

STUDY TITLE: Observation of Deep Water Manifestation of Loop Current Rings

REPORT TITLE: Deepwater Currents in the Eastern Gulf of Mexico: Observations at 25.5°N and 87°W

CONTRACT NUMBER: 14-35-01-99-CA-30951-16805

SPONSORING OCS REGION: Gulf of Mexico

APPLICABLE PLANNING AREA: Eastern

FISCAL YEARS OF PROJECT FUNDING: 1999; 2000; 2001; 2002; 2003

COMPLETION DATE OF REPORT: May 2008

COSTS: FY 1999: \$165,736; FY 2000: \$98,495; FY 2001: \$94,895; FY2002: \$126,522; FY 2003: \$93,282

CUMULATIVE PROJECT COST: \$578,930

PROJECT MANAGER: Masamichi Inoue

AFFILIATION: Coastal Studies Institute and Dept. of Oceanography & Coastal Sciences, Louisiana State University

ADDRESS: Coastal Studies Institute, Louisiana State University, Baton Rouge, Louisiana 70803

PRINCIPAL INVESTIGATORS: Masamichi Inoue, Susan E. Welsh, and Lawrence J. Rouse, Jr.

KEY WORDS: Deepwater current, Loop Current, Loop Current rings, eastern Gulf of Mexico

BACKGORUND: The upper-layer circulation in the eastern Gulf of Mexico (GOM) is dominated by the Loop Current (LC) and the separation of anticyclonic eddies or LC rings. The LC rings migrate westward and dominate the circulation in the central and western GOM. In contrast, deepwater in the GOM below the sill depths is completely isolated. The GOM is a semi-enclosed basin with maximum depths of approximately 3400 m in the eastern basin and 3700 m in the western basin. The deep eastern basin is connected to the deeper western basin by a constriction located near 88°W. This bottom topographic constriction appears to limit exchange of deep water between the eastern and western basins. Flow enters the GOM from the Caribbean Sea through the Yucatan Channel with sill depths of approximately 1900 m and exits through the southern Strait of Florida with sill depths of about 800 m. Despite the isolation of deep water below the sill depths, deep water in the GOM appears to be well ventilated and oxygenated. This suggests some energy propagation from the upper layer to deep water inside the GOM contributing toward vertical mixing of deep water. Dominant

energetic cyclones in deep water and their interaction with bottom topography appear to play an important role in the ventilation of deep water. Observations of energetic events with strong currents in the northern slope water region have been reported and their possible relationship to the LC and LC rings via topographic Rossby Waves has been suggested. The effects of the formation and migration of LC rings on the deep circulation in the GOM have been described by previous model studies. These models suggest the generation of an anticyclone-cyclone pair, a 'modon,' in the lower layer during the formation of a LC ring in the upper-layer. Since the previous observations of the interaction of the LC and the LC rings with bottom topography have been limited to the northern slope water region, in order to fully understand deep-water dynamics and circulation in the central and western GOM, knowledge of the upstream condition, i. e., the LC and deepwater beneath the LC in the eastern GOM away from the northern slope water region, is required.

OBJECTIVES: The objective of this proposed study is to observe the upstream condition near 87°W and 25.5°N at a water depth of 3356 m in the eastern GOM using a deepwater mooring, i. e., currents and water mass properties in the eastern GOM below the LC in a flat bottom area away from the slope water region. The selected site corresponds to the origination point where all of the three major trajectories preferred by the LC rings on their westward journey from the eastern GOM to western GOM converge. It is expected that the water mass directly associated with the LC is expected to be found approximately 65% of the time at this mooring site. Furthermore, the western frontal boundary of the LC is expected to be in the vicinity of the mooring site when the LC makes its characteristic northward intrusion prior to the formation of a LC ring.

DESCRIPTION: Under the initial funding, a total of three deployments were completed. Although the detailed configuration of the mooring did differ from deployment to deployment, the basic configuration remained intact throughout the first three deployments. The mooring was equipped with two ADCPs, one upward-looking set at 140 m and the other downward-looking set at 3200 m, and six Aanderaa current meters set at 155, 750, 1500, 2500, 3000, and 3175 m in order to sample the entire water column. In Deployment 3, an additional Aanderaa current meter was used at 500 m. A total of five Microcats were used to sample temperature, conductivity and pressure. They were set at 157 m, 285 m, 752 m, 1502 m and 2502 m. Deployment 1 extended from May 31, 2000 to August 1, 2001. Deployment 2 extended from August 3, 2001 to June 3, 2002. Deployment 3 extended from April 19, 2003 to June 1, 2004.

