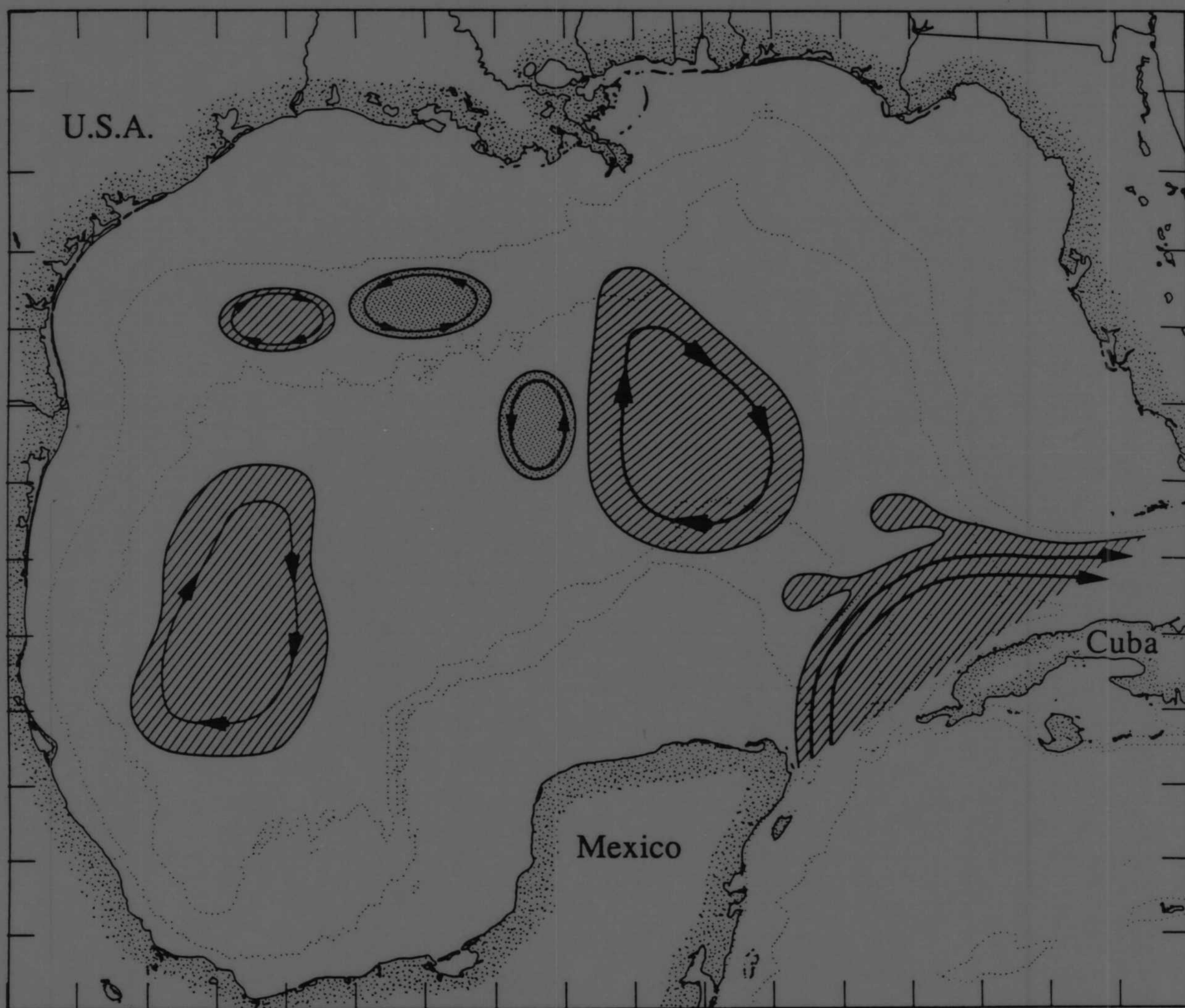
OCS Study
MMS 89-0067

Gulf of Mexico Physical Oceanography Program Final Report: Year 5

Volume I: Executive Summary



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U.S. Department of the Interior
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Gulf of Mexico OCS Region

OCS Study
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Gulf of Mexico Physical Oceanography Program Final Report: Year 5

Volume I: Executive Summary

Author

Science Applications International Corporation

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by
Science Applications International Corporation
Raleigh, North Carolina 27606

Program Manager:
Evans Waddell, Ph.D.
Science Applications International Corporation
Raleigh, North Carolina 27606

Project Officer:
Murray L. Brown, Ph.D.
Minerals Management Service
Gulf of Mexico OCS Regional Office

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Gulf of Mexico OCS Regional Office
1201 Elmwood Park Boulevard
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Attention: Public Information Unit (OPS-3-4)

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ABOUT THE COVER

The cover illustration suggests the richness of the mesoscale eddy field in the Gulf of Mexico. Clockwise and counterclockwise rotating features have a wide range of sizes, are seen in most areas of the Gulf and are a major influence on circulation patterns.

TABLE OF CONTENTS

LIST OF FIGURES

I. EXECUTIVE SUMMARY

1.1 Overview

In October 1982, MMS initiated a multiyear, regionally phased physical oceanographic field program with the long-term goal of developing an improved understanding of the characteristics and influence of circulation patterns and processes in and adjacent to the deeper regions of the Gulf of Mexico. In keeping with this objective the majority of measurements have been made offshore of or proximate to the shelf break.

The multivariate observational data base has and should continue to be used by oceanographers to describe key current patterns and where possible to relate these to causative mechanisms. Three general areas of the Gulf of Mexico have been studied. During Years 1,2 and 4, consecutive and continuous measurements were made in the eastern Gulf, primarily from the middle of the west Florida shelf, seaward across the slope and into and under the Loop Current (LC) and in the deep Gulf. A key objective was to better understand slope and rise circulation patterns and the influence these had on the adjacent shelf. To resolve Loop Current effects required an evaluation of other mechanisms forcing water motion on the middle and outer shelf.

Measurements, analysis and interpretation in Program Year 3 emphasized the western Gulf of Mexico with particular attention given to major anticyclonic eddies which separate from the Loop Current and move westward to eventually interact with the western Gulf slope. These eddies appear to be a primary influence on circulation and conditions in deeper portions of the central and western Gulf, over the adjacent slope, and in some cases the outer shelf.

