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STUDY TITLE: Direct Observations of Ocean Currents over the Western Slope in the Gulf of Mexico

REPORT TITLE: Full-Water Column Current Observations in the Western Gulf of Mexico

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BACKGROUND: The Western Gulf of Mexico owes a large portion of its circulation variability to the translation of Loop Current Eddies (LCEs). These eddies are warm-core anti-cyclonic features produced by a detachment process of the Loop Current in the Eastern Gulf of Mexico. They have typical diameters of 200 km and maximum current speeds of 1 m/s at the surface. Their size and swirl motion generally diminishes with depth remaining coherent up to 800-1,000 m depth. The westward or southwestward translation of these eddies occurs at rates on the order of 2 to 5 km/day, is irregular, accompanied by cyclones of smaller or similar size, and it ends up with a collision against the Gulf's western shelf. As a result of satellite-based measurements, the amount of information at the surface is quite ample, but there is a lack of deep-water observations of these eddies as they interact with the shelf.

OBJECTIVES: To measure and document the breakup and ultimate dissipation of LCEs in their collision process against the western shelf of the Gulf of Mexico. Particular emphasis is given to the full-water column signature of the anti-cyclonic and cyclonic eddies that participate in this process. To determine average currents and temperatures and their principal scales of variability over the experiment area.

DESCRIPTION: Fourteen months, from August 2004 to November 2005, of direct current measurements off the coast of Tamaulipas, Mexico, in the NW Gulf of Mexico capture the evolution of currents and temperatures as several eddies transit a five mooring array. Three of these moorings are located at 500, 2000 and 3500 m bottom depth at a latitude near 25º 22' N, and the remaining two to the southwest of the one at 2,000 m and along the 2,000 m isobath resembling a tilted T. The separation among close-by moorings is of about 80 km. The coverage of the water column is ample with Acoustic Doppler Current Profilers (ADCPs), all looking upward and single level current meters all registering temperature too. In the 500 m mooring a single 75kHz ADCP, from 7 m above the bottom, sampled the full column. In each of the other moorings two 75 kHz ADCPs were deployed near 450 and 1200 m below the surface, with single level current meters recording near 700 and 1500 m depth, and a 300 kHz ADCP located about 8 m above the bottom to measure near-bottom currents. The deepest mooring was also instrumented with single level current meters close to 2,000, 2,500 and 3,000 m. These observations were complemented with satellite altimetry. LCEs Titanic (T), Ulysses (U) and Vortex (V) impacted the mooring area at the beginning, middle and end of the observational record. Cyclones labeled C1 and C4 had very complicated histories since their generation, involving several intensification and merging events. They had a strong impact on the mooring observations. During September-October 2004, LCE Titanic affected the two southern moorings while cyclone C1 was over the eastward moorings. Late November 2004 marks the arrival of eddy Ulysses which was blocked by cyclone C1 and together with cyclone C5 split the eddy in two, forming Ulysses-S and Ulysses-N eddies at the end of December 2004. Cyclonic circulation dominated the mooring area during January and February 2005. In March 2005 eddy Ulysses-S moves northward along the slope and Ulysses-N stretches to the west so that by April the two branches merge again and for the following 7 months (until mid September) this "re-merged" eddy Ulysses defines the circulation over the array. The last three months of observations are marked by the presence of cyclone C4, the result of several merging events including cyclone C1, and the arrival of LCE Vortex.

SIGNIFICANT CONCLUSIONS: The high degree of consistency between the mooring observations and the altimetry data clearly indicate that flow variability in the study area is determined by the passage, formation, regeneration and dissipation of both cyclonic and anti-cyclonic eddies. With surface geostrophic currents derived from altimetry, we find some eddy events reaching all the way to the bottom and some others in which substantial veering of the current occurs between the surface and 800-1,000 m. Strong wind events do leave their signature (and may even be responsible for the formation of some eddies) but arrival of LCEs, eddy-eddy and eddy-topography interactions appear to be the key features that explain most of the observations in the sense that every notable event can be traced to the presence of an eddy, cyclonic or anti-cyclonic. The centroid of the observed LCEs always remained in waters deeper than 2,000 m. High and low sea level values are clearly correlated with warm and cold temperature anomalies as deep as 1,200-1,500 m.

STUDY RESULTS: Besides the main conclusions other results are worth noticing. Weak but persistent mean currents near and above the bottom-boundary layer are directed toward the southwest in all three 2,000 m moorings and stand out above the variability. In contrast to other studies, these observations do not show the coherent intensification of current variability from 1,000 m towards the bottom, although other current features still suggest the presence of topographic Rossby waves (Donohue et al. 2008). The energetic motions are sub-inertial but near-inertial and supra-inertial fluctuations are ubiquitous in all moorings. Deep moorings show that there is a relative increase of high frequency contribution to the total kinetic energy in the 800-1,200 m depth interval. The sub-inertial currents dominate the observed variability representing more than 60% of the total variance at all depths except for a mid-water interval on the southernmost mooring between 1000 and 1,300 m depths where the ratio of sub-inertial to total variance gets as low as 47%. A coherent signal with a period of 20 days is also found within the mooring array at this depth-range. Using ADCP measurements of vertical motion of zooplankton, the mean diel cycle, from near the surface up to 1200 m depth is determined. Similar to the well known behavior from 500 m up to the surface, the deep diel cycle is phase locked to the sunlight cycle. The downward peak velocity occurs earlier closer to the surface; at 220 m it reaches a maximum of 150 m/h half an hour before sunrise, while at 900 m it peaks at only 30 m/h one hour and a half after sunrise. The cycle is nearly symmetric to solar noon, with upward peak velocities happening earlier at depth, a pattern expected if the vertical migration is triggered by critical light levels that reach greater depth closer to noon. Consequently with such differences in timing, at greater depth the nocturnal shallower stay is longer for the deeper migrating biota. The peak vertical migration velocities show relative maxima at 250 and 1,100 m depth, a sign of increased biological activity.

STUDY PRODUCT: Sheinbaum, J., J. Ochoa, J. Candela, and A. Badan. 2010. Full-water column current observations in the western Gulf of Mexico: Final report. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study BOEMRE 2010-044. pp 119

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