Coupled Dynamics of Waves and Fluid-Mud Layers

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LONG-TERM GOALS

The overall goal of the proposed work is to understand and model the interaction between waves and fine-grained sediment, in order to improve the accuracy of analysis and prediction of waves, currents, a suspended sediment distribution in the nearshore and in estuarine environments, where soft mud seabeds and fluid-mud layers are commonly found.

OBJECTIVES

The immediate goal of is to obtain and analyze highly detailed field measurements of surface waves and water/sediment motions within first 1 meter above the bottom (mab). The project will deploy two tripods carrying instrumentation for coherent measurements of waves and near-bottom sedimentary processes, including vertical structure of velocities and suspended sediment concentration, and position and motion of the lutoclines. The effort will provide basic information (lacking at this time) about fluid-mud layers characteristics, necessary for effective modeling of wave propagation over muddy shelves.

APPROACH

Recent field observations show unexpected short-wave sensitivity to sediment type. Sheremet and Stone (2003) compared synchronous wave observations in sandy and muddy environments. Short-wave ($f > 0.2$ Hz) energy levels were comparable at the two sites when wind forcing was significant, however, they dropped much faster at the muddy site during calmer periods. ONR-sponsored sediment monitoring at the same muddy site shows a strong coupling of wave dissipation and fluid-mud layer formation (sediment concentrations > 50 kg/m^3; Sheremet et al., 2004). The mechanism coupling waves and sediment dynamics in cohesive sedimentary environments is not understood. Effective modeling of wave-sediment interaction (e.g. Dalrymple and Liu 1978; Jiang and Mehta, 1996; Ng, 2000) relies on accurate characterization of sediment state. To date, no detailed coherent measurements of sediment and wave dynamics are available.

The experimental site is the muddy inner shelf fronting the Atchafalaya Bay (Figure 1). The shelf is characterized by large reservoirs of fluid mud, particularly on the shallow, low gradient shelf of the Atchafalaya subaqueous delta, that are mobilized and transported during regular winter storm events (Allison, 2000) as well as larger tropical storms. The large sediment influx from the Atchafalaya River

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14. ABSTRACT
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is also responsible for mudflat accretion at rates of up to 60-80 m/yr along the Louisiana-East Texas chenier plain. The westward-flowing Atchafalaya suspended mud plume, typically confined to shoreward of the 10 m isobath, responds quickly to meteorological perturbations (peak activity in late winter and early spring months, associated with cold front passage on 3-10 day timescales, Kemp and Wells, 1987). The instrument clusters will be deployed in different configurations, 3-4 times during Winter 2005-2006, for about 2 weeks at a time.

With ONR DURIP funding Allison has developed and fabricated a bottom tripod-based instrument cluster capable of recording high-frequency (several Hz) time series field data on general flow and sediment characteristics of the zone from 1 mab (Figure 2). The cluster includes a FOS (fiber-optic spectrometers), a high-resolution (700 kHz) pencil-beam acoustic profilers and more traditional instrumentation (PC-ADP, CTD, OBS, pressure sensors) to record bottom boundary layer (BBL) fluid conditions and shear stresses acting on these layers. The FOS tripod will be enhanced with an upward looking ADCP for surface wave detection. An additional instrument cluster will be built for this project, which will include similar downward-looking (first 1 mab) instrumentation (PC-ADP, pencil beam sonar, OBS and CTD sensors) and pressure sensors and an ADCP for surface wave monitoring.

WORK COMPLETED

The project started in November 2004 with the funds made available December 2004. Initially, funds for new instrumentation (upward-looking ADCP for the FOS tripod, and downward-looking PC-ADP and OBS for the additional instrument cluster) were not available. To proceed with an initial test in the first year prior to the end of the winter cold front cycle in the Gulf, the project borrowed the missing instruments from NRL Stennis. Although several incompatibilities and defects affecting the borrowed instruments were uncovered, test deployments were performed in Spring 2005 with the UF tripod. Funding for the new instrumentation was approved early summer 2005, and purchase orders for the instruments have been processed.