In the present Year 5 Program, the objective has been to look at physical oceanographic conditions along a transect normal to the north central slope and shelf (92°W) extending from the inner shelf to the deep Gulf (Figure 1.1-1). It is results from this final program year which are discussed in this report.

1.2 Program Year 5 Objectives

As reflected in the experimental design and the suite of observations, Year 5 involved:

- Documenting and developing an improved understanding of circulation on the Louisiana shelf just west of the major estuaries. These estuaries are a primary source of low salinity water and other constituents.

- Identifying the characteristics and causes of adjacent slope circulation. This, in fact, incorporates consideration of processes associated with the movement of anticyclonic Loop Current eddies. These transit the study area during their westward movement.

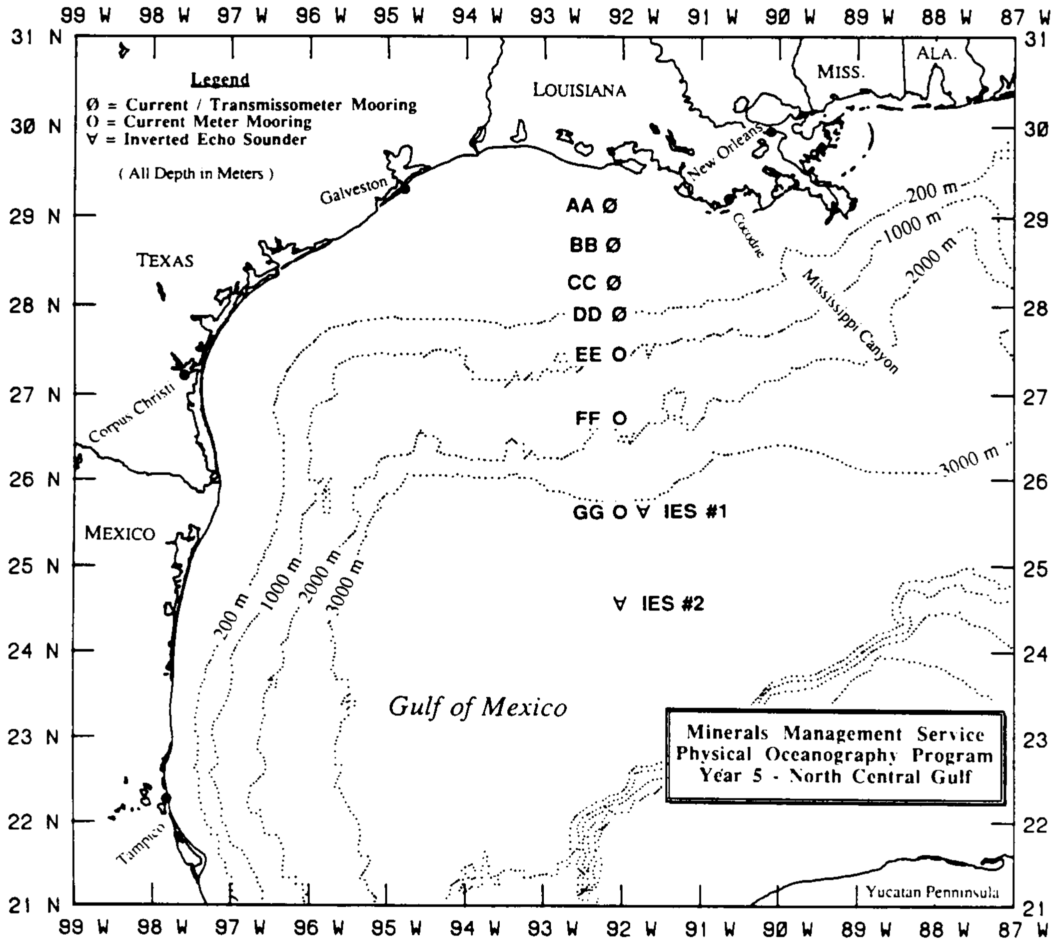

Figure 1.1-1. Map of general study area. Moorings along 92°W are part of the Year 5 program.

- Continue multi-year documentation of LC eddy dynamics and kinematics during evolution and westward translation. The irregular and relatively long eddy-shedding interval resulted in this being a component of almost all program years. This long-term commitment assured that sufficient realizations would be available to begin documenting the range of conditions and paths which these major features may have.
- Initiate documentation of optical properties of the west Louisiana shelf waters.

Measurements made to support the above objectives included: moored current/temperature arrays, periodic hydrographic CTD/XBT/AXBT surveys, satellite thermal imagery, Lagrangian drifters, inverted echo sounders, and a suite of measurements characterizing the optical absorption and transmission characteristics of the shelf water.

1.3 Program Participants

Scientific and technical responsibilities were distributed over personnel from SAIC and several universities and research institutes. Key people and their affiliations are:

Dr. David Brooks (Texas A&M University)
Dr. P. Hamilton (SAIC)
Dr. N. Højerslev (University of Copenhagen)
Dr. J. Lewis (SAIC)
Dr. W. Wiseman (Louisiana State University)
Dr. F. Vukovich (Research Triangle Institute)
Mr. R. Wayland (SAIC)
Mr. J. Singer (SAIC)
Dr. T. Berger (SAIC)
Mr. F. Kelly (Texas A&M University)
Dr. E. Waddell (SAIC)

In addition, Dr. V. Vidal of the Electrical Power Institute of Mexico and Dr. D. Biggs (TAMU) worked cooperatively with this MMS program to provide an expanded survey data base which has been of substantial assistance in developing the characterizations and understandings of conditions in the deep Gulf.

Because of the integrated nature of the design, analysis and collaboration, it would be a disservice to try and isolate specific topics or responsibilities to each of these individuals. Suffice it to say, these participants provided a concerted group effort which produced the insights and understandings presented in this report.

II. TECHNICAL DISCUSSION

2.1 Introduction

Presented below will be an overview of the study area and a description of some of the key insights developed and described in detail in the Technical Volume of this Year 5 Final Report.

