56.13'	92°44.70'	MarkerBuoy	12m	100m	190m	90/120
11	200	27°50.52'	92°00.55'	MarkerBuoy	12m	100m	190m	90/120
12	505	27°55.43'	90°29.68'	MarkerBuoy	17m	100m	190m	180/180
13	200	28°03.45'	90°29.15'	MarkerBuoy	12m	100m	190m	90/120
14	47	28°23.67'	90°29.57'	Platform	11m	26m	42m	45/60
15	27	28°36.50'	90°29.49'	Platform	10m		24m	45/60
16	19	28°52.02'	90°29.45'	Platform	10m		17m	45/60
17	7	29°11.76'	91°57.89'	MetBuoy;Platform	3m		5m	45/60
18	22	28°57.76'	91°58.96'	Platform	10m		21m	45/60
19	51	28°27.91'	92°02.09'	MetBuoy;Platform	3m	21m	44m	45/60
20	15	29°15.65'	94°03.82'	MetBuoy;Platform	3m		13m	45/60
21/51	24	28°50.24'	94°04.77'	MetBuoy;Platform	10m		21m	45/60
22	55	28°21.29'	93°57.35'	MetBuoy;Platform	3m	20m	48m	45/60
23	15	28°42.77'	95°32.13'	Platform	9m		13m	45/60
24	30	28°28.43'	95°26.23'	Platform	11m		27m	45/60
25	45	28°09.72'	95°28.54'	Platform	13m	23m	38m	45/60
42	1540	27°07.02'	92°00.00'	IES;at sea floor			1540m	360/360
43	3130	25°32.52'	92°00.00'	IES;at sea floor			3130m	360/360
44	56	27°43.53'	96°25.44'	MarkerBuoy	9m		49m	90/120
45	200	27°25.09'	96°07.59'	MarkerBuoy	10m		190m	90/120
46	91	27°38.28'	96°14.02'	Platform	10m	50m	84m	90/120
47	200	27°19.30'	96°12.77'	MarkerBuoy	10m	100m	190m	90/120
48	200	27°58.98'	91°17.00'	MarkerBuoy	10m	100m	190m	90/120
49	505	27°22.15'	95°53.64'	MarkerBuoy	10m	100m	495m	180/180
50	20	28°52.86'	95°02.20'	MetBuoy;Platform				45/60
51/21	24	28°50.24'	94°04.77'	MetBuoy;Platform	10m		21m	45/60
52	27	28°48.24'	93°01.07'	MetBuoy;Platform				45/60
53	15	28°48.03'	90°57.26'	MetBuoy;Platform				45/60

MetBuoy = DSI Surface Meteorological Buoy; Marker Buoy = Lighted Surface Marker Buoy;
IES = Inverted Echo Sounder; blank=No instrument

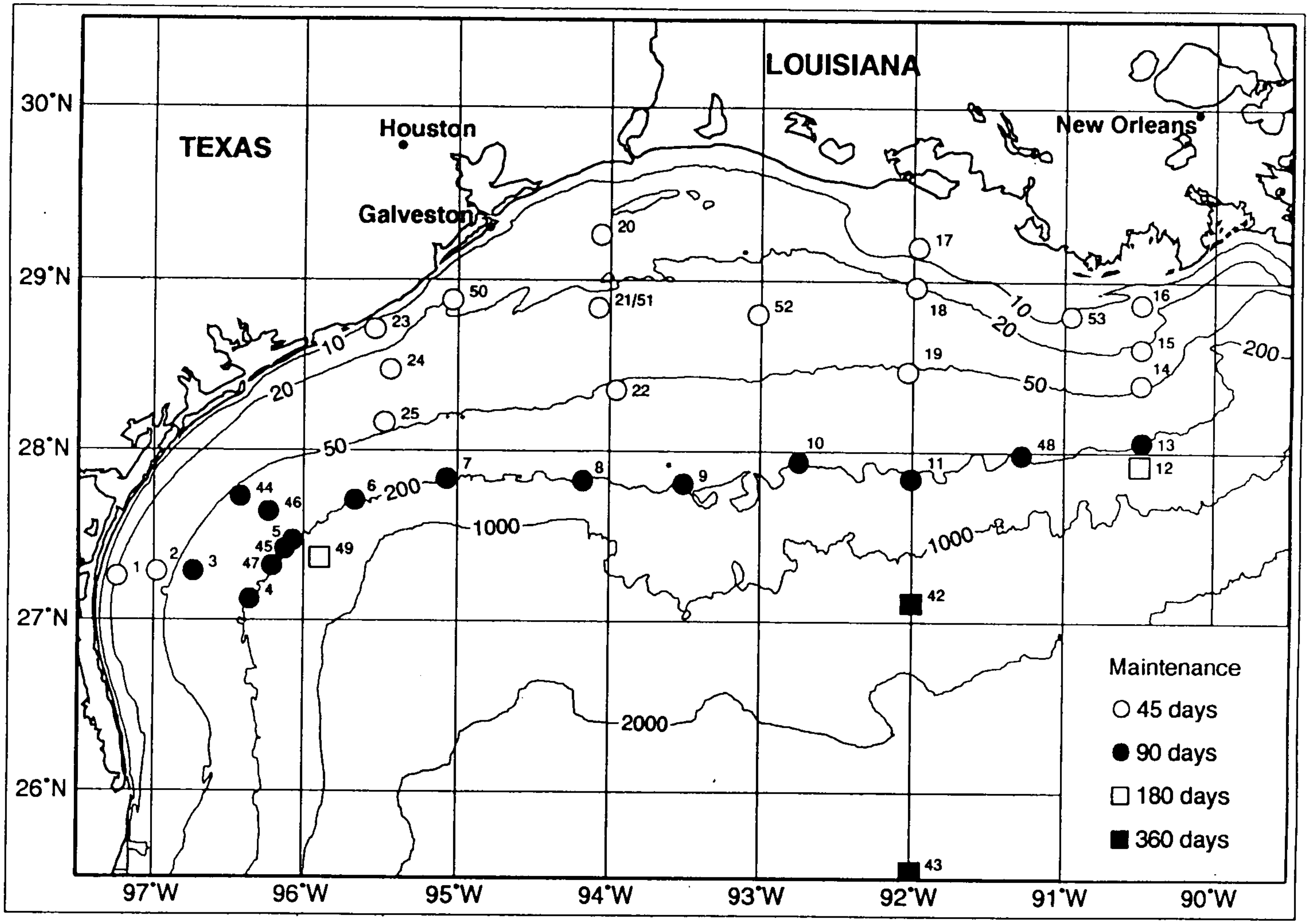

Figure 1. Moored array locations.

