HYDRODYNAMICS AND SEDIMENT TRANSPORT MODELING FOR TIGER AND TRINITY SHOALS OFF THE LOUISIANA COAST

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ABSTRACT

Two oceanographic surveys were conducted at the Tiger-Trinity shoal complex in December 2008 and March-April 2009. Tripods equipped with ADCP, PCADP, ADV, OBS and pressure sensors, were deployed along a transect for monitoring both wave and current fields on the shoal and adjacent environment. During the 2008 deployment, which lasted for two weeks and with a single tripod deployed over Tiger shoal, three cold fronts crossed the study area and significantly influenced the hydrodynamics of the region. The maximum wind speed observed was 14.2 m/s while the maximum wave height recorded was less than 1 m. This substantial wave attenuation observed for Tiger Shoal can be attributed to the nature of the bottom sediments. The highly viscous bottom sediments dissipate energy of incoming waves, a phenomenon confirmed by previous studies conducted along this coast. Also, associated with the winter storm events, a reduction in water level was observed which can be attributed to enhanced wind stress directed offshore. Except for a few instances, the wave-induced shear stress at the bottom was strong enough to re-suspend sediment during the entire deployment period. A suite of hydrodynamic models was also implemented, as a preliminary study, to estimate the effect of waves and currents on shoal dynamics. MIKE 21 wave and Hydrodynamic models, developed by DHI Water and Environment®, were implemented for the Tiger and Trinity shoal system. A substantial reduction in wave height was observed seaward off Trinity Shoal. This can be attributed to rapid decrease in slope off Trinity Shoal. Also, our preliminary hydrodynamic model data demonstrate that strong currents existed over the shoal region, which are critical in the redistribution of sediment, although the precise patterns and magnitude are remain to be quantified, particularly during the winter storm period.

INTRODUCTION

In Louisiana, large tracts of the coastal area have been experiencing severe land loss, particularly the retreat of Louisiana shorelines over the long-term (rates of 6.1 m yr^{-1}) and over the short-term (rates of 9.4 m yr^{-1}, NRC, 2006; Penland et al., 2005). This loss can be attributed to a number of natural processes including land subsidence and Mississippi River deltaic processes, anthropogenic activities including control of sediment discharge partially controlled by engineered structures (NRC, 2006). Federal and State Agencies have been working together to mitigate this coastal erosion issue and have developed various strategies, including replenishing the severely disintegrating barrier islands and marsh. Ship Shoal, Tiger and Trinity Shoals, in addition to Sabine Bank, are identified as potential sediment sources to rebuild the coast. Recent studies (Stone et al., 2009; Kobashi 2009 etc.) demonstrate that restricted dredging of sediments from Ship Shoal to be potentially used in restoring the adjacent barrier islands would not significantly influence the shoal hydrodynamics and wave field in the region. A similar study has been commissioned by the US Bureau of Energy Management, Regulation and Enforcement (BOEMRE) to study the impact of partial dredging from Tiger and Trinity Shoals (see Figure 1 for the shoal location). Unlike Ship Shoal, this shoal complex is well within the influence of the mud stream from the Atchafalaya River (See Figure 2 for the MODIS true color imagery of the sediment plumes from the River) and is frequently blanketed with fine sediments, especially during the Spring flood season. The given study consists of seasonal measurements of waves, currents and sediment characteristics, using advanced oceanographic instrumentation and implementation of wave and hydrodynamic models.

METHODOLOGY

A PCADP tripod was deployed on the crest of Tiger Shoal (blue diamond on Figure 1) in December 2008 for a period of two weeks (2008/12/03-2008/12/17). The Tripod was configured with a downward looking PCADP, two OBS sensors and an upward looking 1200 KHz ADCP (Figure 3). The above instrument arrays have been widely used to investigate the bottom boundary layer (BBL) characteristics all over the world (Cacchoine et al., 2006). All instruments recorded *in-situ* data in burst mode (discontinuous).

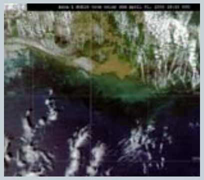


Figure 2. MODIS imagery from study area. Data courtesy ESL Lab, LSU

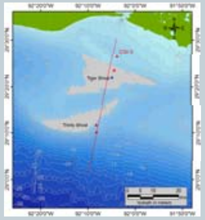


Figure 1. Location map.▲ represents 2008 survey location and ▲ for 2009 locations

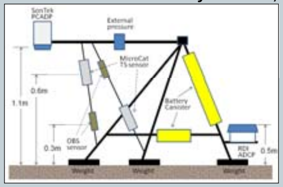


Figure 3. PCADP tripod assembly

IN SITU DATA

In addition to the survey data, met-ocean data from NDBC's Buoy 42001, farther offshore from the shoal location, and CSI 03 (WAVCIS) were used in data analysis and discussions. Bulk wave parameters were computed from ADCP data using the WavesMon® package developed by Teledyne RDI. The time series plots of significant wave height (H_s), peak period(T_p) as well as wind speed and direction during the 2008 deployment are provided in Figure 4. Sediment samples were collected during the deployment and retrieval cruises for analyzing the sedimentological characteristics (see Figure 5). The alongshore and cross-shore wind stress were computed to study the effect of wind forcing in directing the river plumes along the innershelf. The time series of alongshore and cross-shore velocities at various depths of the water column (1.02 m, 2.02 m 3.27 m and 4.52 m) were extracted from the PCADP and ADCP data (Figure 6).

