

Storm induced hydrodynamics and sediment transport in a coastal Louisiana lake



Angelina M. Freeman^{a,*,1}, Felix Jose^{b,2}, Harry H. Roberts^b, Gregory W. Stone^b

^a Department of Oceanography and Coastal Sciences, Louisiana State University, Coastal Studies Institute, Howe-Russell Geoscience Complex, Baton Rouge, LA 70803, United States

^b Coastal Studies Institute, Louisiana State University, Howe-Russell Geoscience Complex, Baton Rouge, LA 70803, United States

ARTICLE INFO

Article history:

Received 17 October 2014

Accepted 28 April 2015

Available online 9 May 2015

Keywords:

tropical cyclones

storm surge

hydrodynamics

modeling

suspended sediment

Mississippi River Delta Plain

ABSTRACT

Coupled hydrodynamic modeling and sediment core analysis was used to investigate Hurricane Rita hydrodynamic conditions and associated sediment dynamics in Sister Lake, a shallow coastal lake in Terrebonne Basin, Louisiana. Tropical cyclone impacts on wetland, terrestrial, and shelf systems have been previously studied and reasonably delineated, but little is known about the response of coastal lakes to storm events. This initial investigation of tropical cyclone impacts on a shallow coastal lake clarifies sediment transport and deposition patterns in a geologically complex deltaic region. Modeling results from Hurricane Rita forcing conditions hindcast a maximum storm surge elevation of approximately 1.1 m and a significant wave height of 1.0 m in Sister Lake. Bed shear stresses across almost the entire model domain leading up to Hurricane Rita's landfall were above the critical value causing erosion of fine-grained bottom sediments, and quickly decreased in the western portion during Rita's landfall, indicating significant deposition in this western portion of the lake. The ideal event sedimentation unit that would result from the storm conditions hindcast from the numerical model was corroborated with stratigraphy identified in box cores; sedimentary units with an erosional base overlain by recently deposited silty material topped by clays. This study provides a fundamental understanding of lake bottom characteristics and impacts of storm-related physical processes on erosion and deposition.

Published by Elsevier Ltd.

1. Introduction

The northern Gulf of Mexico coast experiences both tropical and extra-tropical cyclones on a repeated basis, strongly impacting coastal morphology. Tropical cyclone induced impacts on wetland (McGee et al., 2006; Turner et al., 2006, 2007; Day et al., 2007; McKee and Cherry, 2009; Tweel and Turner, 2014), terrestrial (FAPRI-UMC, 2004; Guidroz et al., 2006; Williams and Flanagan, 2009; Williams, 2010; CPRA, 2012), and shelf systems (Allison et al., 2005, 2007; Dail et al., 2007) have been previously studied and reasonably delineated. Compared to these more easily accessible coastal plain environments, coastal lakes and bays are grossly

understudied. Fundamental knowledge about sediment distribution as well as benthic habitat types is virtually unknown in all but a few coastal bay and lake settings, and the ways lakes and bay bottoms are impacted by major tropical cyclones are only beginning to be understood (Rego and Li, 2010; Liu et al., 2011; Freeman and Roberts, 2012).

Sediments are often resuspended and redeposited multiple times in coastal systems, although the complex tropical cyclone-induced transport and deposition processes are not completely understood (Wright and Nittrouer, 1995). Storms can cause scouring and erosion of wetlands; Hurricanes Katrina and Rita eroded 260 km² of wetlands (McGee et al., 2006). Storm forcing can alternately also cause deposition of suspended sediment in the water column onto wetland surfaces during inundation events; Hurricanes Katrina and Rita also redistributed sediment, depositing an estimated 131×10^6 metric tons of inorganic sediment in coastal wetlands (Turner et al., 2006, 2007). Hurricane Rita formed washover terrace deposits up to 50 cm in thickness (FAPRI-UMC, 2004; Guidroz et al., 2006). Tweel and Turner (2014) estimated an average annual deposition of 5.6 million tons of inorganic

* Corresponding author. Louisiana Coastal Protection and Restoration Authority, 450 Laurel Street, Baton Rouge, LA 70801, United States.

E-mail address: Angelina.Freeman@la.gov (A.M. Freeman).

¹ Present Address: Louisiana Coastal Protection and Restoration Authority, 450 Laurel Street, Baton Rouge, LA 70801, United States.

² Present Address: Department of Marine and Ecological Sciences, Florida Gulf Coast University, Fort Myers, FL 33965, United States.

sediment across the Louisiana coast between 1851 and 2008. Hurricanes Katrina, Rita, and Lili were found to have induced intense reworking and redeposition of sediments on the Louisiana shelf and slope (Allison et al., 2007; Goni et al., 2007). Freeman and Roberts (2012) identified increments of sedimentation in a Louisiana lake 1–10 cm in thickness, corroborated with radionuclide dating as being products of the Hurricanes Katrina and Rita. There are only a limited number of studies with direct measurements of the hydrodynamics in Louisiana's backbarrier bays during tropical cyclone events (Liu et al., 2011; Smith et al., 2011).