2.2 Long Term Variability

The Ship-of-Opportunity (SOOP) data combined with a ten-year set of monthly (six-months/year) frontal maps provided a valuable data base to examine long-term characteristics of Loop Current and related eddy processes. The frequent SOOP temperature sections, which were spatially dense but irregular in time, provided valuable insight to Loop Current and eddy mean statistics and variability. SOOP transects showed that the Loop Current boundaries exhibited low frequency variability with periods of over a year. This was reflected in a long interval (14 months) when the LC was well away from the west Florida slope and apparently did not shed eddies. In contrast, much of the rest of the seven to eight year record showed consistent ranges of variability with eddy shedding periods ranging from four to 12 months with a mean of about seven months. These records also provided insights to the movement and characteristics of deep water cyclones which may be linked to LC anticyclones (Figure 2.2-1).

Digitization and contouring of monthly frontal maps showed the mean distribution of Loop Current and eddy fronts, and the warmer water contained within these fronts. The LC frontal probability maps (Figure 2.2-2) tend to have the classical configuration, however, it should be remembered that these are statistical representations reflecting the probability of occurrence. A similar presentation for eddy fronts shows the general path as major eddies translate westward. These statistics should provide an estimation of the probability of occurrence at particular sites.

2.3 Loop Current Eddies - Lagrangian Frame

Using drifters, a further range of eddy motions was documented and analyzed. Observations over the several years of this program have illustrated and characterized the basic mode of LC surface eddy circulation. They are rotating (period = 10 to 15 days), westward translating (~ three to seven km day^{-1}) masses of relatively warm water which have horizontal shear and normal deformation and convergence/divergence. Clearly, they are complicated phenomena. An explanation for the basic rotation and westward translation is available. However, understanding how all the various components adjust in response to interaction with other circulation patterns and the continental slope is not clear. In addition, the relation of the surface and subsurface dynamics and circulation is not well resolved. Because the subsurface processes can directly affect the surface circulation patterns, the dynamics below the surface need to be better understood.

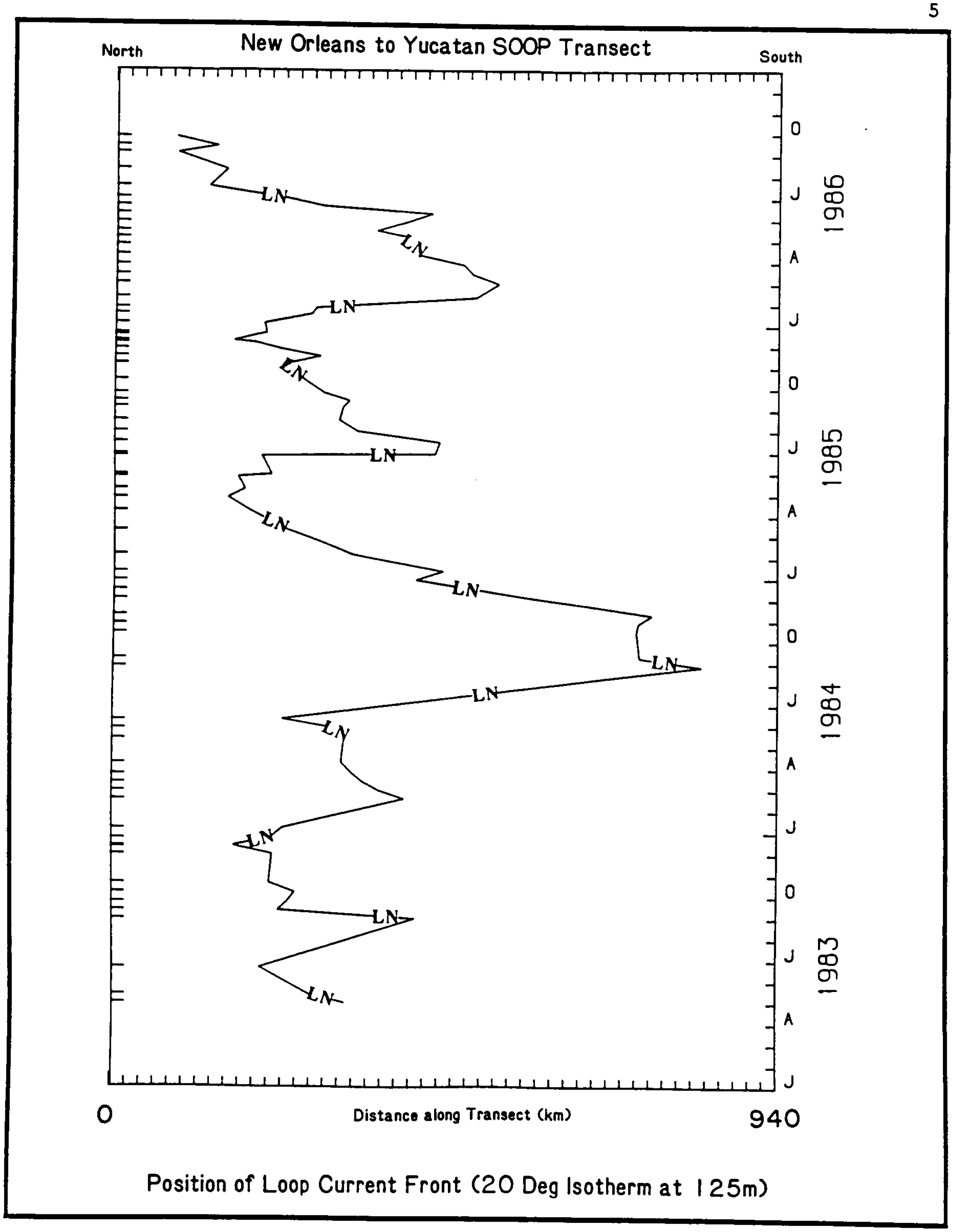

Figure 2.2-1. A time-location plot showing the Loop current northern boundary (LN) as determined from SOOP XBT transects.