2.3 Drifting Buoy Measurements

Nine drifting buoys were deployed during the hydrographic surveys, four in August 1992 and five in November 1992. They were deployed inshore and offshore of the coastal boundary frontal zone, mid-shelf, and over the outer shelf near the continental shelf break (~100 m isobath). The drifters deployed at the shelf break on the November cruise did not return any data. The other drifters provided information on their locations and sea surface temperature via satellite. The mean lifetime of the seven drifters that functioned was 82 days with a range of six to 266 days. The drifters that escaped the inner-shelf survived longest.

2.4 Hydrographic/ADCP Measurements

Four hydrographic/ADCP surveys were conducted with over 100 hydrographic sampling stations per survey and continuous ADCP measurements along the cruise track. Figure 2 shows a typical cruise track and station locations. At each hydrographic sampling station continuous profiles were made of conductivity, temperature, dissolved oxygen, downwelling irradiance, particle scattering, fluorescence, and beam attenuation. Up to 12 water samples were taken at each station and analyzed for six nutrients: nitrate, nitrite, phosphate, silicate, urea, and ammonium. At 40 or more of the stations, the water samples were analyzed for dissolved oxygen, salinity, phytoplankton pigments, and the surface and bottom particulate matter concentrations. Secchi disk depths were taken at each daylight station. Meteorological measurements were transmitted to the Global Telecommunications System four times a day. Table 3 shows the type of measurements made and the number of scientific participants on each of the four surveys.

2.5 Collateral Data

Information from historical or concurrent programs on the Texas-Louisiana shelf is being collected to augment the LATEX A data set and to aid in interpretations. This is the collateral data. Historical records from hydrographic surveys on the shelf were compiled and examined for quality. Sixty-one were identified as potentially useful for the LATEX A study. Historical information on temperature, salinity, surface waves, tidal currents, and ocean models also was collected. Concurrent data were obtained from numerous other programs collecting oceanographic data in the LATEX region during the first field year, including data from LATEX B and C and weather buoy data from NOAA.

2.6 Observations/Model Comparison

A key element in the LATEX A program is to provide a setting in which relevant observational data from the components of LATEX may be compared with the results from the MMS modeling efforts directed at the Texas-Louisiana shelf and adjoining continental slope. The purpose of this observation/model comparison is to aid in the development and validation of numerical models of shelf circulation. During the first field year of LATEX, the MMS models were under development. No graphics from model simulations were provided to LATEX A for comparison with standard computer-produced graphics of the data.

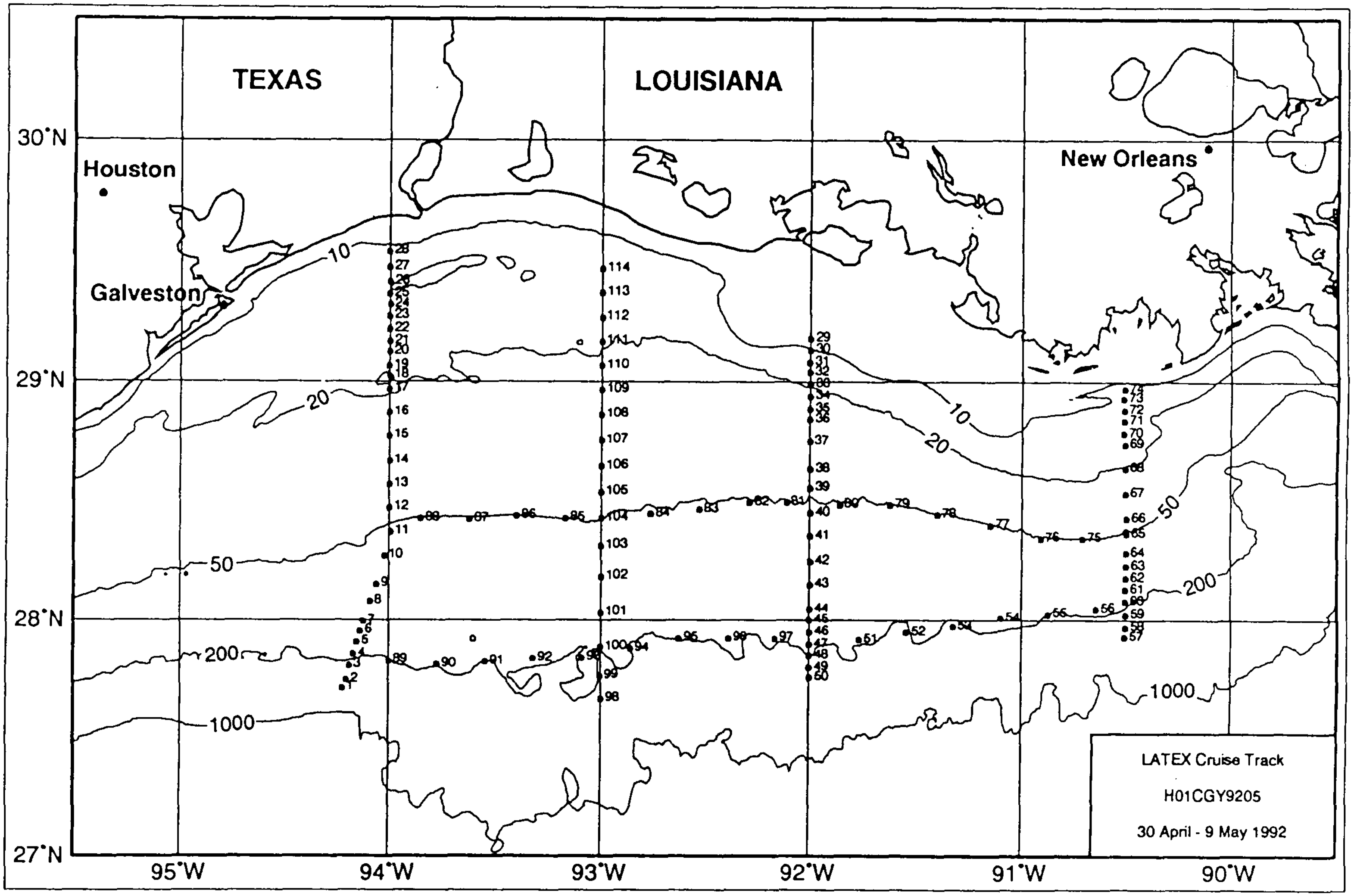

Figure 2. Typical hydrographic/ADCP cruise track and station locations.

