Hurricanes can greatly modify the sedimentary record, but the coastal scientific community has rather limited capability to predict hurricane-induced sediment deposits. A three-dimensional (3-D) sediment transport model was developed in the Regional Ocean Modeling System (ROMS) to study the spatial and temporal changes in seabed erosion and deposition on the Louisiana shelf in response to Hurricane Katrina in the year 2005. Sensitivity tests were performed on erosional and depositional processes for a range of erosional rates and settling velocities. Estimated maximum erosional depths were sensitive to both erosional rates and settling velocities, but horizontal erosional patterns seemed to be controlled mainly by hurricane tracks and high wave-current combined shear stresses located between the 10- and 50-m isobaths. During the passage of the hurricane, local resuspension and deposition dominated the sediment transport mechanisms. Hurricane Katrina followed a shelf-perpendicular track before making landfall and its energy dissipated rapidly within about 48 hours along the eastern Louisiana coast. Conditions to either side of Hurricane Katrina’s storm track differed substantially, with the region to the east having stronger winds, taller waves and thus deeper erosions. This study illustrated the nonlinear, non-steady and episodic nature of sediment transport in the northern Gulf of Mexico and indicated that major hurricanes can disturb the shelf at centimeter to meter levels. Hurricane Katrina suspended seabed sediment mass that far exceeded the annual sediment inputs from the Mississippi and Atchafalaya River, but the net transport from shelves to estuaries is yet to be determined. Future studies should focus on the sediment exchange between estuaries and shelves during hurricanes.