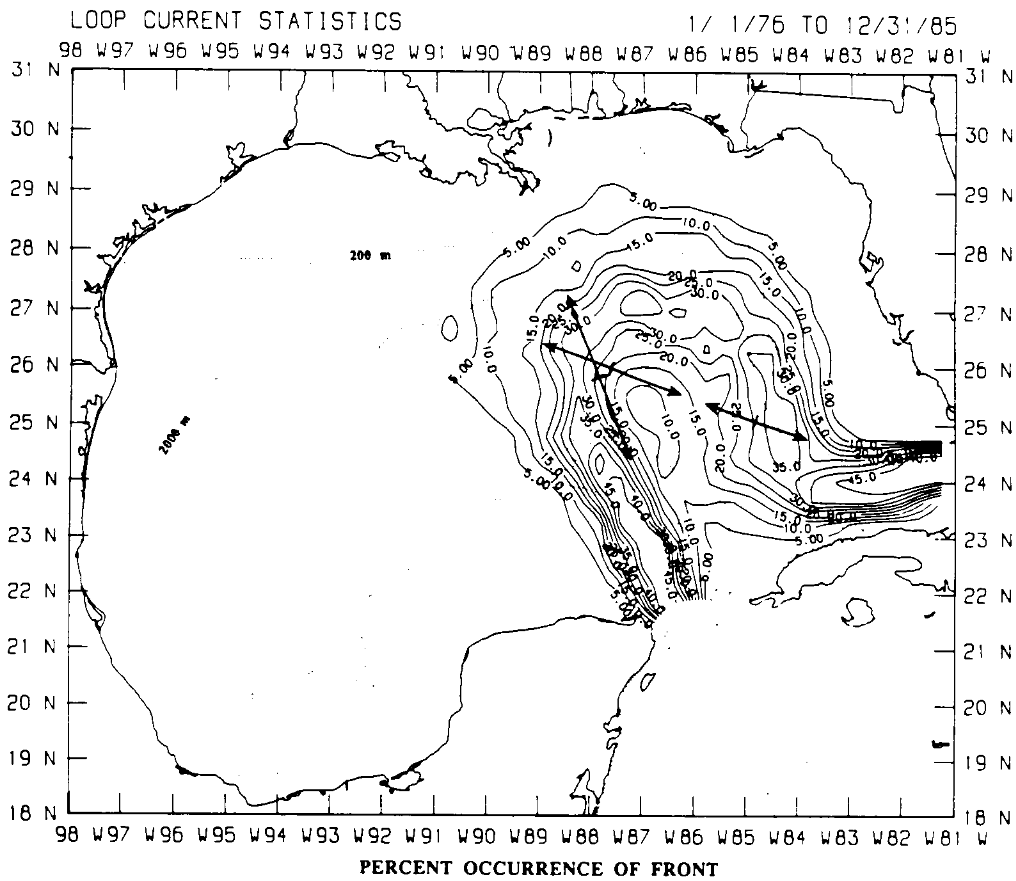

Figure 2.2-2. Isopleths of the relative frequency that the Loop Current Front was observed in the indicated 1/2° squares. The arrows show the mean east-west and northern LC boundary location as determined from SOOP transects.

2.4 Slope Circulation

Composite hydrographic surveys (Figure 2.4-1a) and Inverted Echo Sounder measurements (Figure 2.4-1b) clearly showed a rich eddy field active over the slope and deep Gulf. In addition to the LC anticyclones, several substantial (50 to 100 km diameter) cyclones were documented. These were seen across the middle and deep portion of the northern Gulf slope. Some were fairly persistent, having well documented histories of over a month, with possible life spans of over 100 days. The slope and deep water cyclones often have no near-surface temperature expression (i.e., over the cyclones isotherms are almost level above 200 m, see Figure 2.4-2), and the associated circulation extended upward to the surface (Figure 2.4-3). These slope features, which may be dynamically linked to LC eddies are a factor affecting shelf/slope exchange processes in the central Gulf.

Decomposition of each observed current component showed that the barotropic and first baroclinic modes generally accounted for a very substantial part (most) of the observed current variance. The barotropic component is a constant speed from the water surface to the bottom. The first baroclinic mode has only one zero crossing so the upper part of the water column goes in one direction, while that part below the zero crossing goes in the opposite direction. In the deeper Gulf (Mooring GG), the cross-over of the first baroclinic mode was in the range of 750 to 1000 m below the surface. This result suggests that the general flow field can be approximated fairly well as a two-layered system.

An examination of the primary barotropic current velocity below 1000 to 1500 over the slope and deep Gulf, suggested that Topographic Rossby Waves (TRW's) may be responsible for a substantial portion of observed current variance. These barotropic wave motions which depend on the combined influence of the Coriollis force and water depth to establish their flow organization, seem, at least in part, to be generated in the eastern Gulf under the Loop Current, and to propagate counterclockwise along the isobaths around the northern Gulf. In this transit the associated current magnitudes are diminished (Figure 2.4-4). Initiated in the eastern Gulf, these TRW's are not coupled to LC eddies although eddy-topography interaction may also induce some TRW's. The absence of eddy-TRW coupling suggests that the deep circulation in the western Gulf, even when a LC eddy is present, may, in certain frequency bands, not be directly linked to the circulation patterns higher in the water column.

2.5 Shelf Circulation, Hydrography and Optics

Substantial but seasonally modulated fresh water contribution to the Louisiana shelf combines with local and remote atmospheric forcing to produce a complex circulation pattern. In the Fall and Winter, vertical mixing due to wind and waves as well as surface cooling create a vertically uniform and horizontally stratified temperature-salinity field. As shelf waters warm and the freshwater contribution increases with spring runoff, the shelf water becomes increasingly vertically stratified. The reduction in vertical mixing combined with warming

