Observations of Wave-Sediment Interaction, Louisiana, USA
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Abstract
In an ongoing field experiment two instrument clusters are deployed at various locations on the muddy subaqueous delta of the Atchafalaya River, Louisiana, to conduct high resolution observations of water and sediment motion. The experiment studies fluid mud formation and its effects on wave propagation under wave conditions associated with winter cold fronts.

Background
Limited observations show that waves propagating above muddy seafloors can be strongly dissipated. Wells and Coleman (1981) recorded more than 90% wave energy dissipation across the 20-km wide shallow shelf of Surinam; Mathew et al. (1995) observed 95% energy loss as waves crossed 1.1 km-wide mudbanks off the coast of India.

Various models have been proposed to describe mud-induced wave dissipation, e.g. soft bottom damping Shemdin et al., 1980; viscous fluid-mud layers Dalrymple and Liu, 1978; formation of a high-density near-bottom mud layer Sheremet et al., 2005; surface-internal wave interaction waves Hill and Foda, 1999. However, the physical mechanisms for wave dissipation over muddy seabeds remain poorly understood.

The state of near-bottom sediment changes significantly during a storm. Waves and currents are sensitive to the state of the sea bed (Neill and Allison, 2005; Sheremet et al., 2005). Figure 1 illustrates the variability of suspended sediment concentration in relation to wind and the vertical structure of the horizontal current.

Figure 1. Hydrodynamics and sediment evolution during a few frontal passages Winter 2005. Variance of a) swell (frequency < 0.2 Hz) and b) sea (frequency ≥ 0.2 Hz); c) Turbidity measurements at 0.3 and 1 mab; d) Wind speed and direction (muddy, direction-coded; sandy, blue - wind direction is similar at the two sites). e-f) vertical structure of current (velocity and direction). Wind and current direction convention is “to”, not “from”.

In the absence of detailed coherent sediment and hydrodynamic measurements, characteristic sediment parameters are inferred based on postulated dissipation mechanisms and rheological models (e.g viscous, visco-elastic, or poro-
elastic medium). Figure 2 illustrates the range of wave dissipation effects for three wave-bottom interaction models (bottom friction, poro-elastic bed and viscous fluid mud layer).

![Graph](image)

**Figure 2.** Spectral evolution in 5-m water depth over a flat bottom, after a) 0.5 and b) 1.5-km propagation. Initial spectrum (black) is JONSWAP shape. Spectra are shown for mud (red, viscous fluid mud), clay (green, poro-elastic), and sand (blue, bottom friction).

**Questions**

What are the mechanisms of wave-sediment interaction? How can they be identified in the field? How does sediment state change with surface wave characteristics? How do different wave frequency bands interact with the sea bed? What are the relevant sea bed parameters for wave evolution? Are wave nonlinearities significant for waves propagating over muddy sea beds?

**Instrumentation**

The goal of this project is to conduct high resolution observation of sediment and wave motion. Two instrumented platforms were designed to monitor fluid motion throughout the entire water column, with increased resolution (2 cm bins) in the first 50 cm above (Figure 3). Suspended sediment concentration is monitored using acoustic backscatter intensity and optical sensors. Acoustic backscatter sensors (ABS) are used to monitor sea bed motions. Some information about the instruments is presented in Table 1.

![Diagram](image)

**Figure 3.** A schematic of the instrument clusters deployed. The instruments shown are: ADCP, (acoustic Doppler current profiler); PC-ADP (pulse-coherent acoustic Doppler profiler); P (pressure); ABS (Acoustic Backscatter Sensor); OBS (optical backscatter sensor); FOS (fiber-optics spectrometer). The FOS are available only on the Tulane tripod.
Figure 4. Photographs of the two tripods before the first deployment on January 16, 2006. a-b) Tripod deployed by University of Florida; c) Tulane tripod. In the first deployment in shallow water, a smaller version of the Tulane tripod was used.

Experiment Site

The experiment site is the shallow (≤10 m depth) inner shelf off Atchafalaya Bay, Louisiana. The Atchafalaya river discharge is ≃ 84 million tons of sediment per year. Figure 5a shows a satellite image of the site (the sediment plume is visible). Figure 5b presents an approximate map of the sea bed sediment type.