The Tulane FOS tripod was in a more advanced state at the start of the project (except for the upward-looking ADCP component) and was tested initially in a 13 day deployment on the Atchafalaya shelf in March 2005 at the close of the cold front season (Figure 2). The tripod was deployed and recovered successfully from the R/V *Longhorn* in about 5 m water depth on the Atchafalaya subaqueous delta using a method of tethering to a nearby gas platform, that facilitates recovery and minimizes potential disturbance by shrimpers. This initial test uncovered several software and hardware problems with the system including a software programming error that caused the FOS insertion probe to freeze after the second of 100 planned vertical sampling profiles. In addition, a flaw in the PC-ADP pressure release valve allowed water to enter the pressure housing, necessitating replacement of all computer boards and invalidating the data collection of the velocity, OBS and CTD data. Finally, hardware problems during initial laboratory testing of the acoustic backscatter sensor (ABS) for measuring suspended sediment time-series in the near bed, required return to the manufacturer, so that it was unavailable in the initial deployment. High-frequency wave data (Paroscientific pressure sensor) was collected over several weak cold front cycles in this initial deployment.

Inability to test the ABS system and need to further field test the FOS tripod prior to the main winter 2005-2006 deployments, led us to reconfigure a small version of the Tulane tripod that could be deployed without the FOS sensors from a small boat (Figure 2) without requiring additional UNOLS vessel time. It was decided that this non-cold front interim period was an opportunity to examine wave-sediment interaction in the shallowest part of the subaqueous Atchafalaya delta—the 2-3 m deep topset area that we surmise serves as the source area for resuspension that leads to fluid mud formation further offshore in our main study site. Accordingly, the small version of the Tulane tripod was deployed with PC-ADP, ABS, OBS, and CTD on August 26, 2005 from LUMCON's R/V *Whiskey Pass*. Three days later, Hurricane Katrina made landfall 150 km east of the study area disrupting recovery efforts. The tripod was configured for a 14 day deployment but was finally recovered using Tulane's R/V *Eugenie* on September 19th, prior to the area suffering enormous impact from Hurricane Rita on September 24th. All instrumentation functioned perfectly throughout the 14 day period of memory and battery, however, tilt and compass data on the PC-ADP indicate that the tripod was overturned by the unexpectedly large wave and current energies caused by Hurricane Katrina on the 28th.

RESULTS

Figure 3 shows selected data from the Tulane tripod deployment during the period from August 26th until it was overturned on the 28th. These data indicate that the topset area was experiencing increasing currents reaching almost 80 cm/s and significant wave heights of 1 m in only 2.5 m water depth. LSU's WAVCIS platform data indicates that winds were oriented offshore here on the western side of Katrina's approach, leading to water level setdown (pressure record in Figure 3e). Interestingly, no evidence of an offshore swell is shown in the wave directional data: Mean wave direction is from the north following local winds. This suggests that the soft muds of the inner shelf are highly effective at dissipating waves prior to their reaching this shallow, inshore zone. Suspended sediment concentrations (yet to be calibrated, Figure 3d) were increasing, indicating benthic shear stresses exceeded critical erosional stress. The water column was likely well mixed, as indicated by the similar turbidities observed in the OBS records at 35 and 75 cmab. Fluid mud concentrations were not reached in this phase, as indicated by the OBS sensors not reaching peak voltage output which generally occurs at 1-5 g/l. Detailed analysis of this dataset is continuing and will be presented at the AGU Ocean Sciences meeting special Katrina session in February 2006. In addition, some of the data after the tripod was overturned is likely useful (e.g., OBS, pressure, single-beam velocities) suggesting valuable information can be extracted about the peak of the Katrina event and the possible fluid muds forming in the waning phase.

PUBLICATIONS AND PRESENTATIONS TO DATE

Sheremet, A. and Allison, M.A., 2006. Observations of wave-sediment interaction, Louisiana, USA. AGU Ocean Sciences Meeting, Honolulu, February.

**Allison, M.A., Sheremet, A., Gõni, M.A., and Stone, G.W., in press. Storm layer deposition on the Mississippi-Atchafalaya subaqueous delta generated by Hurricane Lili in 2002. *Continental Shelf Research*.