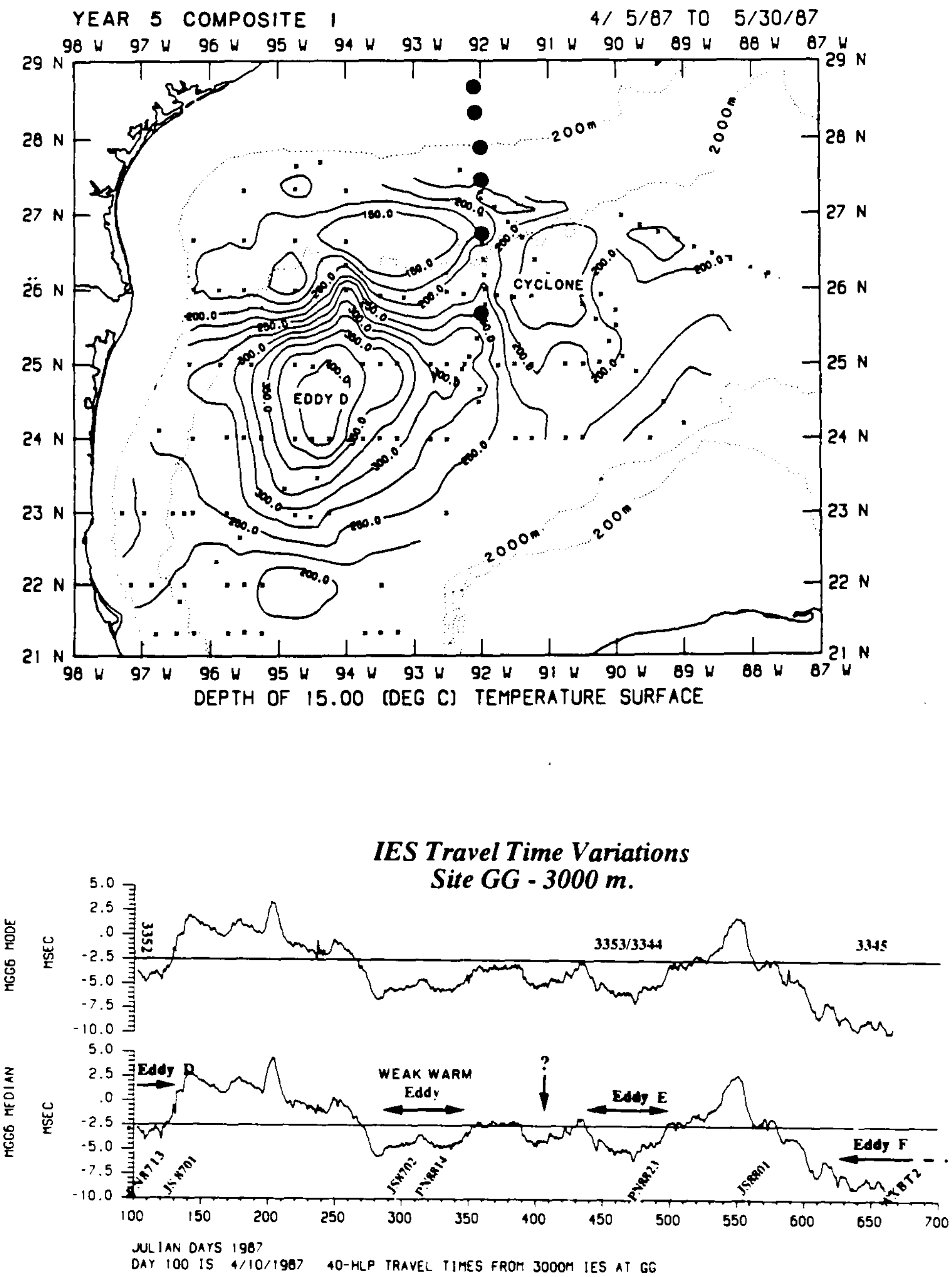

Figure 2.4-1. (a) Composite survey showing depth of the 15°C isotherm. Note Eddy D and the mooring locations (solid dots).
(b) Inverted Echo Sounder time series showing the changes which result from cyclones and anticyclones (eddies) moving over the site.