During the 20th century, coastal Louisiana including the Mississippi River Delta lost approximately 5000 square kilometers of coastal land due to a variety of natural and anthropogenic causes including tropical cyclones. Coastal wetland loss rates in Louisiana are projected by Barras et al. (2003) at 26.7 km² per year. Blum and Roberts (2009) determined that in the absence of sediment input, an additional 10,000–13,500 km² of coastal Louisiana land will drown by 2100 due to subsidence and a sea level rise rate that has tripled since the coastal plain was constructed. During the prolonged period of delta deterioration which is the final stage of the delta cycle, shallow coastal lakes form on the subsiding marshland surfaces of these once active delta complexes (Penland et al., 1988). The lakes, like the rest of the coastal landscape, are in a constant state of change as the deltaic landscape subsides and is progressively impacted by marine processes. Sediment resuspension, transport, and deposition processes on the inner shelf and in coastal bays from major storm events are highly dynamic and poorly understood. Understanding the response of coastal lakes, which are among the most biologically productive coastal environments, to storms is a crucial component for effective coastal management in Louisiana, and also important in other

deteriorating deltaic systems worldwide. The goal of this study is to better understand the interaction of physical forcing during storm events and sedimentary response in a shallow coastal lake.

To expand the limited understanding of sediment dynamics in Louisiana's coastal bays, hurricane induced hydrodynamics and sediment transport processes in Sister Lake (Fig. 1) were studied using hydrodynamic modeling integrated with geophysical data analysis. This study focuses on the main research question: How to assess, quantify, and model impact of storms on a coastal lake bottom? The research question was answered by: 1) developing the bathymetric configuration of the lake using echo-sounder profile data; 2) collection of post-storms box cores; 3) identifying bottom roughness and bottom friction from side-scan sonar and grain size data; 4) winter storm field data collection; 5) calibration and skill assessment of hydrodynamic models using winter storm period data; 6) hindcasting Hurricane Rita storm conditions and estimation of related sediment transport in Sister Lake; and 7) relating the stratigraphy of the event layers in X-ray radiographs of box core to model predictions. Results of this analysis provide an initial understanding of how coastal Louisiana lakes respond to major storm events.

1.1. Regional setting: Sister Lake study area

Sister Lake (also known as Caillou Lake), a shallow coastal Louisiana lake, is the site of this study (Fig. 1). Two tidal channels connect Sister Lake to the Gulf of Mexico, and a northern channel connects Sister Lake to Lake Mechant and to Bayou Dularge. Sister Lake is located in the deteriorating Lafourche delta, which was an active prograding delta system 500–2500 years ago (Blum and Roberts, 2009). A state oyster seed ground, Sister Lake is the site

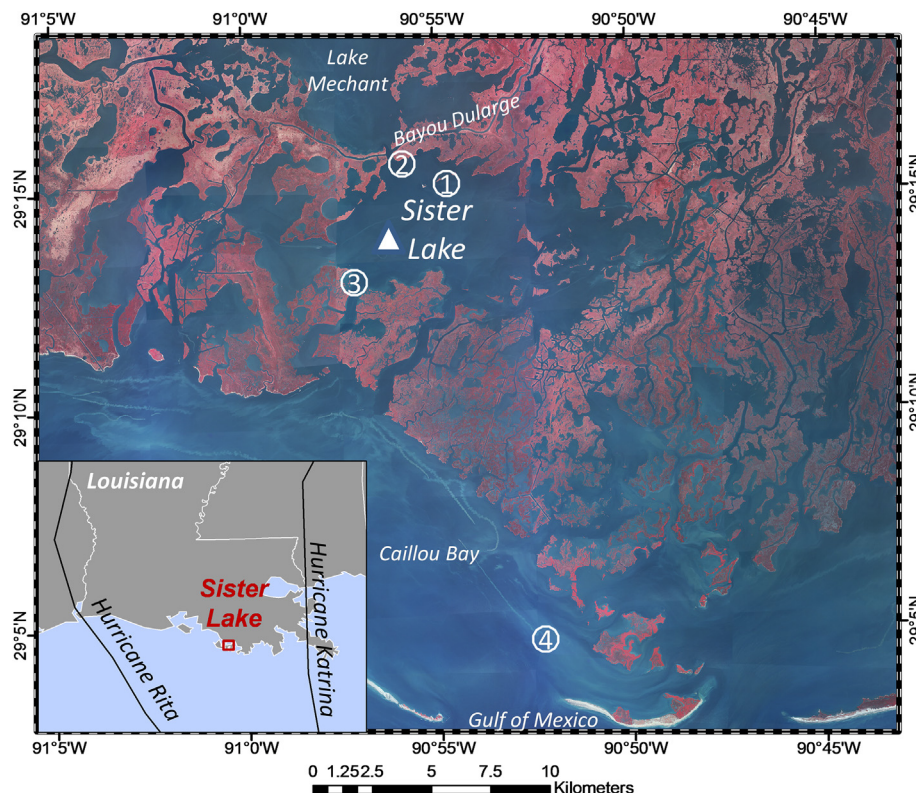


Fig. 1. Sister Lake study site. Hurricane Katrina passed 130 km east of Sister Lake and Hurricane Rita passed 230 km west of Sister Lake. Circles denote locations for (1) Water level sensor in Sister Lake (2) Water level sensor tripod in northern channel, (3) Water level and current sensor tripod in southern channel, and (4) Water level and wind sensor in Caillou Bay. Triangle denotes box-core location. Projection: UTM Zone 15 N.

Download English Version:

<https://daneshyari.com/en/article/4539463>

Download Persian Version:

<https://daneshyari.com/article/4539463>

[Daneshyari.com](https://daneshyari.com)