Table 3. Summary of data collected and participation in hydrography surveys.

Description	H01 May 1992	H02 Aug. 1992	H03 Nov. 1992	H04 Feb. 1993
Cruise Duration (days)	9	9	9	9
Cruise Track (km)	1117	1050	1050	1080
Total Hydro Stations	114	124	114	119
CTD Stations	114	124	114	118
Nutrient Stations	114	118	114	118
Oxygen Stations	64	72	77	80
Salinity Stations	64	73	68	71
Pigment Stations	83	88	85	87
Particulate Stations	52	50	56	58
Secchi Disk Stations	51	59	45	47
Weather Obs	27	30	32	30
Nutrient Samples	936	1008	955	932
Salinity Samples	485	588	461	556
Oxygen Samples	481	590	544	636
Pigment Samples	644	689	701	900
Particulate Samples	107	93	116	122
Drifters Deployed	0	4	5	0
Total Scientific Party	20	20	17	22
LATEX Scientists	14	16	14	18
Guest Investigators	6	4	3	5
Graduate Students	5	8	8	9
Complementary Studies	5	4	3	4

To assist and advise in the observations/model comparison effort, a team of experts in coastal physical oceanography, the LATEX Science Advisory Panel (SAP), was assembled prior to the initiation of the field program. The members of the SAP and their affiliations are: John S. Allen (Oregon State University), John D. Cochrane (Texas A&M University, retired), George Z. Forristall, Chairman (Shell Development Company), A. D. Kirwan (Old Dominion University), Dong-Ping Wang (SUNY - Stony Brook), Clinton D. Winant (Scripps Institution of Oceanography), and William J. Wiseman, Jr. (Louisiana State University). Two meetings of the SAP were held during the first annual report year. The first meeting was 26-29 May 1992, the second 1-4 December 1992, both held in New Orleans. Recommendations from the meetings addressed aspects of data collection strategy and identified specific events for which model simulations should be carried out by the MMS-supported modelers.

3 TECHNICAL DISCUSSION

3.1 Introduction

This first annual report focuses on the data collection and processing activities of LATEX A. As required by the contract, it contains representative graphical products and no analysis of the data. Below are given five examples of the representative products that are associated with interesting phenomena. See Volume II of this report for additional products and discussion.

3.2 Low-Frequency Circulation

One goal of the LATEX A study is to test the Cochrane and Kelly (1986) seasonal circulation schema. Cochrane and Kelly used monthly mean geopotential anomaly maps based on the *GUS III* data to infer a general seasonal circulation pattern. This pattern projects an elongated cyclonic gyre extending from the Rio Grande to the Mississippi River Delta. This gyre persists from September to May, with the center of the low migrating upcoast during this period. During June through August, when winds are dominantly out of the southeast to southwest, the coastal current reverses, initially in the coastal bend region and then progressing upcoast, resulting in an anticyclonic cell centered off the Texas-Louisiana border in July and August.

Preliminary results from LATEX A indicate that the Cochrane and Kelly (1986) seasonal circulation schema is supported generally for the field year in question. The hydrographic data for the LATEX A hydrographic cruises carried out over the eastern half of the study region during May, August, and November 1992, and February 1993, were used to calculate the geopotential anomaly (in dynamic cm) of the three decibar surface (about 3-m depth) relative to the 160 decibar (≈ 160-m depth) surface. Data from the cruises in non-summer months generally have a large cyclonic region (low or lows) over the midshelf region. This is the feature shown by Cochrane and Kelly (1986) in their monthly mean geopotential anomaly maps except for July and August. The feature implies downcoast (westward or southward) flow for the inner shelf and upcoast (northward or eastward) flow for the outer shelf and slope regions. In May 1992, this pattern was very prominent (Figure 3). The major feature of the August 1992 geopotential field is the relatively strong, largely eastward flow extending across the entire extent of the observations (Figure 4). Here again the indicated geostrophic flow provides confirmation of the flow proposed by Cochrane and Kelly. Their picture is of a prevailing eastward flow in July and the first half of August. It should be noted, however, that in the east the eastward flow is interrupted by a ribbon of westward current near 29°N. Current roses (not shown) for the first field year also support the Cochrane and Kelly circulation schema.

3.3 Eddy-Shelf Interactions

The Loop Current, which enters the Gulf of Mexico through the Yucatán Straits and through the Florida Straits, sheds anticyclonic eddies which then move westward into the western Gulf. The trajectory, velocity components, and speed of drifter 2447, shown in Figure 5, provide evidence of the interaction of an eddy with the shelf. Within a fortnight of its release on the shelf, drifter 2447 was pulled off into the deeper waters of the central Gulf. For a month drifter 2447 moved in an anticyclonic orbit approximately 100 km in diameter, at speeds between 50 and 150 $cm{\cdot}s^{-1}$. The associated eddy was identified in infrared images by Jeff Hawkins (NRL-Stennis), who estimated the eddy