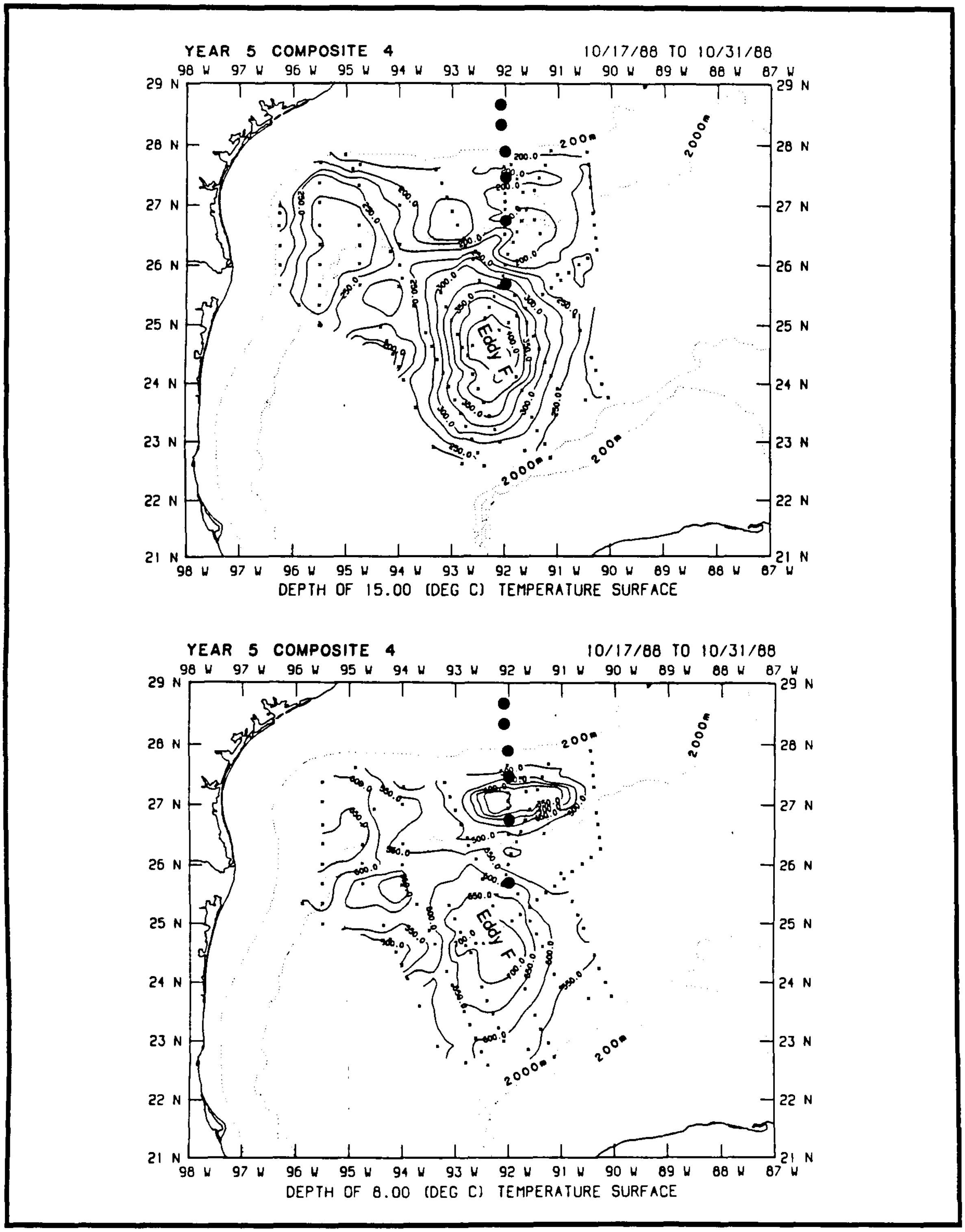

Figure 2.4-2. (a) Composite survey showing Eddy F and (b) a cold subsurface slope cyclone.

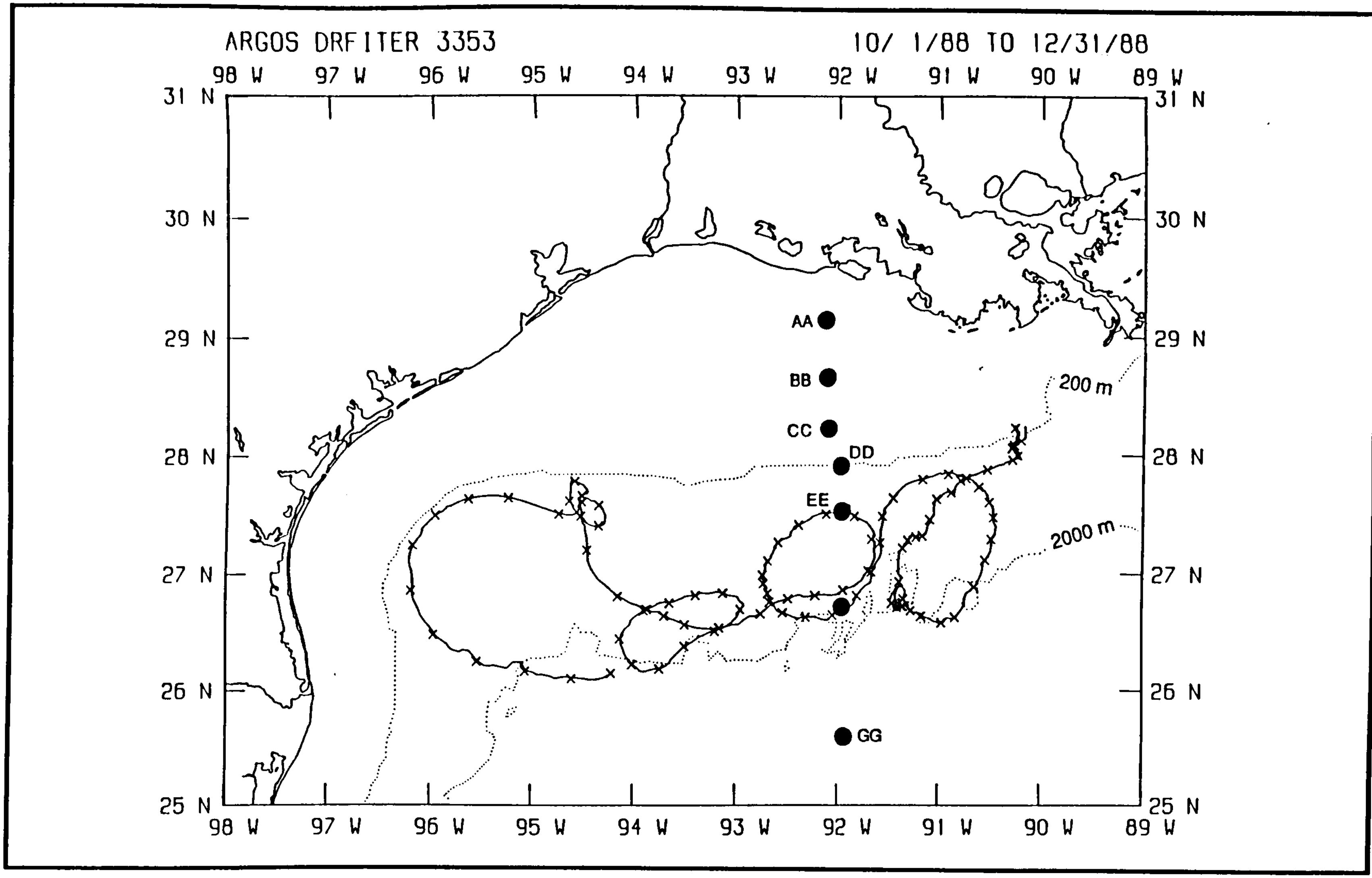

Figure 2.4-3. Trajectory of a surface drifter moving west to east in a series of rotating features over the slope. The cyclonic loop between Mooring EE and FF coincides with the subsurface slope feature shown in Figure 2.4-2(b).

