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STUDY TITLE: Model waves and currents produced by Hurricanes Katrina and Rita

REPORT TITLE: Modeling Waves and Currents Produced by Hurricanes Katrina, Rita, and Wilma

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BACKGROUND: The destructive forces of Hurricanes Katrina and Rita had a marked effect on oil and gas production in the northern Gulf of Mexico in the second half of 2005. Energy from these storms can impact OCS infrastructure directly, but much hurricane damage is indirect impact through the extraordinarily high waves and powerful currents they create. Surface waves are thought to have exceeded 130 feet in height near the eyewall of Hurricane Ivan, and waves as high as 91 feet were actually recorded at moorings that were fortuitously placed in the path of Ivan. These are the largest waves ever directly measured. Similar observations are not available in the path of Hurricanes Katrina and Rita two category 5 hurricanes. The response of the ocean to hurricanes depends upon the speed at which the storm moves across the sea surface and includes a train of lee waves behind the storm and a zone of upwelled water due to Ekman pumping associated with the hurricane. The ocean's response to Hurricane Georges, for example, propagated downwards to at least 500 feet, resulting in a current jet (Dimarco, 2004). Because the scarcity of observations, it is necessary to simulate three dimensional current structures in order to capture the complexity of the ocean response to energetic hurricanes.

OBJECTIVES: (1) To assess the response of waves and currents throughout the water column on the Northern Gulf of Mexico slope, shelf, and nearshore areas to Hurricanes Katrina and Rita, using numerical modeling techniques in conjunction with meteorological and physical oceanographic data; (2) to produced a realistic simulation of circulation throughout the entire water column in the study areas; (3) to determine the length of time of large ocean response to hurricanes; and (4) to determine the area(s) of greatest wave height and current speed.

DESCRIPTION: The Loop Current is the dominant feature of the circulation in the eastern Gulf of Mexico and the formation region of the Florida Current-Gulf Stream system that transports significant amounts of heat poleward. The Loop episodically sheds warm-core rings at intervals of approximately 3 to 18 months. The Loop Current and its rings are powerful oceanic features that affect, either directly or indirectly just about every aspect of oceanography of the Gulf. In addition to producing strong ocean currents, the Loop and rings possess, large values of the Ocean Heat Content (OHC) and regions where OHC > 60~90 kJ/cm2 have been found to be conducive to storm intensification. Typical values of OHC within the Loop and rings in summer through autumn easily exceed 60 kJ/cm2. It is therefore of scientific and practical values to accurately forecast (and hindcast) the locations, paths and strengths of the Loop Current and rings and especially during hurricanes. We employed our circulation model for the Caribbean Sea and the Gulf of Mexico that is based on the Princeton Ocean Model. The model domain includes the northwestern Atlantic Ocean west of 55ºW. The model is forced by wind and monthly discharges from 34 rivers along the northern Gulf Coast. In this work, surface heat and evaporative fluxes are set to zero so that the SST variations are due to model's internal dynamics; in the case of forcing by a hurricane.

SIGNIFICANT CONCLUSIONS: This project has advanced our knowledge of hurricane-induced current and wave responses in the Gulf of Mexico by examining in details two cases of importance: Hurricanes Katrina and Rita. In addition, the ocean responses due to Hurricane Wilma were examined. The length of time for which substantial ocean response to these hurricanes persisted is relatively short, about 2~3 days. For currents, we concentrate on the inertial currents which contain most of the energy of hurricane-induced responses in the ocean. Near the surface, strong inertial currents can persist for a few days but depending on the underlying vorticity field the energy can penetrate to great depths (~1000 m) and can persist for 10 days or longer. We find strong modification of these energy paths and lengths of time of persistent energies by Loop Current and rings. The model wave heights exceed 25 m for Katrina and about 20 m for Rita. They are higher to the right of the storm than to the left. The great waves occurred just as the storms reached the continental slope and outer shelves; in the case of Katrina, this probably accounted for the severe damage to the oil platform Mars just south/southeast of the Mississippi delta. We found swaths of maximum near-inertial current speeds at $z = 0$ m and at $z = -600$ m produced by Katrina and Rita. Consistent with the wind-waves, strongest inertial currents again occur to the right of the storms. Top speeds reach 3.8 m s^{-1} for Katrina and 2.8 m s^{-1} for Rita. Strong currents occur again just over the outer shelves and slope regions of the northern Gulf of Mexico, and also near the coast where great sea levels due to storm surges prevail.

STUDY RESULTS: This study analyzed the response of the ocean to strong hurricanes, particularly Hurricanes Katrina, Rita, and Wilma in 2005. The study showed that high waves and currents occur predominantly on the right side of the hurricane. Maximum wave heights of 20 to 25 m were hindcasted and occurred over the shelf and shelf. Top currents between 2 and near 4 ms^{-1} were hindcasted. These maximum values occur over the shelf and near the coast causing large storm surges there.

STUDY PRODUCTS: Oey, L.-Y. and D.-P. Wang. 2009. Modeling waves and currents produced by Hurricanes Katrina, Rita, and Wilma. U.S. Dept. of the Interior, Minerals Management Service,Herndon, Virginia. OCS Study MMS 2009-060. xviii + 135 pp.

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