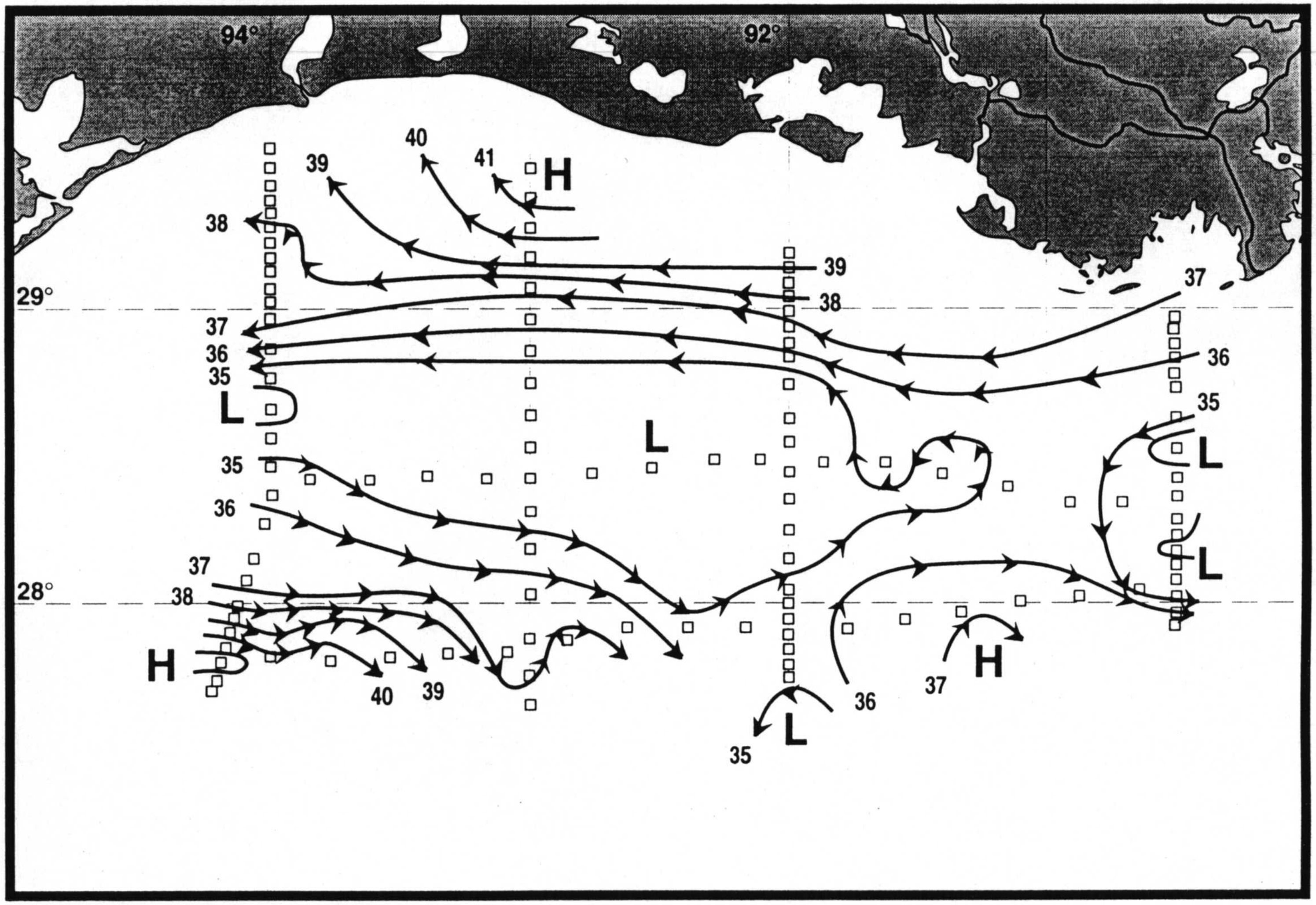

Figure 3. Geopotential anomaly at 3 decibars relative to 160 db. for LATEX A cruise of May 1992. Arrows indicate the direction of geostrophic flow.

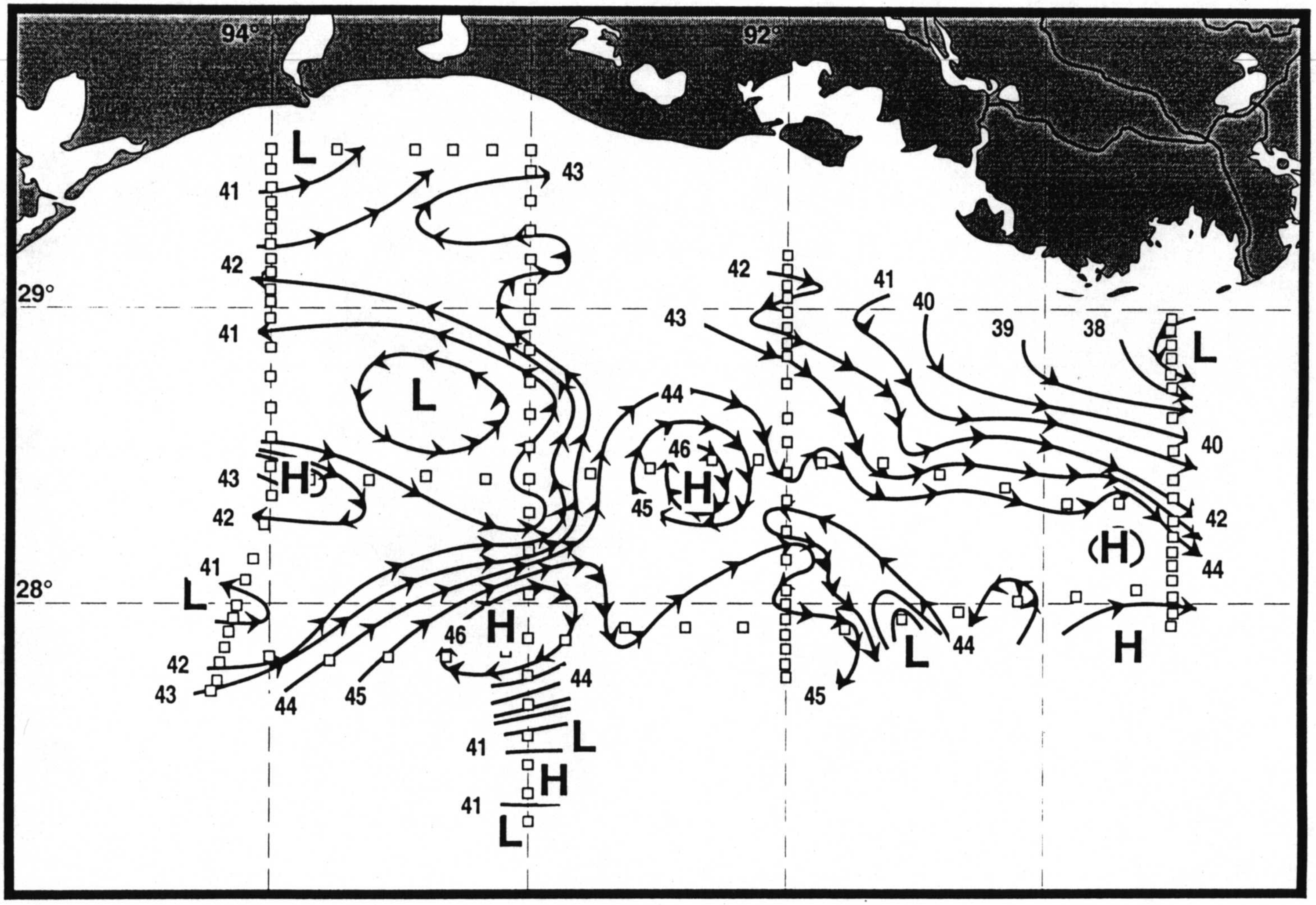

Figure 4. Geopotential anomaly at 3 decibars relative to 160 db. for LATEX A cruise of August 1992. Arrows indicate the direction of geostrophic flow.