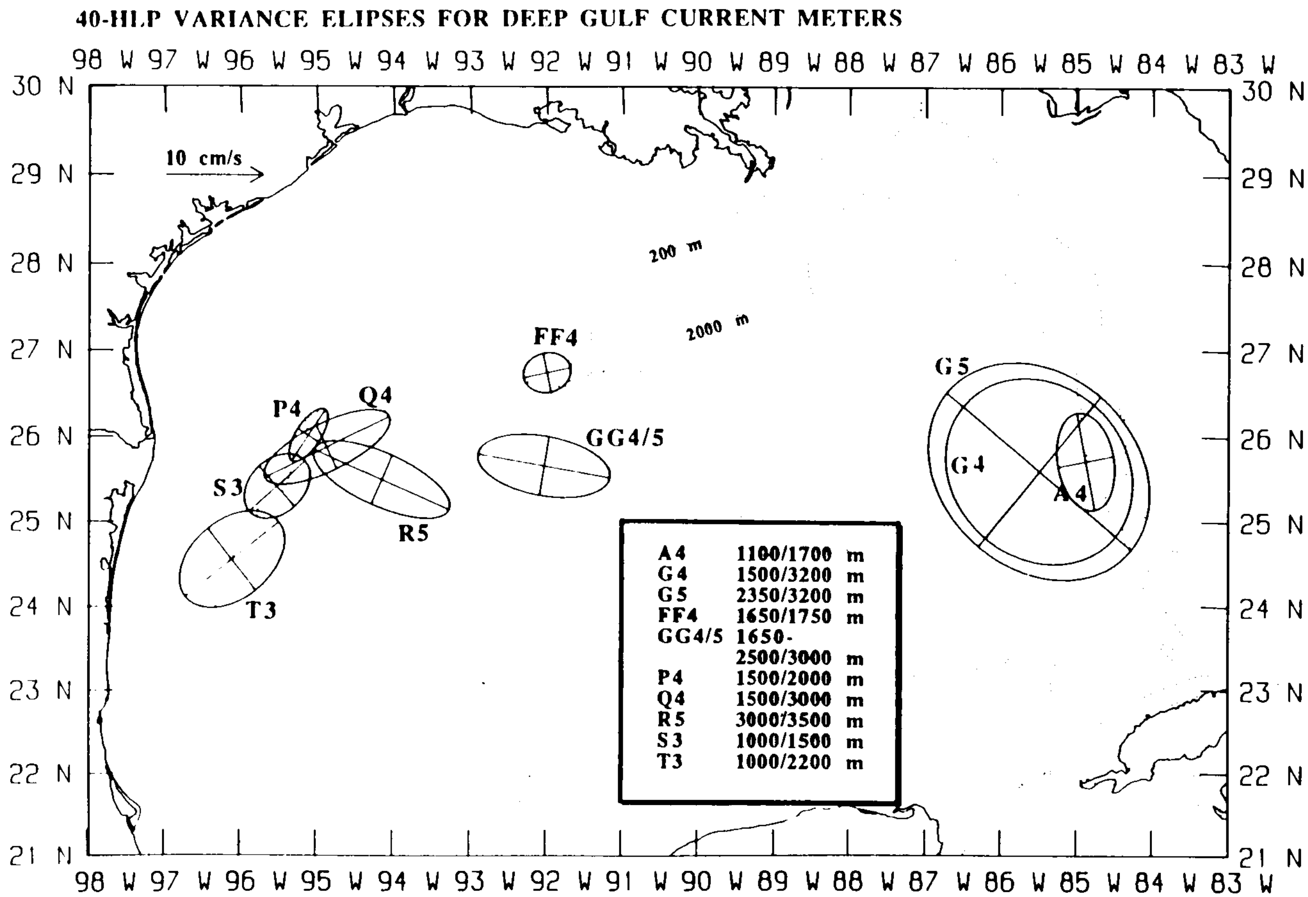

Figure 2.4-4. Graphic presentation of the low frequency current variability in the deep Gulf as measured on moorings during all years of this general program.

causes the surface waters to become increasingly isothermal across the shelf.

Superimposed on the above annual cycle are locally and remotely forced circulation. From Fall to Winter to Spring, there is a cycle of increasing and then decreasing numbers of strong atmospheric frontal passages with associated patterns of changing wind stress. These can drive a complex and not completely resolved pattern of shelf current (Figure 2.5-1). In addition, it appears that shelf waves, which are probably initiated by atmospheric forcing well away from the study site, may be responsible for a part of the observed current field. These episodes of remote forcing tend to diminish the correlation of local winds and currents.

In the mean, shelf currents showed westward (downcoast) current on the inner shelf and eastward (upcoast) current on the outer shelf (Figure 2.5-2). In a mean sense (or net volume transport) the central shelf had little net flow and acted as a node (zero crossing) for this cross shelf reversal of velocity.

A major optical property of shelf waters is the large amount of yellow substance found in the estuarine-riverine discharge. Although concentrations may be seasonally modulated, it is a persistent and regular constituent in waters affected by the Mississippi and Atchafalya River outflows. In contrast, clear blue water with an offshore source was documented half way across the shelf.

The inner and mid-shelf lens of estuarine water can have fairly sharp horizontal and vertical gradients. These were identified in the optical constituents. At times a near bottom gradient showed decreases in transmissivity which were suggestive of sediment resuspension.

The optical measurements showed large variability in the vertical transmission of various components of the incident radiation field. The depth of the euphotic zone varied considerably depending on the water constituents and properties.

