ACCESS NUMBER: M04PC00008
(1435-01-04-CT-34239)

STUDY TITLE: Study of Deepwater Currents in the Eastern Gulf of Mexico

REPORT TITLE: Study of Deepwater Currents in the Eastern Gulf of Mexico

CONTRACT NUMBERS: M04PC00008 (1435-01-04-CT-34239)

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREA: Eastern

FISCAL YEAR(S) OF PROJECT FUNDING: 2004; 2005; 2006; 2007; 2008; 2009

COMPLETION DATE OF REPORT: December 2010

COSTS: FY 2004: $843,752; FY 2005: $1,207,416; CUMULATIVE PROJECT COST: $2,051,168.

PROJECT MANAGER: J. Cox

AFFILIATION: Evans-Hamilton, Inc.

ADDRESS: 4608 Union Bay Place NE, Seattle, Washington, 98105

PRINCIPAL INVESTIGATORS*: J. Cox, C. Coomes, S. DiMarco, K. Donohue, G. Forristall, P. Hamilton, R. Leben, D. R. Watts

KEY WORDS: Eastern Gulf of Mexico, Loop Current, Loop Current Eddy, deep water currents, PIES array, topographic Rossby waves, spectral energy, kinetic energy, altimetry, satellite imagery, hurricanes, vertical coupling, hydrography, remote sensing.

BACKGROUND: The major source of energy forcing currents in the surface waters of the Gulf of Mexico is the Loop Current (LC) which flows northward through the Yucatan Channel into the Gulf of Mexico, and then turns eastward and exits through the Straits of Florida to join the Gulf Stream. The LC varies in its penetration into the Gulf of Mexico, sometimes constraining itself to the southern Gulf, and sometimes penetrating far northward into the northern Gulf. During most periods when the LC has penetrated northward, cold core eddies and warm water filaments can be found migrating around its periphery. Often when extended far northward, the LC pinches off, forming a Loop Current Eddy (LCE) that migrates through the northern Gulf, eventually moving westward to die within its western regions. LCEs detach from the LC at periods ranging from 3 to 17 months, with a mean frequency of separation near 10 months (Sturges and Leben 2000). Very energetic LCEs interact with one another, the LC, and bathymetry, forming cyclonic eddies with which they also interact; this activity imparts significant energy to the surface waters of the Gulf of Mexico. While the overall net circulation of the surface waters in the Gulf of Mexico is generally understood, the magnitude of the velocity and variance of the surface currents are known to be greatest in the vicinity of the Loop Current, where speeds often exceed 1.5 m s^{-1}.

ACCESS NUMBER: M04PC00008
(1435-01-04-CT-34239)

OBJECTIVES: (1) Conduct measurements of currents using moorings to increase the regional database of ocean currents in the Eastern GOM; (2) Improve the scientific community's overall knowledge and understanding of circulation features in this deepwater area; (3) Collect hydrographic, remote sensing, and other relevant measurements useful to understanding what controls the region's circulation; (4) Assess the key processes energizing the circulation; (5) Add to the database of LC and LCE characteristics, and how these features affect the study area; (6) Establish an improved base of knowledge to help design future circulation studies in this part of the GOM; (7) Provide measurements and knowledge which could assist with future calculations of horizontal and vertical trajectories of released oil and its dispersion.

DESCRIPTION: The study called for a one-year measurement program to collect an integrated set of current, hydrography, remote sensing, and ancillary measurements that could provide an excellent understanding of the circulation processes in the area. As a result, from January 2005 to January 2006 one year of current measurements were collected from four moorings in water depths from ranging from 2500 to 2800 m. The moorings also contained measurements of water temperature and conductivity in the upper 500 m. The mooring measurements were supplemented with measurements from bottom-moored PIES, three hydrography (profiling CTD and XBT) cruises, and satellite imagery and altimetry. Eddy Watch, a proprietary operational oceanographic product that tracks, maps, and forecasts the LC and its eddies, along with drifting buoy data used in the Eddy Watch analysis, were obtained from Horizon Marine, Inc. for the period of the study's measurements, and utilized under a limited license for additional analyses of the characteristics of the LC and LCE's. Publicly available river discharge data, coastal and offshore wind data, and coastal water level data during the measurement period were also obtained as ancillary data.