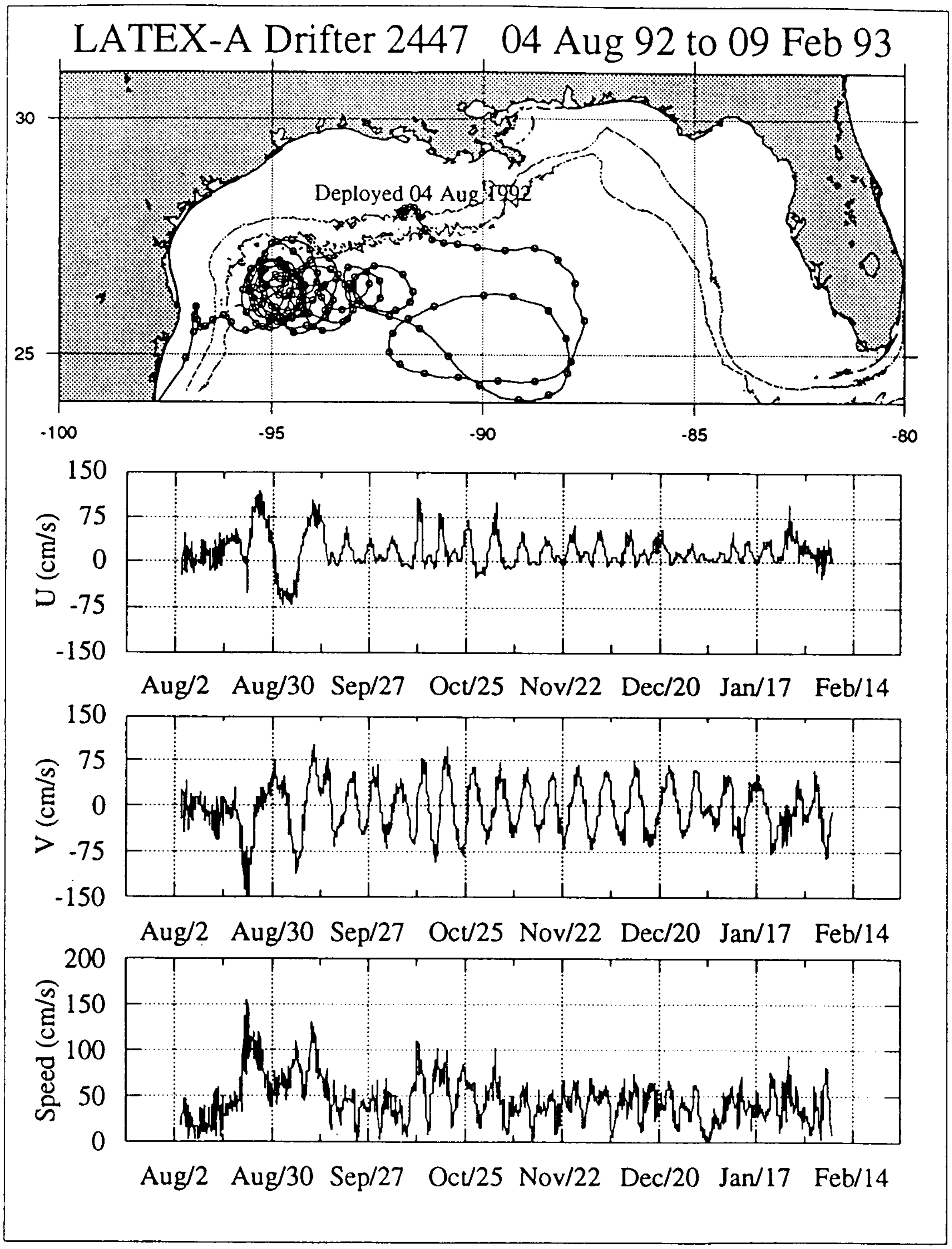

Figure 5. Trajectory of drifter 2447 August 1992 to February 1993 with U (East) and V (North) velocity components and speed. Circles on the trajectory trace represent the drifter's position at midnight each day. This drifter was captured after 185 days.

diameter to be 300 km. This was an eddy named "Unchained Eddy" that had detached from the Loop Current sometime in July. During the last four days of the record, drifter 2447 appeared to be onboard a vessel which ultimately docked at Boca Jesus Maria, Mexico.

3.4 Inertial Oscillations

Dramatic, energetic, near-inertial oscillations are triggered over this shelf by the passage of atmospheric fronts. Several such frontal passages occurred during July 1992. Each event seems to result in near-inertial ringing for a week or more. The oscillations appear to be coherent over large areas of the shelf, and they are more energetic at the shelf break, decreasing in energy shoreward and rapidly offshore.

3.5 Hurricane Andrew

Mooring 13 was located at 28°03.45'N and 90°29.15'W on the outer Louisiana shelf in water depth of approximately 200 m. Mooring 14 was located approximately 20 miles to the north. The eye of Hurricane Andrew passed northwest over the Louisiana shelf on 25-26 August 1992; at about 2300 UTC on 25 August it passed about 10 km east of mooring 14. During this passage, recorded current speed at 11 m on mooring 14 reached 134 $cm{\cdot}s^{-1}$. However, the 12-m currents at mooring 13 were even greater; see the 3-hr, low-passed current in Figure 6. At 100 m on this mooring, the 3-hr, low-passed currents peaked at a speed of about 70 $cm{\cdot}s^{-1}$. At 190 m on the same mooring they exceeded 100 $cm{\cdot}s^{-1}$. For the current record shown, note how small and relatively steady were the currents until 21-22 August at which time a generally westward along-shelf component of current began to increase gradually. The record at 190 m shows similar behavior. Then, on 25 August, the current at 12 m increased dramatically toward the southwest followed about 1 day later by similarly changing currents at 190 m. Following the passage of Andrew, very energetic inertial oscillations continued for about two weeks at meters affected by the hurricane.

