Observations and modeling of cohesive seafloor response to energetic surface waves on the Louisiana Shelf

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HYDRODYNAMICS ON MUDDY SHELVES

- Marine sediment transport affects shoreline change, methods of coastal protection, design of marine structures, underwater detection, navigation, water quality, and fate of pollutants and biomatter.
- There is a strong coupling between boundary layer turbulence and sediment processes in shallow muddy environments (Fig.1a). Strong waves form near-bed fluid mud layers of high concentration.
- These mud layers dissipate surface wave energy significantly (Fig.1b, e.g., Sheremet et al., under review) and are transported throughout the shelf in the presence of currents.

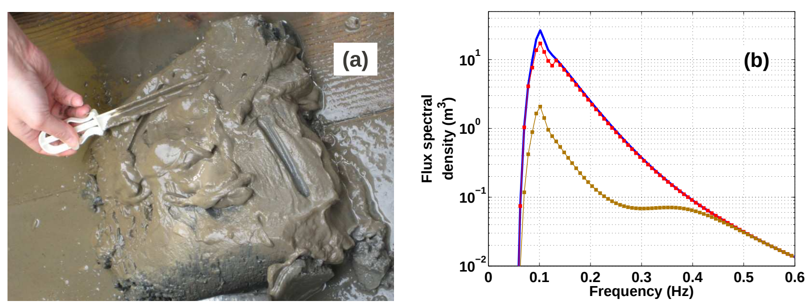


Figure 1.(a) Mud sample collected at the LA Shelf; (b) Evolution of a wave field (blue) after propagating 5-km in 5-m depth over sandy(red) and muddy(brown) seafloors.

Goal: Investigating under which flow conditions mud suspensions form and bed state evolves.

METHOD

- Field observations on the Atchafalaya Shelf, LA
- A method to estimate vertical structure of sediment concentration based on the acoustic backscatter of a current profiler (Thorne and Hanes, 2002)
- A 1-D bottom boundary layer numerical model developed for for combined wave-current flow on cohesive beds (Hsu et al., 2007)

FIELD EXPERIMENT

- The high discharge of cohesive sediment into the shelf (Fig.2a) and strong swell action during early spring make this area a prime location for studying flow-mud interaction.
- Between February-April 2008, wave, current, and sediment observations were collected with a suite of acoustic&optical instrumentation (Fig.2b; e.g., Safak et al., in press).

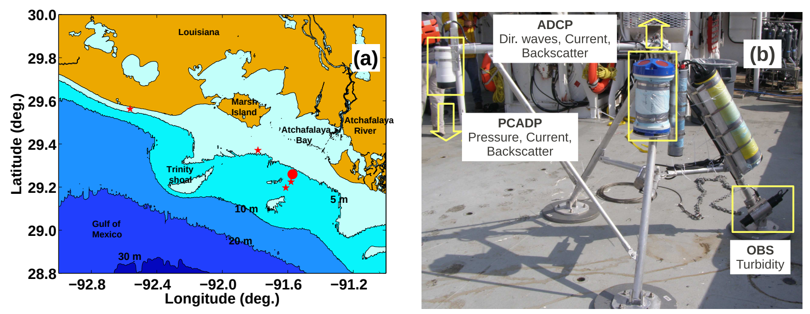


Figure 2. (a) Atchafalaya Shelf and the observation locations (dot:observations herein); (b) Instrumentation platform.

SEDIMENT CONCENTRATION ESTIMATION

Concentration of sediment in suspension, *SSC*, is determined from the backscatter intensity of the current profiler (Fig.3a).

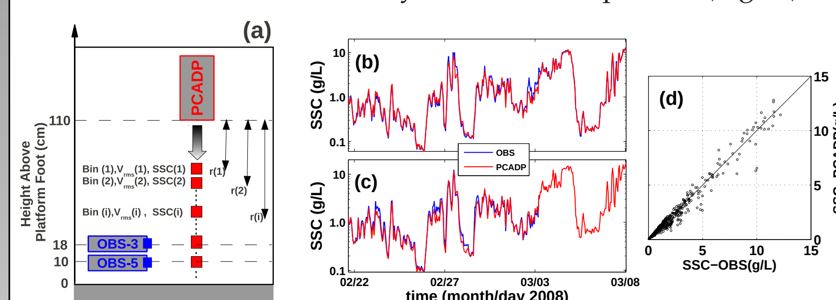


Figure 3. (a) Vertical structure of OBSs and PCADP bins; (b-d) Comparison of OBS measurements and PCADP estimates.

Unknowns of the method are determined by searching for the minimum RMS-error between estimated concentrations and those obtained from the OBSs (Figs.3b,c,d).

OBSERVATIONS AT 4-M DEPTH

During a 2-day event (rectangle in Fig.4), near-bed flows responded to onshore propagating swells (with a 1-m peak).