SIGNIFICANT CONCLUSIONS: The first observations of deepwater manifestation of the Loop Current and the Loop Current rings in the eastern Gulf of Mexico have been completed using a deepwater mooring deployed in a flat bottom area away from the northern slope water region. This location turns out to be an ideal location to monitor the Loop Current and deepwater currents in the eastern gulf because of its proximity to the Loop Current. The mooring data suggest that a two-layer approximation is a reasonable way to characterize currents at the mooring site with the interface located near 700-800 m. The upper-layer currents are dominated by the Loop Current while generally the upper- and lower-layer currents appear to be decoupled except occasional

establishments of coupling between the two layers. Deepwater in the eastern gulf is energetic and barotropic throughout the lower layer, and it appears to be driven by the Loop Current and Loop Current rings. Deepwater at the mooring site appears to be relatively energetic characterized by 40-50 day variability with 10-30 cm s⁻¹ currents. Short-duration energetic events lasting a few days could result in strong deepwater currents exceeding 1 knot all the way to the bottom. These energetic events in deepwater appear to take place when the Loop Current makes notable northward extension preceding the formation of Loop Current rings. Deepwater currents at mooring site appear to be manifestations of a modon pair which forms underneath a Loop Current ring in the eastern Gulf of Mexico. Shorter time scales associated with deepwater flow at the mooring site is a reflection of smaller deepwater eddies resulting from deepwater eddies interacting with the bottom topographic constriction located between the eastern and the central gulf. So far every one of the three deployments turns out to be unique, confirming the previous observation that every Loop Current ring formation is unique and a long-term measurement is required in order to establish basic statistics of ocean dynamics in the eastern Gulf of Mexico.

STUDY RESULTS: During Deployments 1 and 3, the mooring was close to the high-speed jet of the LC while it primarily remained well inside the LC, away from the high-speed jet during Deployment 2. The upper-layer flow above 700-800 m was dominated by the LC and LC rings. In contrast, the lower-layer flow appears to be generally decoupled from the upper-layer flow. In general, dominant time scales for the upper-layer flow are much longer than those for the lower-layer flow. What is interesting is that every deployment turned out to be different for both upper-layer and lower-layer flow dynamics. This is a reflection of the observation that the dominant time scales associated with the LC in the eastern GOM are dictated by time scales associated with the formation of LC rings. In deepwater, Deployment 3 exhibits more energy in terms of background flow as well as peak energy levels than the first two deployments. A few short-duration energy bursts of deepwater events were observed. The strongest event observed had current magnitude exceeding 1 knot in deepwater during Deployment 3. Interestingly, the most energetic events observed appear to coincide with concurrent northward extension of the LC that preceded the formation of LC rings reported by Leben (2005). These energetic events were accompanied by notable temperature and salinity signal in deepwater. In particular, Event 3 resulted in significant cooling and increases in salinity in deepwater. These observations suggest that short-duration energy bursts in deepwater associated with the formation of LC rings could result in stirring of deepwater in the eastern GOM.

STUDY PRODUCTS: Inoue, M., S. E. Welsh, L. J. Rouse, Jr., and E. Weeks, 2008. Deepwater Currents in the Eastern Gulf of Mexico: Observations at 25.5°N and 87°W. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2008-001. 95 pp.

Inoue, M., S. E. Welsh, L. J. Rouse, Jr., E. Weeks, 2002: Observation of deep water manifestation of Loop Current and Loop Current rings in the eastern Gulf of Mexico. EOS Transactions American Geophysical Union, Vol. 83, No. 4, 321.

Inoue, M., S. E. Welsh, and L. J. Rouse, Jr., 2003: Observation of Deepwater Currents in the Eastern Gulf of Mexico Below the Loop Current. Proceedings, the 22nd Information Transfer Meeting, Sponsored by the Minerals Management Service.

Inoue, M., S. E. Welsh, L. J. Rouse, Jr., Deepwater mooring at 87°W and 25.5°N. Proceedings, the 23rd Information Transfer Meeting, Sponsored by Mineral Management Service, New Orleans, January 2005.

Inoue, M., S. E. Welsh, L. J. Rouse, Jr., Observations at 25.5°N and 87°W: Deepwater Currents in the Eastern Gulf of Mexico. Proceedings, the 24th Information Transfer Meeting sponsored by Minerals Management Service in New Orleans, January 10, 2007.