The current measurement moorings consisted of three tall (M1, M2, & M3) and one short (M4) moorings. The tall moorings were full water column moorings designed to reach within 70 m of the surface. The short mooring was 250 m tall, and was designed to provide additional near-bottom current measurements. The tall moorings contained upward-looking 75 kHz ADCPs at 500 m depth, with single point current meters spaced at intervals from 750 m to near bottom. PIES measurements were obtained from seven locations. The PIES moorings were deployed in December 2004, interrogated in August 2005 when additional PIES were added to the array, and recovered in January 2006.

Hydrographic measurements consisting of CTD casts and XBT profiles were collected in January and August 2005, and January 2006 during mooring deployment, servicing, and recovery cruises. The hydrographic measurements were targeted to capture interesting loop current, eddy, or other related features affecting the study area. The final hydrographic survey was targeted to capture small scale interactions between the edge of a Loop Current Eddy (LCE) and a Cold Core Eddy (CCE) that lay over a portion of the study area.

SIGNIFICANT CONCLUSIONS: The primary conclusion from the study is that the eastern GOM is a very active region in terms of circulation, especially when the LC or

an LCE is present. The circulation characteristics of the region are very similar to those in the north-central GOM when similar processes are at work, whether they be the presence of the LC, and LCE, frontal features, or major storms. Deep circulation experiences TRW packets, though generations of TRWs that translate into the north-central GOM do not appear to be generated in this region. TRW generated currents are also not affected significantly by steep bathymetry in this region.

STUDY RESULTS: Prior to the study, the deep water portion of the eastern GOM was thought to be impacted less frequently by the LC and LCEs or their frontal features, resulting in less energetic circulation than is found in the north-central GOM where the LC and LCE's often penetrate. On a quasi-annual basis, the northern edge of the Loop Current reaches between 24° and 28° N into the Gulf of Mexico (Sturges and Evans 1983), yet for the majority of the field measurement period, the northern edge (as the LC or Eddy Vortex) remained between 27° and 28° N, and impacted the study area for much of the measurement period.

During the study, the LC spawned Eddy Vortex. Eddy Vortex had the largest number of detachment/reattachment events observed during a single LC intrusion cycle within the historical altimeter record. During this period of detachment and reattachment, the extended intrusion of the LC and an associated eddy was one of the most northerly intrusions on record. It was only exceeded by the intrusion that generated Eddy Sargassum during the Exploratory Study. As a result of the detachment and reattachment process, Eddy Vortex resided in, and impacted the circulation of, the study area for much of the field measurement period. During the mooring deployments five hurricanes and one tropical storm traversed the gulf, the most severe being Hurricanes Katrina and Rita. The combination of the extended stay of the LC and Eddy Vortex in the northern GOM, and the number of severe storms passing near the study area, resulted in extensive periods of energetic currents within the study during the study.

STUDY PRODUCTS: Cox, J., C. Coomes, S. DiMarco, K. Donohue, G. Z. Forristall, P. Hamilton, R. R. Leben, and D. R. Watts. 2010. Study of Deepwater Currents in the Eastern Gulf of Mexico. U. S. Department of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEMRE 2010. 473 pp.

Cole, K. L. and S. F. DiMarco. 2010. Low-frequency variability of currents in the deepwater eastern Gulf of Mexico. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2010-015. 136 pp.

Cole, K. L. 2008. Low frequency variability of currents in the deepwater eastern Gulf of Mexico. MS Thesis, Dept. of Oceanography, Texas A&M University.

Cole, K. L., S. F. DiMarco and R. R. Leben. Febuary 2008. Dynamic mode variability in the deep Gulf of Mexico. CORALS, Texas A&M Seminar Series. College Station, TX. Poster presentation.

Cole, K. L., S. F. DiMarco and R. R. Leben. March 2008. Dynamic mode variability in the deep Gulf of Mexico. OCEAN SCIENCES MEETING, Orlando, FL. Poster presentation.

Coomes, C. January 2007. Gulf of Mexico Circulation Study: Intensive Hydrographic Survey of Loop Current Edge Fine Scale Features. PowerPoint presentation for: MMS 24th Information Transfer Meeting.

Cox, J. 2007. Eastern GOM Circulation Study: Overview of the Study Goals and Objectives, Measurements Obtained, and Features Measured. PowerPoint presentation for: MMS Information Transfer Meeting.

Cox, J. 2006. Eastern GOM Circulation Data Meeting: Overview of Study Goals, Objectives, Measurements Obtained, and GOM Storms. PowerPoint presentation for: MMS Data Meeting.

---

* P.I.'s affiliation may be different than that listed for Project Managers.