**Although not based on the field results of the present study, this manuscript was written after the onset of our collaboration and examines wave-sediment interactions using data collected in the field area during Hurricane Lili in 2002.

IMPACT/APPLICATIONS

Much of the present and near-future Navy capability on predicting regional and nearshore processes assumes a sandy (non-cohesive) sedimentary environment. The present research enhances this capability by providing field data essential for model validations and by identifying processes and developing mechanisms which allow expansion into areas with significantly different characteristics.

RELATED PROJECTS

The project is closely related to the ongoing ONR project “Wave forecasting in muddy coastal environments: Model development and real-time applications” (PI Sheremet, UFL, Stone, LSU and Kaihatu, NRL Stennis). The project is also well aligned with the large multi-year NRL project “Coastal Dynamics of Heterogeneous Sedimentary Environments” (PI. Dr. K. Todd Holland).

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Sheremet A., A. J. Mehta, B. Liu, and G. W. Stone, Observations of nearshore wave dissipation over muddy sea beds, submitted to Estuarine, Coast and Shelf Science.

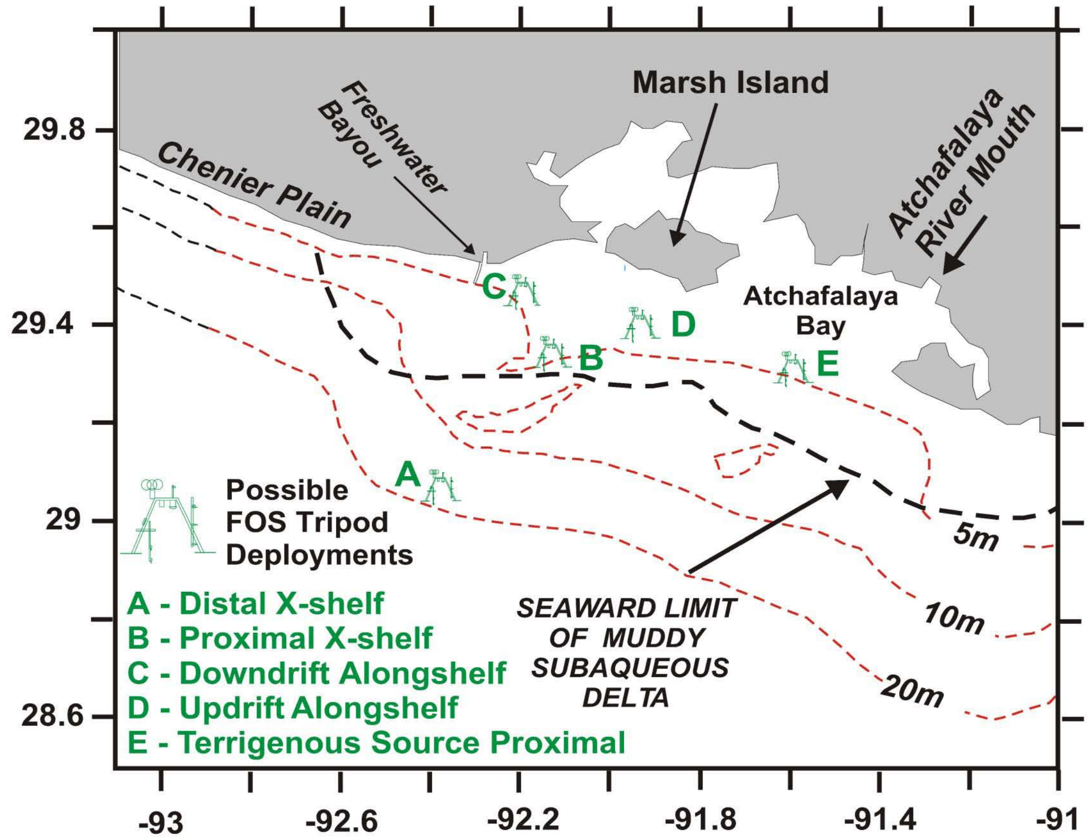

Figure 1: Deployment plan.