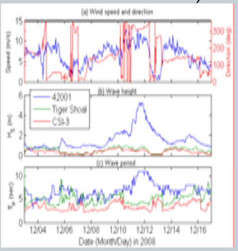


Figure 4. Times series of wind speed and direction (top), SWH (middle) and Tp (bottom) during 2008 survey

Figure 5. Shoal-surface samples collected during deployment (upper) and retrieval (bottom)

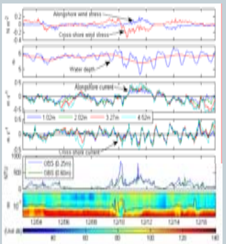


Figure 6. Times series of wind stress, water level, alongshore and cross shore currents, suspended sediment concentration and Acoustic back-scatter intensity (PCADP), during 2008 deployment

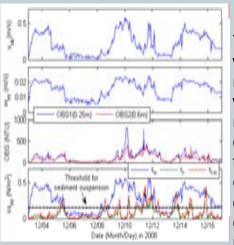


Figure 7. BBL parameters computed from the 2008 data

Three cold-fronts crossed the study area during the two-week deployment period. Wind speed reached up to 14.2 m/s during the December 11th storm (Figure 4). The deep water H_s reached up to 5m, at NDBC 42001, while the H_s measured at Tiger Shoal was less than 1m. The wave data from CSI 03 shows a reduction in energy, signifying the effect of bottom friction in the dissipation of wave energy. A Similar trend has been observed for the T_p distribution, when waves propagated to the coast. The computed wave-induced bottom boundary layer (BBL) parameters (Figure 7) show that except for short intermittent durations, the bottom shear stress and shear velocity exceeded the critical threshold for sediment transport. This has been translated into significant sediment re-suspension and transport during much of the deployment period. The OBS data during the deployment show peaks corresponding to the storm events (Figure 7) and during the December 11th storm, sediments remain in suspension for a prolonged period of time, which was reported by Kobashi & Stone (2009) also. It is expected that sand and hash fabric of the shoal would be exposed during the post-frontal phase of the storm. The bottom sediments collected 7 days after the December 11th storm (Figure 5) confirmed this observation.

The hydrodynamics in the study area are strongly influenced by inputs from the Atchafalaya River and the passage of cold fronts. During the observation period, 40-hour low-pass filtered water level varied up to ~0.5 m (Figure 6). Also, surface currents of >0.5 m/s were observed, especially during the passage of cold fronts. Strong currents are expected over the shoals due to flow modulation from shallow bathymetry. This ephemeral strong currents likely results in flush-out of the fine-grained sediments from the shoal during the extra-tropical winter storm (Kobashi 2009).

WAVE AND HYDRODYNAMIC MODELING

A third-generation wave and hydrodynamic modeling suite, MIKE 21/MIKE3, has been implemented to study the effect of waves and currents in the re-suspension and transport of sediments in the shoal environment. The model suite is implemented on a un-structured grid (Figure 8), with high resolution for the Tiger and Trinity Shoals and Ship Shoal. The river discharge from the Atchafalaya River is also included in the model as

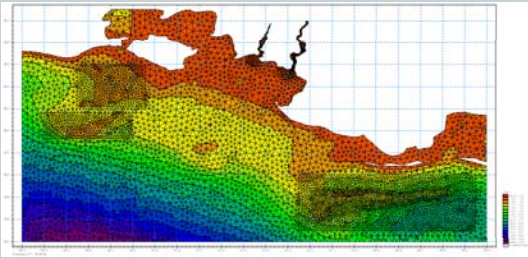


Figure 8. Un-structured mesh grid for the model domain. High resolution mesh for the shoals is embedded to resolve the flow dynamics of the shoals originated from complex bathymetry

point sources at Wax Lake Outlet and the Lower Atchafalaya River mouth (see Figure 8). The model was forced with NCEP NARR re-analyzed wind data and tidal data extracted from a global tide model. The mesh grid was prepared using NGDC, NOAA bathymetry. WAVCIS data from the domain along with *in situ* data collected during the 2008 deployments were used for skill assessment of the wave and hydrodynamic models (Figures 9 & 10). Bulk wave parameters computed using the model were in excellent agreement with the *in situ* data. The surface current data also show excellent agreement with the *in situ* data while the bottom current fields show low correlation. Figures 11 & 12 provides snap shots of the SWH and current fields associated with the passage of a cold front across the study area.

In conclusion, this is an ongoing study to unravel the effect of fine grained sediments on the dissipation of waves over Tiger and Trinity Shoals. The data from spring and summer are currently being analyzing to estimate the impact of restricted dredging from these shallow shoals on hydrodynamics in South central Louisiana.

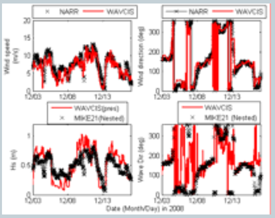


Figure 9. Time series of wind speed and direction (top), SWH and wave direction (bottom) plotted against in situ data

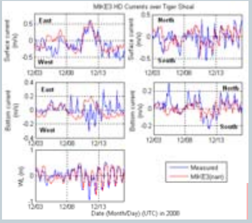


Figure 10. Time series of surface current (top), bottom current (middle) and water level (bottom) plotted against in situ data

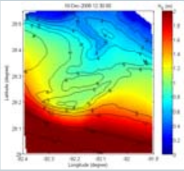
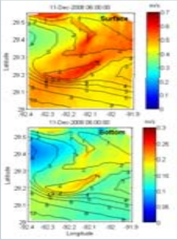


Figure 11. Snap-shot of the simulated SWH distribution for the study area (left) and surface and bottom currents (right), during a winter storm passing the region



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