3.6 Cyclogenesis and the "Storm of the Century"

To study the intensity of winter cyclogenesis over the Gulf of Mexico, a classification scheme based on the approximate balance between the centrifugal force and the pressure gradient of the storm was devised by Hsu (1993). Based on this classification, there were eight winter cyclogenesis cases between November 1992 and May 1993 (Table 4). Typically, there are approximately 10 cyclogenesis events per year (Johnson et al. 1984).

Note that among the eight cyclogenesis events that occurred, the one that developed on 12 March 1993 over the southern LATEX region was a class four cyclone and later evolved into the Blizzard of 1993, which some refer to as the Storm of the Century (Hsu 1993). During the initial cyclogenesis stage of this storm both air and sea-surface isotherms were generally oriented along the isobaths, with the gradient larger over the southwestern than over the northeastern shelf (Figures 7 and 8). Figure 9 is a current meter record for March 1993 from 12 m at mooring 25. The pronounced affects of the cyclone are clear in the records. For the current records associated with these cyclones that were examined, the generation of the near-inertial motion so prominent with many frontal passages is not seen.

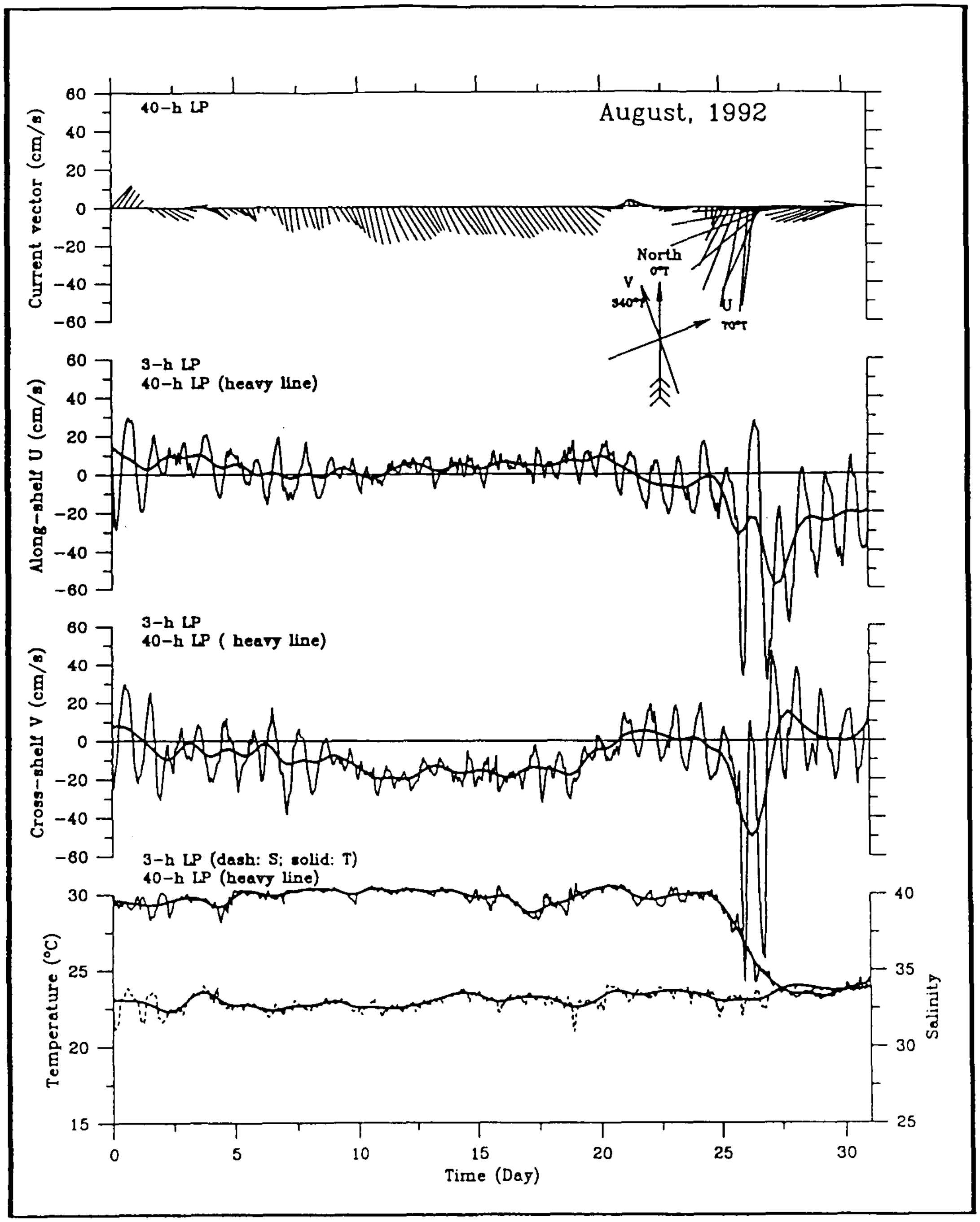

Figure 6. Monthly plot of current velocity (40-hour stick vectors, and 3- and 40-hour low passed components), and temperature and salinity (3- and 40- hour low passed) at 12 m for mooring 13, August 1992.

Table 4. Winter cyclogenesis over the northwestern Gulf of Mexico from November 1992 through May 1993.

Year	Month	Day	Intensity*
1992	November	4	2
	November	24	3
	December	9	2
	December	15	3
1993	February	22	2
	March	12	4
	April	8	3
	May	12	1

*The intensity classification is based on Hsu (1993). The data source is "Daily Weather Maps," published weekly by NOAA.