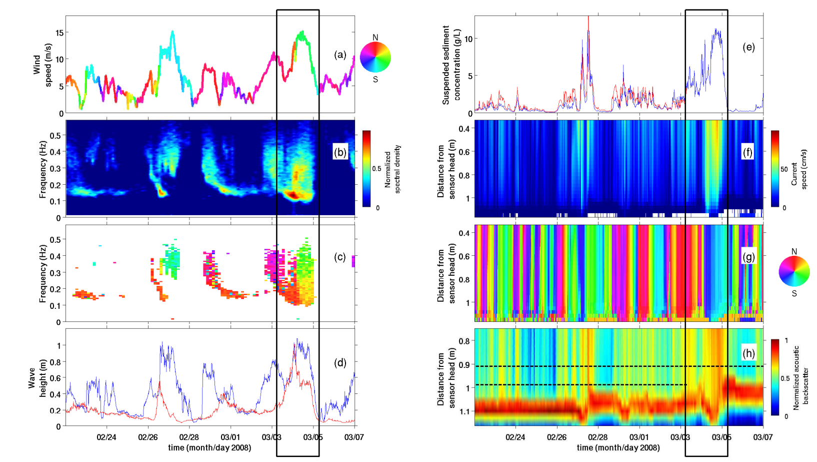
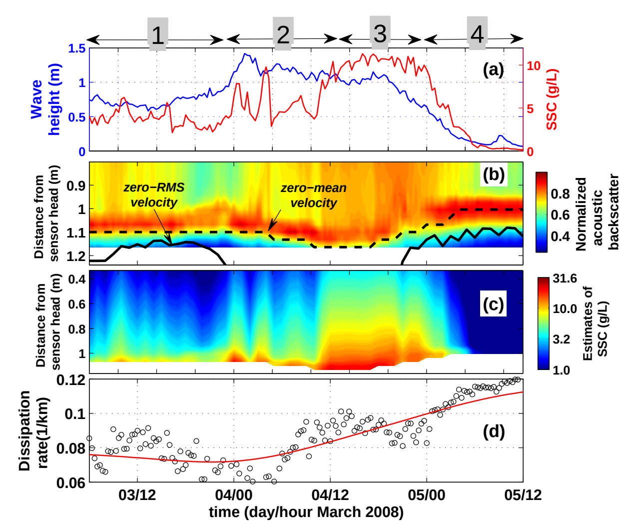


Figure 4. (a) Winds; (b-c) spectral density and peak direction; (d) significant sea (blue) and swell (red) heights; (e) *SSC*; (f-g) currents; (h) acoustic backscatter intensity, vs. time. In (a,c,g), the color code indicates where the flow is towards.

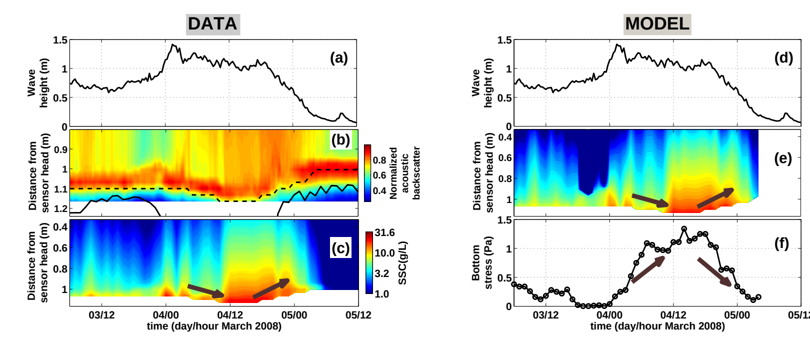
EVOLUTION OF SEAFLOOR



1.Consolidated bed
2.Possible liquefaction and resuspension: Levels of zero-RMS velocity and zero-mean velocity separate significantly, currents are penetrating deeper in bed.
3.Decreasing wave energy brings curves of zero-RMS velocity and zero-mean velocity to their initial levels; the water column is still sediment-laden.
4.Settling, soft bed formation, maximum wave dissipation rate (between an 8-km offshore site and the study site).

MODELING

- The model is calibrated with wave-current observations and *SSC* estimates (panels (c,e) below).
- Flow parameters which can not be directly measured (e.g., bottom stress, panel (f) below) are calculated.
- Bottom stress is controlling the seafloor level that currents are penetrating into.



SUMMARY

- Observations suggest that strong swell action caused liquefaction and resuspension of an initially consolidated muddy seafloor. Finally, a soft bed was formed due to rapid settling of suspended sediment.
- Modeling results show that a threshold bottom stress (and associated wave energy) that changes seafloor state might be found (Sahin et al.,in prep.).
- Can evolution of seafloor be estimated based on wave-current data (which are easier to collect)?

Acknowledgments

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