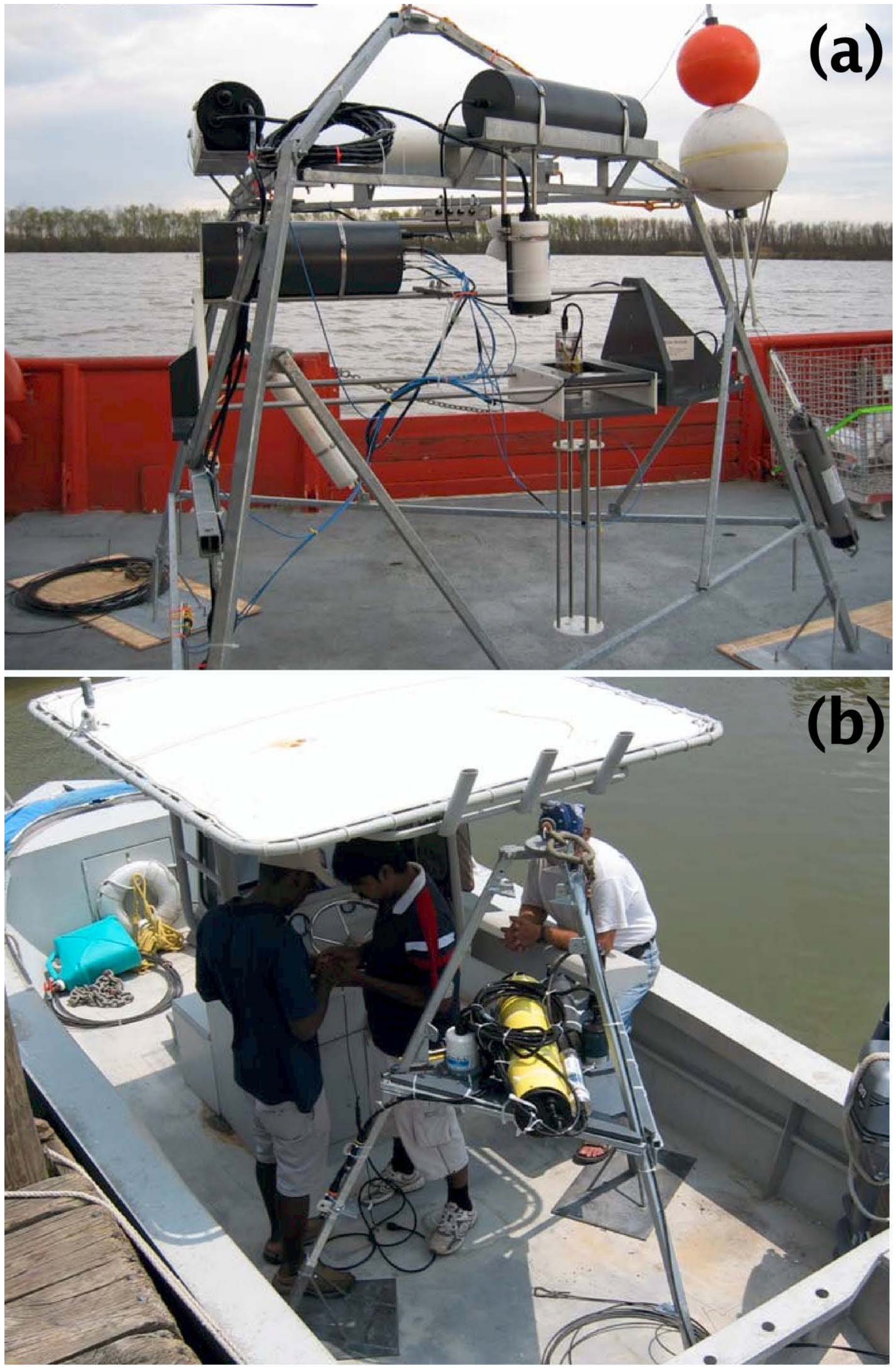

Figure 2: Tulane instrumented tripod: (a) FOS configuration deployed in March 2005; (b) smaller version deployed in August 2005.