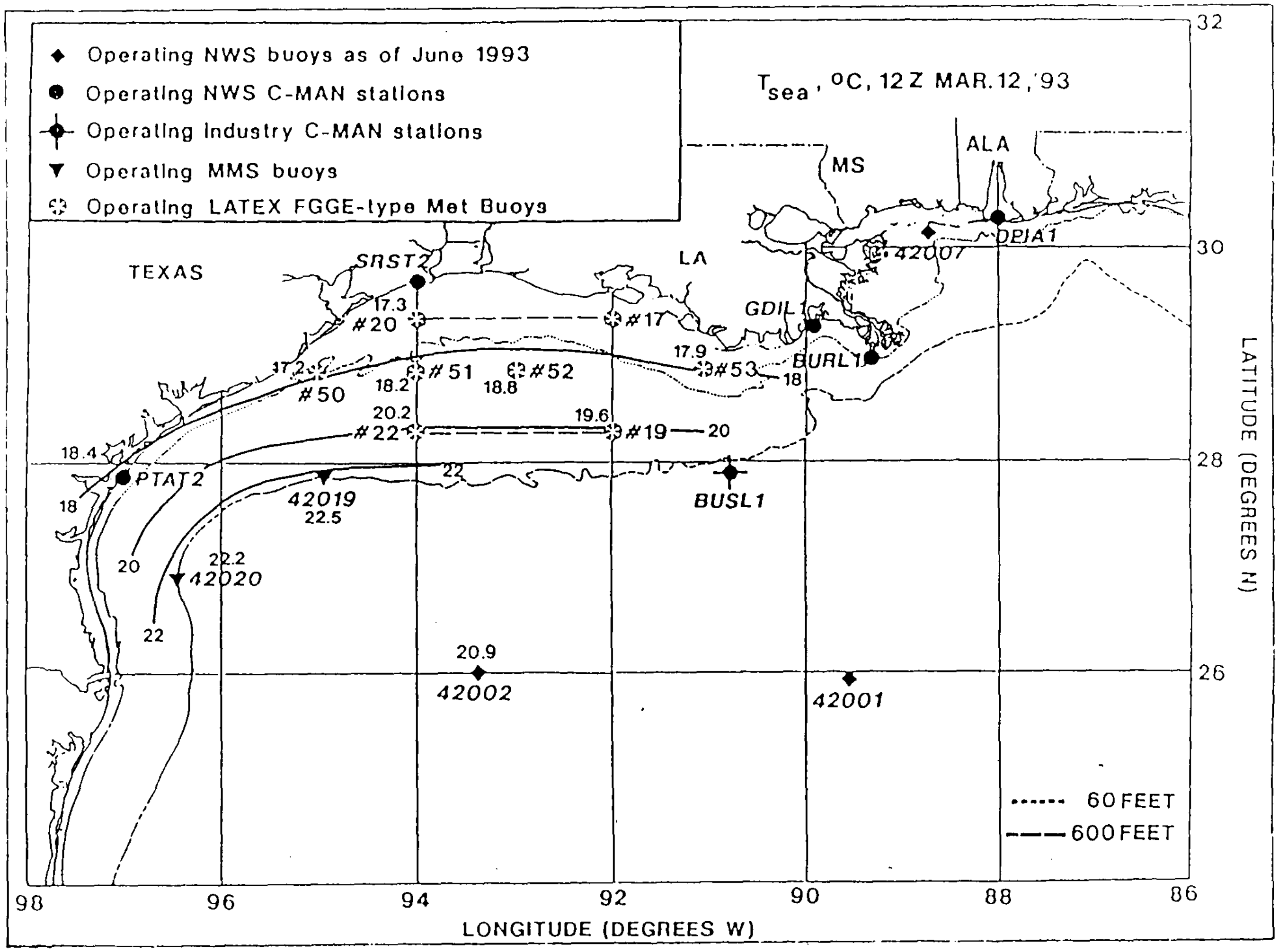

Figure 7. The distribution of the sea-surface temperature at 12 UTC, on 12 March 1993 during the initial stage of the "Storm of the Century."