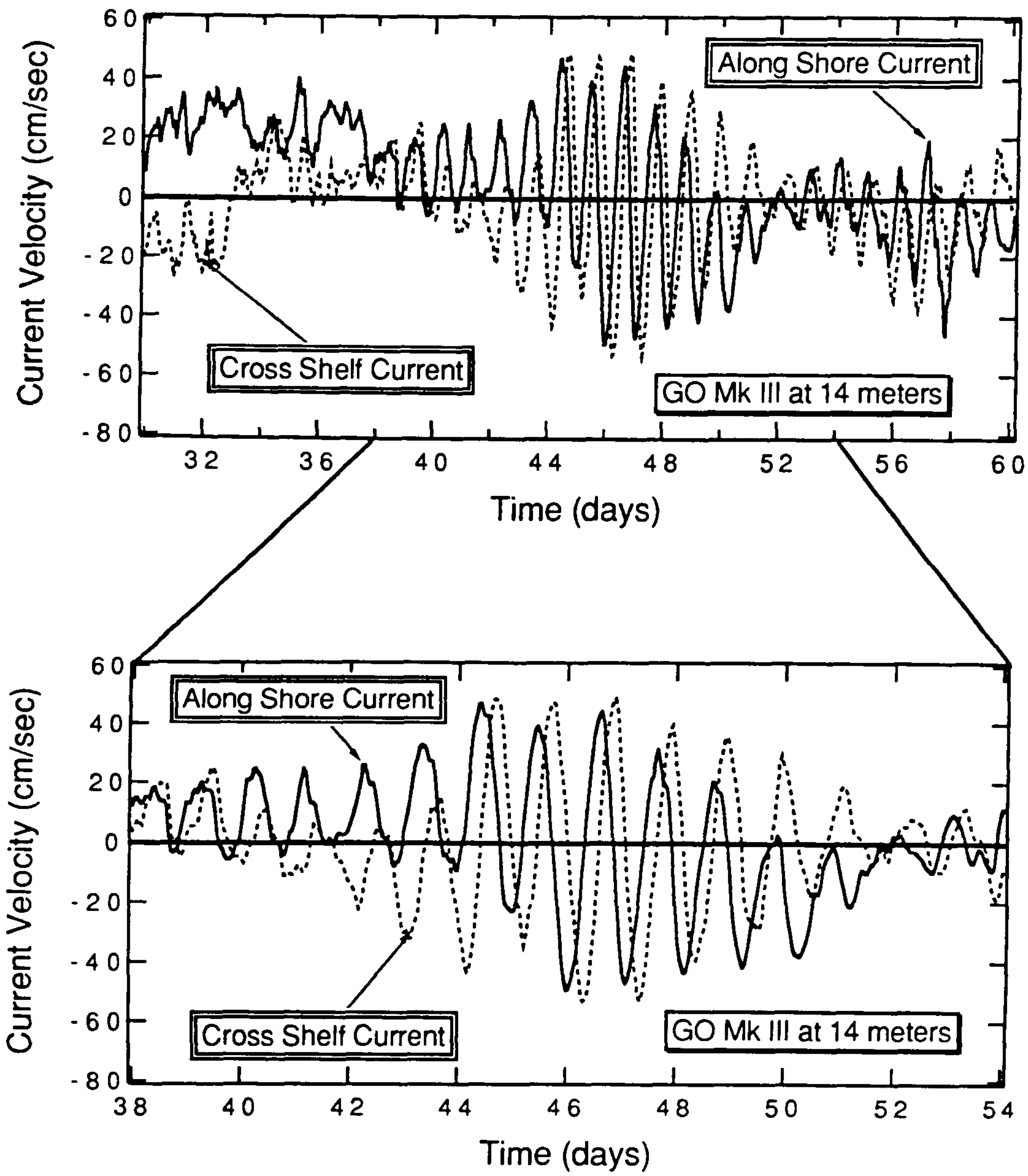

Figure 2.5-1. Time series plots of alongshelf and cross-shelf currents at the near surface (10 m) on Mooring DD. The strong inertial oscillation would tend to reduce general correlation of currents to winds.

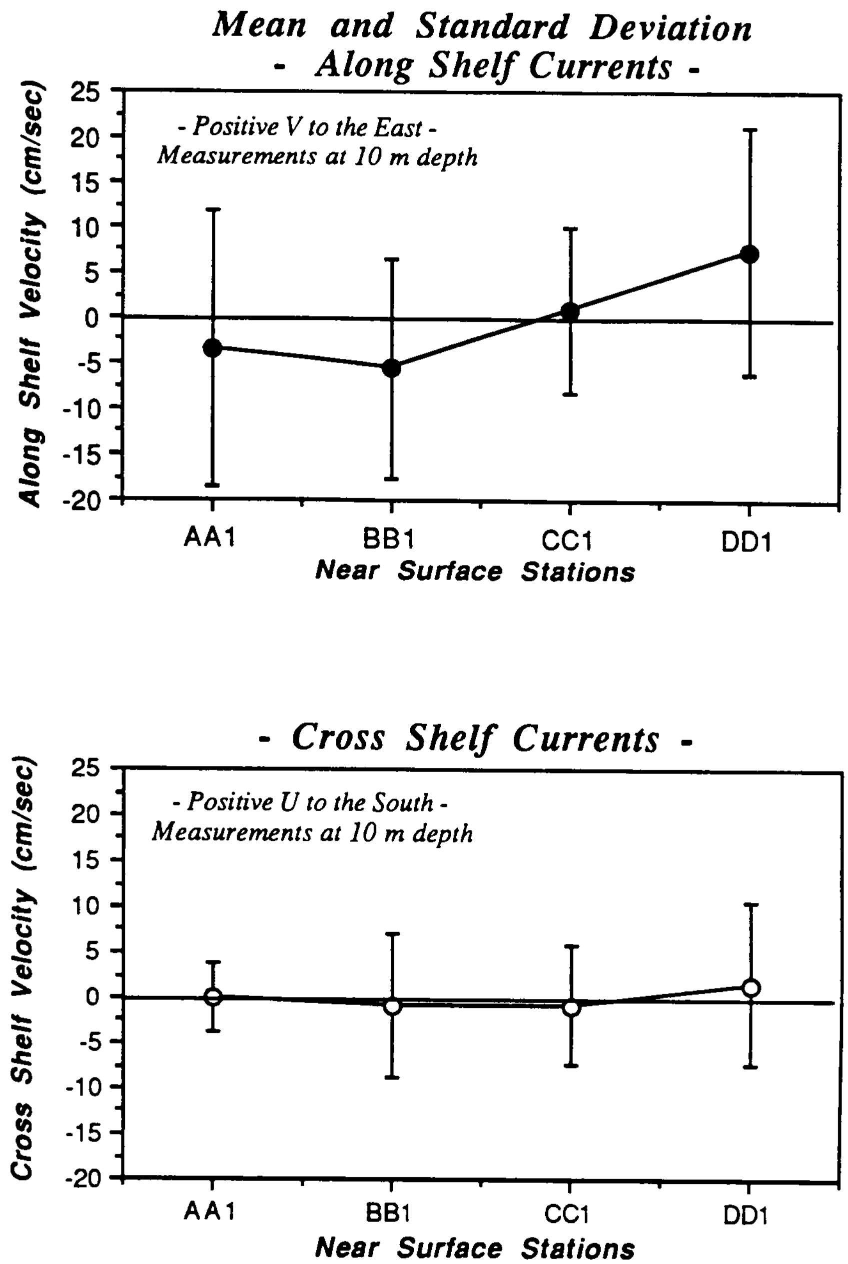

Figure 2.5-2. Overall mean alongshore (a) and (b) cross-shelf currents at the near surface. The inner shelf is directed westward while the outer shelf goes eastward. Little net cross-shelf flow occurs.

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.