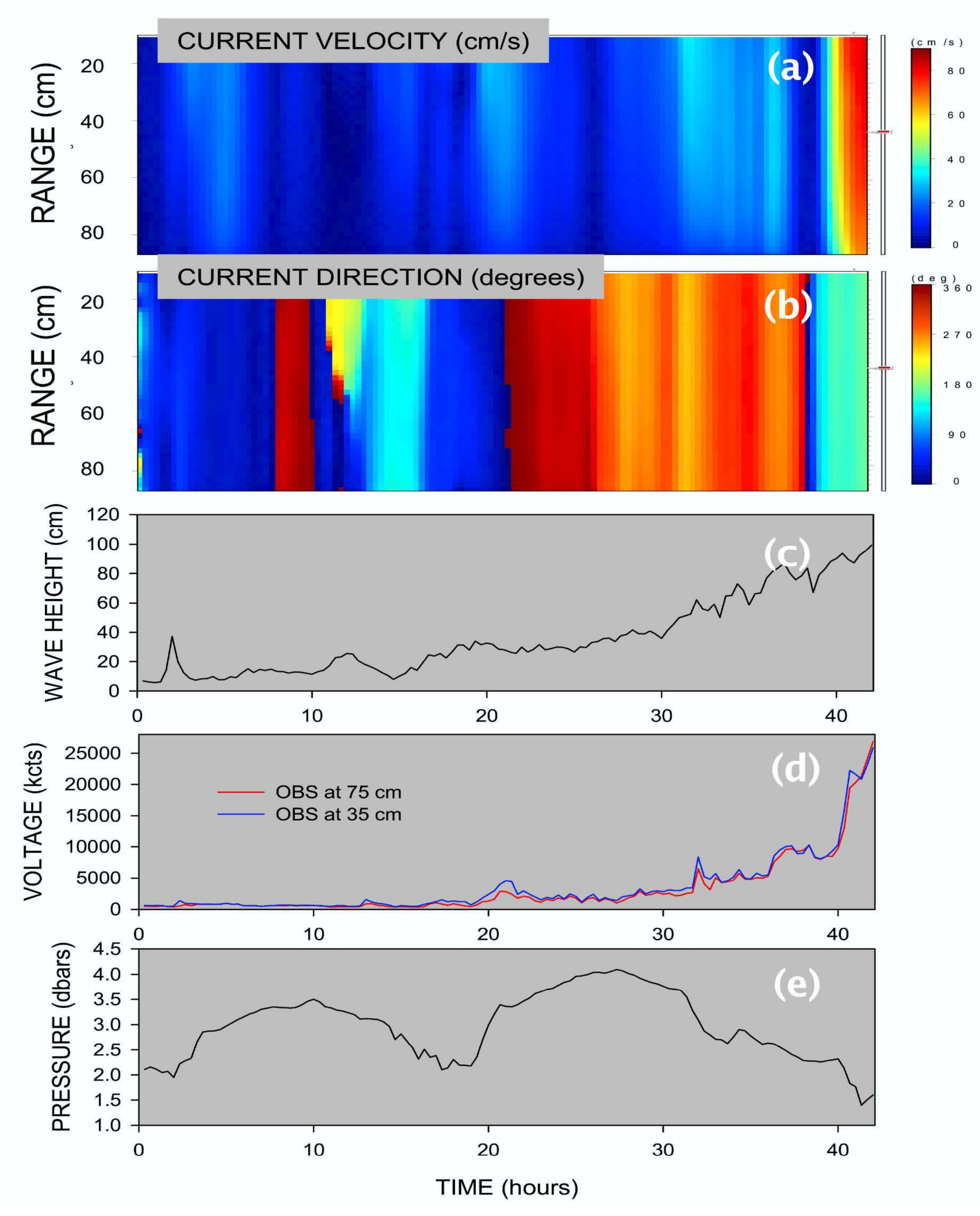

Figure 3: FOS tripod deployment data in the 45 hr period prior to the tri[pod being turned over in the initial stages of Hurricane Katrina.