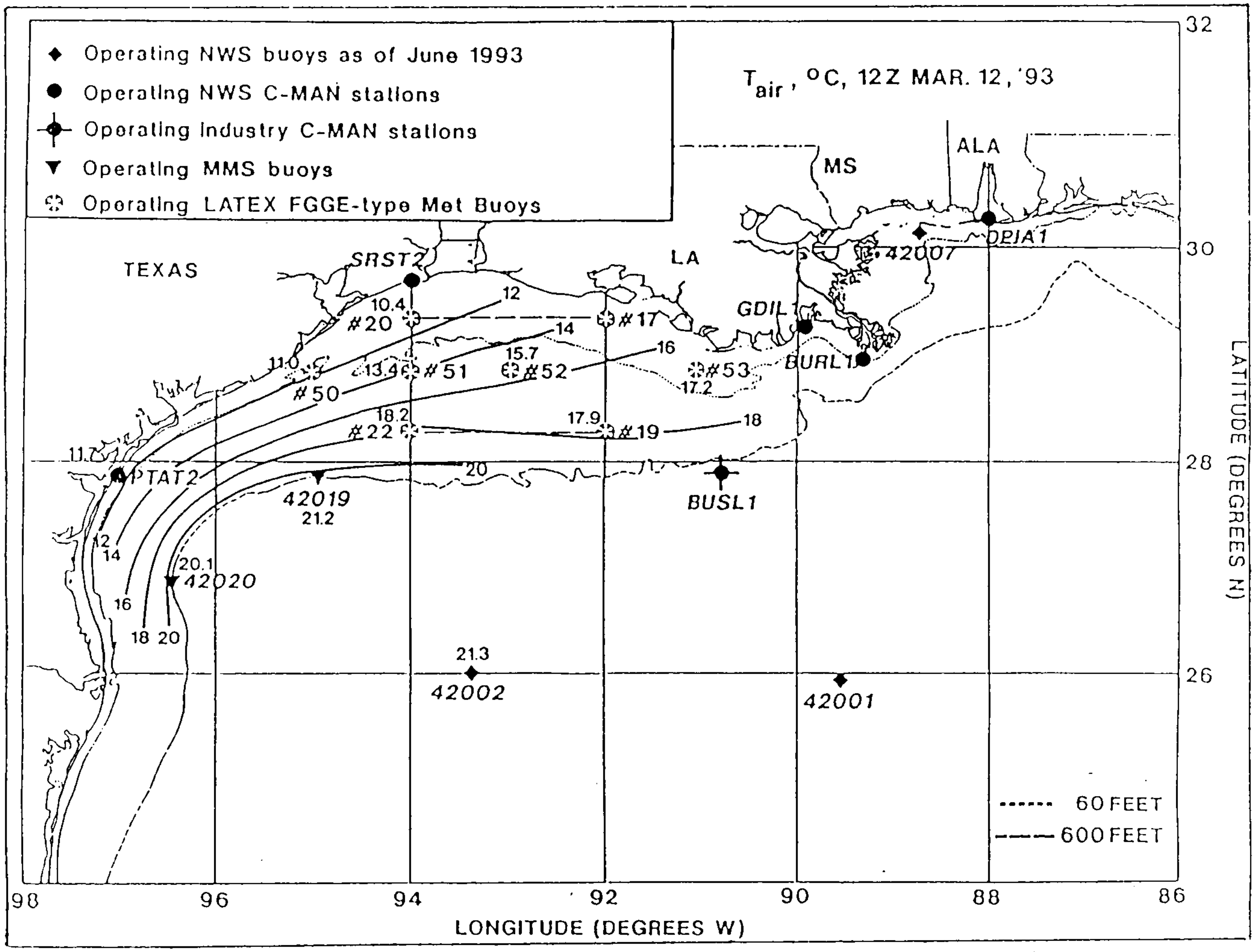

Figure 8. The distribution of the air temperature at 12 UTC, on 12 March 1993 during the initial stage of the "Storm of the Century."

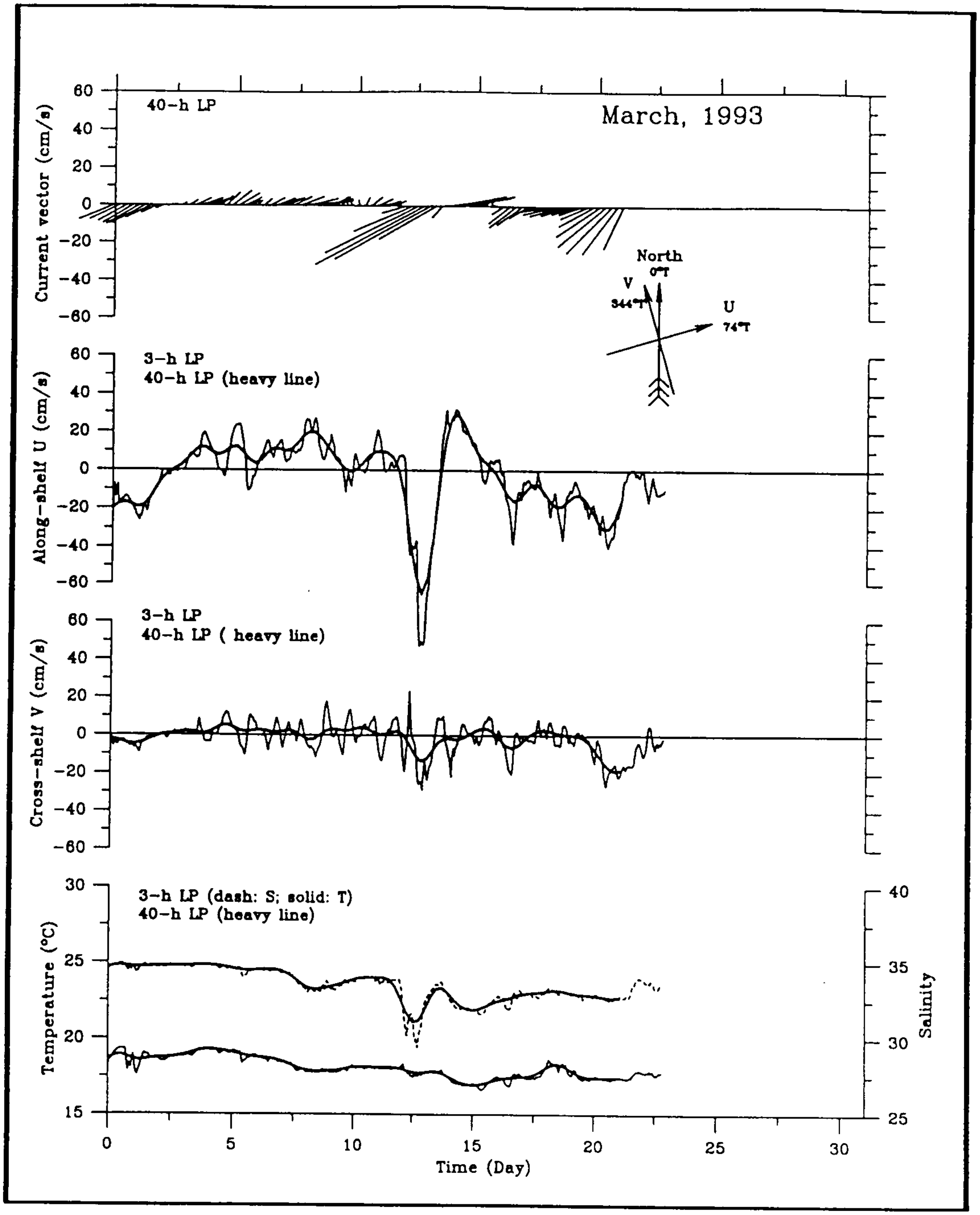

Figure 9. Monthly plot of current velocity (40-hour stick vectors, and 3- and 40-hour low passed components), and temperature and salinity (3- and 40- hour low passed) at 12 m for mooring 25, March 1993.

4 REFERENCES

Cochrane, J.D. and F.J. Kelly. 1986. Low-frequency circulation on the Texas-Louisiana continental shelf. Jour. Geophys. Res. 91(C9):10,645–10,659.

Hsu, S.A. 1993. The Gulf of Mexico - a breeding ground for winter storms. Mariners Weather Log 37(2):4-11.

Johnson, G.A., E.A. Meindl, E.B. Mortimer, and J.S. Lynch. 1984. Features associated with repeated strong cyclogenesis in the western Gulf of Mexico during the winter of 1982-83. In *Postprints, Third Conference on Meteorology of the Coastal Zone*, pp. 110-117. Amer. Meteorol. Soc., Boston, Mass.

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.