Figure 5. Atchafalaya bay and shelf. a) Satellite image of the bay and shelf. b) Facies map of the surficial sediments of the Atchafalaya shelf experiment area. Contours are in meters.
<table>
<thead>
<tr>
<th>Instrument</th>
<th>Parameters</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>PC-ADP (Sontek, 1.5 MHz)</td>
<td>U,V, W</td>
<td>2 Hz; Bin: 2 cm; Range 0 – 0.50 mab.</td>
</tr>
<tr>
<td>ADCP (Nortek, 1 MHz)</td>
<td>U,V, W, Directional wave Backscatter, intensity</td>
<td>Wave: 2 Hz, burst 20 min; Current: 2-min burst.</td>
</tr>
<tr>
<td>OBS</td>
<td>Absolute SSC</td>
<td>Saturation (\approx 4 \text{ kg/m}^3); 1-min burst</td>
</tr>
<tr>
<td>FOS</td>
<td>Absolute SSC</td>
<td>Saturation (\approx 200 \text{ kg/m}^3); 1-min burst</td>
</tr>
<tr>
<td>Paroscientific transducer</td>
<td>Pressure</td>
<td>2Hz; 3-hr burst</td>
</tr>
<tr>
<td>MicroCAT</td>
<td>Conductivity Temperature</td>
<td>Sample interval 30 min.</td>
</tr>
</tbody>
</table>

**Table 1.** Some characteristics of the instruments deployed.

**Deployments**

There are 4 deployments planned, with two already executed. The instruments will be deployed in total for a period of about 3 months, and will record continuously. About once every two weeks the pods are retrieved, cleaned, and redeployed. During onsite service, memory cards are also replaced with empty ones, allowing for data retrieval without interrupting the deployment. Deployments locations are shown in Figure 6. During the first two runs, the UF tripod was in about 5.4 m depth of water; the Tulane tripod was first in 2.5-m depth, then moved near the 4.5-m isobath.

![Figure 6. Deployment configurations of the UF (blue) and Tulane (red) instrumented pods. Lighter color symbols mark future deployments.](image)

**Nonlinear Wave Models**

Nonlinear wave models have been proposed (e.g. Sheremet *et al.* 2005) to explain observations of short wave dissipation. The characteristics of wave dissipation due to a fluid mud layer are shown in Figure 7. Typical nonlinear wave-triad evolution in the presence of mud-induced wave dissipation is illustrated in Figures 8-9 for a single triad and a full spectrum.
Figure 7. a) Attenuation coefficient and b) amplitude transmission factor at 1 km (fraction of initial amplitude preserved after a propagation distance of 1 km), versus frequency. Numerical simulation based on Jiang and Mehta (1996) model, for water depth of 5 m, mud layer depth 30 cm, mud density 1,130 kg/m$^3$, and viscosity 103 Pa·s.

Figure 8. Nonlinear evolution of modal flux (normalized by initial value) versus normalized distance (solid lines). Triad frequencies are 0.05, 0.5, and 0.55 Hz (red, blue, magenta), with 1-km transmission factors of (a,b) (< 1%, 93%, 99%), and (c,d) (10%, 93%, 99%). Dashed lines represent the linear evolution.

Nonlinear triad interactions coupled with long-wave dissipation generate a net energy flow toward long waves which over large scales dissipates the energy in the short wave band. Numerical simulations yield results consistent with observations of short wave dissipation.

Figure 9 Large scale evolution of flux density spectrum (normalized by initial value) in 5-m depth, flat bottom for a JONSWAP spectrum, with 0.4 Hz peak, 1-m height. a) Linear evolution. b) Nonlinear evolution. The 1-km amplitude transmission (Figure 7b) is sketched above the plots.

CONCLUSIONS AND FUTURE WORK

Extensive and high-resolution field observations are needed. Data should provide detailed, coherent measurements of sediment and water dynamics. This experiment focuses on high resolution (but local) observations of hydro- and sediment dynamics. Future work includes extending the spatial coverage of the experiment, improved monitoring of sediment dynamics, as well as data analysis and modeling of wave propagation in muddy environments.

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References