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STUDY TITLE: Analysis and Validation of a Mechanism that Generates Strong Mid-Depth Currents and a Deep cyclonic Gyre in the Gulf of Mexico

REPORT TITLE: Strong Mid-Depth currents and a Deep Cyclonic Gyre in the Gulf of Mexico

CONTRACT NUMBER: 1437-01-99-CT-31027

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PROJECT MANAGER: Prof. Wilton Sturges

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KEY WORDS: Gulf of Mexico, ocean currents, deep circulation, topographic Rossby waves, Loop Current, eddies, Loop Current Rings, numerical modeling, Princeton Ocean Model, MICOM

BACKGROUND: It has long been observed that strong but puzzling currents are found at depths of ~ 1000m and deeper along the steep topography beyond the edge of the west Florida continental shelf. These currents have been documented primarily in technical reports of MMS programs in the early 1980s, in NOAA reports (by Molinari), and others. Strong sporadic currents at shallower depths are often reported by the drilling operators. Our desire in this study was to understand the cause(s) of the deep flows as well as the sporadic strong shallower jets. We intended to use three approaches: an analysis of all available current meter and hydrographic data, simultaneous analyses of 3 operational numerical models, and the working hypothesis that the strong deep flows were the result of topographic rectification of topographic Rossby waves. Note that this study was initiated and carried out almost in its entirety before we knew the results of the Deep Star Joint Industry – Mexican mooring program in Yucatan Channel.

OBJECTIVES: (1) To coordinate the analyses of the MICOM and Princeton Ocean Model, carried out by their usual principal scientists, as to the behavior of the deep flow in Yucatan Channel and the full Gulf of Mexico; (2) To analyze the existing (non-proprietary) long-duration

current meter mooring data on the basis of topographic rectification; (3) To search the numerical modeling output data for bursts of strong shallow-to intermediate depth flows, and correlate any such flows with the motion of the Loop Current (or other available large-scale features).

DESCRIPTION: This project did not involve the *collecting* of data, but the analysis of many data sets and comparisons with numerical model results. The work, involving major commitments of time by the principal investigators, one PhD student and a post-doc, resulted in over half a dozen published papers in refereed journals (see list below).

SIGNIFICANT CONCLUSIONS: One major result was that all the historical mooring data, as well as the data that were taken (or discovered) as the project took place, can be fit into the framework of the original hypothesis: the mean currents around the edge of the deep Gulf of Mexico appear to flow in the counter-clockwise (or cyclonic) direction. The flows are observed to be in both directions (along topography) but the means, over many months, are consistently in the direction expected from topographic rectification. This mechanism is the most obvious candidate, but there is no firm evidence that this is the only mechanism involved. The Princeton Ocean Model contains this flow direction in its output, the MICOM does not; the Principal Investigators are now working together in an effort to explain or resolve this (previously unknown) discrepancy. High-speed flows are found at the “appropriate” depths in both models that *resemble* the high-speed flows reported by the drilling operators, but of lesser speeds. This may be a problem with model resolution, but the primary difficulty is that the observations are scarce and poorly (if at all) documented. During the course of our work the results of the moorings across the Yucatan Channel (by the Ensenada group) began to emerge; these results have changed our knowledge and understanding of this important region of the flow enormously but have not changed our results or interpretations in the open Gulf.

STUDY RESULTS: The results, other than as contained in the Conclusions section, are described in full in the publications described below.

STUDY PRODUCTS: Sturges, Chassignet, and Ezer, Strong Mid-Depth currents and a Deep Cyclonic Gyre in the Gulf of Mexico. Final Report OCS Study, MMS 2004-040.

Cherubin, L.M, W. Sturges, and E. Chassignet, 2004. Deep flow variability in the vicinity of the Yucatan Straits from a high resolution MICOM simulation. *J. Geophys Res., submitted.*

Cherubin, L.M., Y. Morel and E. Chassignet, 2004. Loop Current ring formation: a new mechanism. Submitted to *J. Phys Oceanogr.*

DeHaan, Christopher J., 2002. Determining the Deep Current Structure in the Gulf of Mexico and the Yucatan Strait from Multiple Data Types**.** Doctoral Dissertation, Dept. of Oceanography, Florida State University, Tallahassee. October, 2002.

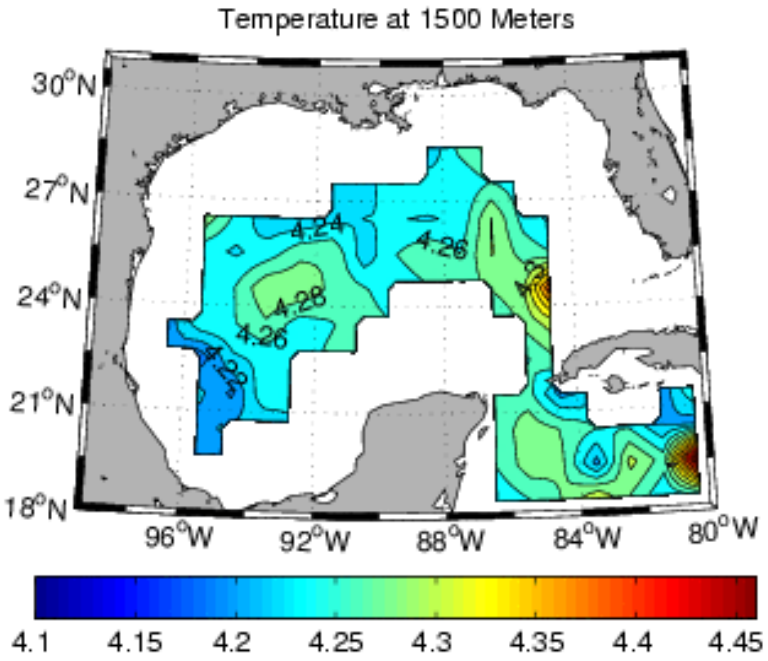
DeHaan, C.J., and W. Sturges, 2004. Deep cyclonic circulation in the Gulf of Mexico. *J. Phys Oceanogr. in press.*

Ezer, T., L.-Y. Oey. and H.-C. Lee, 2002. Simulation of velocities in the Yucatan Channel, In: Proc., Oceans 2002, MTS/IEEE Publ., 1467-1471.

Ezer, T., L.-Y. Oey, H.-C. Lee, and W. Sturges, 2003. The variability of currents in the Yucatan Channel: Analysis of results from a numerical ocean model, *J. Geophys. Res*., *108*, 3012, 10.1029/2002JC001509.

Romanou, Anastasia, Eric P. Chassignet, and Wilton Sturges, 2004. The Gulf of Mexico circulation within a high-resolution numerical simulation of the North Atlantic. *J. Geophys. Res., 109*, C01003, doi:10.1029/2003JC001770.

Wang, D.-P., L.-Y. Oey, T. Ezer, and P. Hamilton, 2003. Near-surface currents in DeSoto Canyon (1997-99): Comparison of current meters, satellite observation and model simulation, *J. Phys. Oceanogr.*, 33(1), 313-326.



The figure above shows the “deep” Gulf of Mexico, the focus of the study, as well as the mean temperature from all historical hydrographic observations at a depth of 1,500 m, averaged into one-degree bins. One of the remarkable features is that there is a warm region at the base of the mean Loop Current, although we know that this flow has to pass through the 800-m deep restriction off Miami.

The figure below shows a 3-D view of the Gulf bottom topography.