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**REPORT TITLE:** Exploratory Study of Deepwater Currents in the Gulf of Mexico, Final Report, Volume I: Executive Summary and Volume II: Technical Report

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SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREA: Central Gulf of Mexico

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COSTS: FY 2002: $297,938; FY 2003: $2,178,782; FY 2004: $1,266,797: FY 2005: $739,886 FY 2006: $608,478. CUMULATIVE PROJECT COSTS: $5,091,881

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KEY WORDS: Gulf of Mexico, Loop Current, Loop Current eddies, cyclones, current, PIES, Lagrangian, PALFOS, RAFOS, topographic Rossby waves, sea surface height, circulation, field measurements, transport, Sigsbee Escarpment, slope, two-layer flow.

**BACKGROUND:** This study was planned and developed by the MMS to examine several key hypotheses and to evaluate methods of cost effective, broad regional documentation of important ocean processes in the deepwater of the northern Gulf of Mexico.

**OBJECTIVES:** There were three stated program objectives. These are:

- Increase deepwater current database and knowledge of the deep circulation in the Gulf of Mexico (GOM),
- Make measurements sufficient to estimate parameters needed to design full-scale PO studies in deepwater regions of the GOM, and
- Collect current data sufficient to test and/or evaluate the eight hypotheses relating to ocean physical processes in the study area.

**DESCRIPTION:** This study area was in the mid-Gulf, approximately south of New Orleans. The east-west extent of this study area was between 88°W and 94°W. The

north-south extent was from the 1,000 m isobath in the north to the 3,000 m isobath or the limit of the US EEZ in the south. The year of field measurements were made nominally from March 2003 through April 2004. Actual moored arrays were placed between 88.5°W and 92.25°W and the 1,200 m isobath and the EEZ. Measurements were made with a variety of moored arrays and Lagrangian PALFOS and RAFOS drifters. In water measurements were supplemented by use of remote sensing, primarily sea surface heights and sea surface temperatures.
Four full-depth moorings were used to measure currents and hydrographic characteristics over the complete water column at locations near the corners of the measurement domain. Two moorings each were above and below the Sigsbee Escarpment. Available to the study scientists were measurements made by two other MMS funded full depth moorings (made by LSU and CICESE) that were placed in or adjacent to the measurement area. Fifteen near-bottom mooring were also deployed; 12 extended 500 m above the local bottom and had two current meters at 100 m and 500 m. Three supplemental short moorings were also placed on three transects across the Sigsbee Escarpment to enhance resolving horizontal scales of motion in the vicinity of this significant bathymetric feature. These latter moorings extended 100 m above the bottom and had one current meter at 100 m.

Observations from 26 PIES (Inverted Echo Sounders with Pressure) supplemented the data from the moored arrays. Using data reduction/processing schemes developed at the University of Rhode Island, accurate time series estimates of temperature, salinity and density profiles could be determined. Using density profiles, geostrophic velocities could be computed. These were then referenced to velocities measured at the fixed arrays. Thus, PIES and mooring placements were coordinated to optimize environmental and process descriptions and data analyses. PIES placements were also coordinated with groundtracks of various satellites with altimeters. The combination of pressure and density profiles was used to evaluate and enhance interpolation schemes applied to altimetry in the Gulf of Mexico. All mooring and PIES servicing was accomplished during the deployment, rotation and recovery cruises that occurred at six-month intervals.

Six PALFOS floats were deployed. These had a residence depth of 1,000 m and a profiling interval of ten days. Each had a RAFOS receiver on board so that trajectories at the residence depth were recorded and transmitted via ARGOS along with the salinity and temperature profiles taken with each surfacing. Thirty RAFOS floats were ballasted to reside and move with currents at 1,000, 1,500, 2,000, 2,500 and 3,000 meters below the water surface. Approximately six months into the observations six additional RAFOS floats were deployed to help resolve lower-layer events. In April and May, RAFOS floats surfaced and transmitted via ARGOS the cumulative trajectories at each deployed depth.

**SIGNIFICANT CONCLUSIONS:** As deployed, the combination of fixed position current measurements, PIES, Lagrangian drifters and satellite remote sensing combined to provide a cost-effective database that supported documentation and resolution of significant dynamic ocean processes and resulting circulation patterns. Horizontal

spacing of measurement sites was sufficient to resolve most key patterns. The expected two-layer flow patterns were again present and well documented using the range of deployed instruments. In the lower layer, an almost continuous sequence of eddy and wave-like motions resided in or moved through the measurement domain. In the upper layer, the Loop Current that impinged on the measurement domain for significant portions of the observations was a major factor affecting upper-layer currents and circulation. Strong Loop Current eddies separated close to the study region and moved west and southwest through the array. Boundary features/eddies on the Loop Current and Loop Current eddies also had a significant influence on circulation patterns in the upper layer. It is a key result that the multivariate data set produced for this study was able to document and reconstruct many of the characteristics of these dynamic features. The Sigsbee Escarpment was a barrier to lower-layer currents. Lower-layer conditions on the upper side of the Sigsbee were generally and consistently less vigorous than observed at the base of the Escarpment.

**STUDY RESULTS:** Excellent data return from the varied observational methodologies over the one-year field effort combined to support a previously unrealizable reconstruction and quantitative mapping of ocean dynamics in the study area. Loop Current and associated eddies, both anticyclonic and cyclonic, dominated the upper-layer circulation. As an initial effort to provide a dynamical basis for the resulting features a shielded vortex instability was proposed. Energetic inertial oscillations were observed in the core of Eddy Sargassum. Inertial oscillations were also observed in response to several hurricanes and tropical storms that moved through or near the study area.

Deep (lower layer) energetic currents were typically associated with eddies in the deep pressure fields. These deep eddies may be interpreted as a field of dispersive topographic Rossby waves (TRWs). The dispersive nature of the bottom circulations as shown by model results and float trajectories confirm the wavelike character of the deep flows. The Sigsbee Escarpment differentially affected the behavior of cyclonic and anticyclonic eddies that encountered this relatively steep bathymetric feature. Generally, flows below the Escarpment were consistently more vigorous that those above the Escarpment. Using a series of sequential upper and lower layer conditions, three possible linkages between the two layers are hypothesized.

Comparison of satellite altimetry and comparable PIES data showed a good correlation with the lowest correlation above the Escarpment. Utility of altimetry for the weak surface signal of TRWs can be resolved with altimetry, although some continued consideration of shorter period fluctuations may help resolve this question.

Deep drifting floats showed evidence of strong east-west exchange in the central Gulf, but significantly different once the float moved to the east or west of this central region. There appeared to be relatively little exchange between the eastern and western Gulf basins. Floats that moved to the western basin tended to converge closer to the slope and align with the local bathymetry. Further to the west, some floats were moved by deep eddies into the deeper portion of the basis away from the slope.

**STUDY PRODUCTS:** Donohue, K., P. Hamilton, K. Leaman, R. Leben, M. Prater, D.R.Watts and E. Waddell, 2006. Executive Summary: Exploratory Study of Deepwater Currents in the Gulf of Mexico. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-073, 76 pp.

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