Sand Ripple Dynamics on the Inner Shelf

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Document Number # N00014-04IP20098

LONG-TERM GOALS

To explain the genesis, dynamics, morphology, and evolution of bedforms found in sandy inner-shelf environments, with emphasis on those bedforms that affect the penetration of sound into the seabed.

OBJECTIVES

We seek to improve our understanding of the relationships between hydrodynamics and sediment motion near the seabed, as well as the development of models derived from our understanding of the relevant physical processes. This requires coupling between hydrodynamic forcing, bedform response and feedback, bedload sediment transport response, and the suspended sediment response.

APPROACH

We will utilize a combination of field observations, laboratory experiments, and numerical modeling to determine the relationships between ripple morphology, wave and current conditions, and sediment characteristics.

WORK COMPLETED

A laboratory experiment studying ripples formed under combined waves and currents was completed in Tsukuba, Japan, in January 2005.

We constructed an oscillating tray system and installed it in the flume in Japan so that we could vary the angle between currents and waves. The four-meter width of the flume allowed us to create combined wave-current flows on the same scale as those that produce bedforms in the natural environment.

A field experiment was completed near Fort Walton Beach, Florida, in Fall, 2004. The goal of our component of the field experiment was to document the spatial distribution of bedforms and sediment size in the SAX04/Ripples DRI experiment region.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2005**	2. REPORT TYPE	3. DATES COVERED **00-00-2005 to 00-00-2005**
4. TITLE AND SUBTITLE **Sand Ripple Dynamics on the Inner Shelf**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Geological Survey,Coastal and Marine Geology Program, Reston,VA,20191**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
code 1 only

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**9**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESULTS

Laboratory experiment

Twenty runs with varying wave-current conditions were completed. Current velocities ranged from 0 to 26 cm/s, maximum oscillatory velocities ranged from 16 to 40 cm/s, oscillation period was 8 or 12 s, and the angle between waves and currents was 45, 60, or 90 degrees. Median sediment grain diameter was 0.3 mm. An instrumented frame mounted on the oscillating tray held two acoustic Doppler velocimeters to measure tray motions and current velocities at two heights above the bed, and two imaging sonars to monitor bedform evolution (Figure 1).

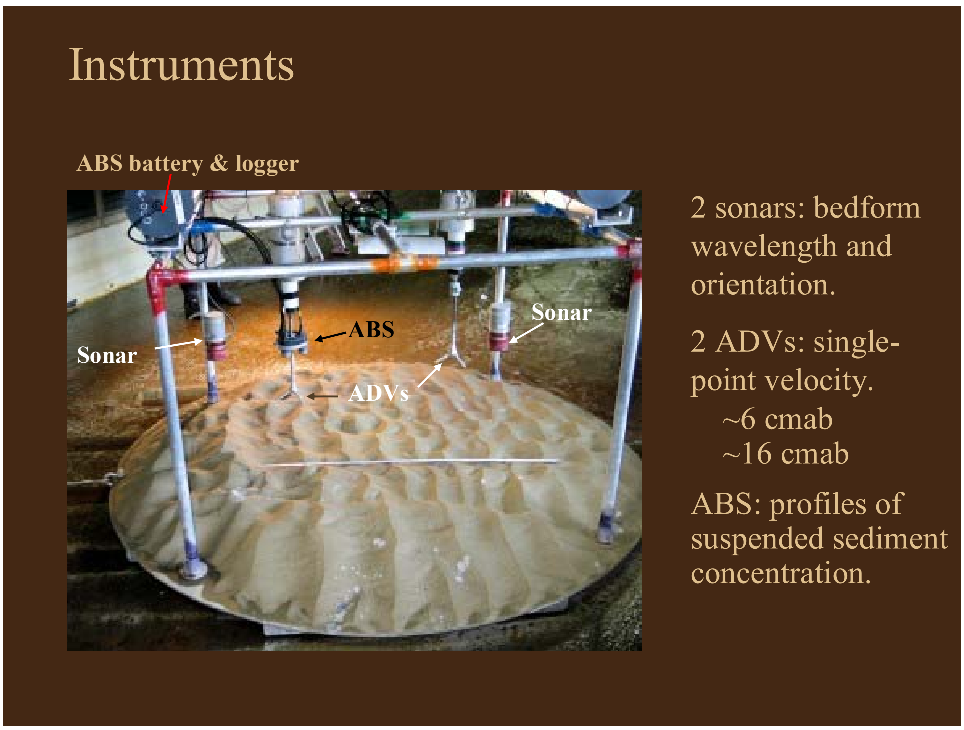

Figure 1: Photograph of oscillating tray showing position of instrumentation.

After each run the bed test-section was photographed and bedform height and wavelength were measured manually. The bedforms varied from linear ripples to strongly three-dimensional structures (Figure 2).

A. B.

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Figure 2: Bedforms produced by two experiments. A) Current 12 cm/s, maximum oscillatory velocity 26 cm/s, oscillation period 12 s, wave current angle 90 degrees. B) Current 6 cm/s, maximum oscillatory velocity 39 cm/s, oscillation period 6 s, wave current angle 90 degrees.

Coherent ripples appeared in the sonar images after about 5 minutes in most runs. An example of a sonar image near the end of a run is shown in Figure 3.

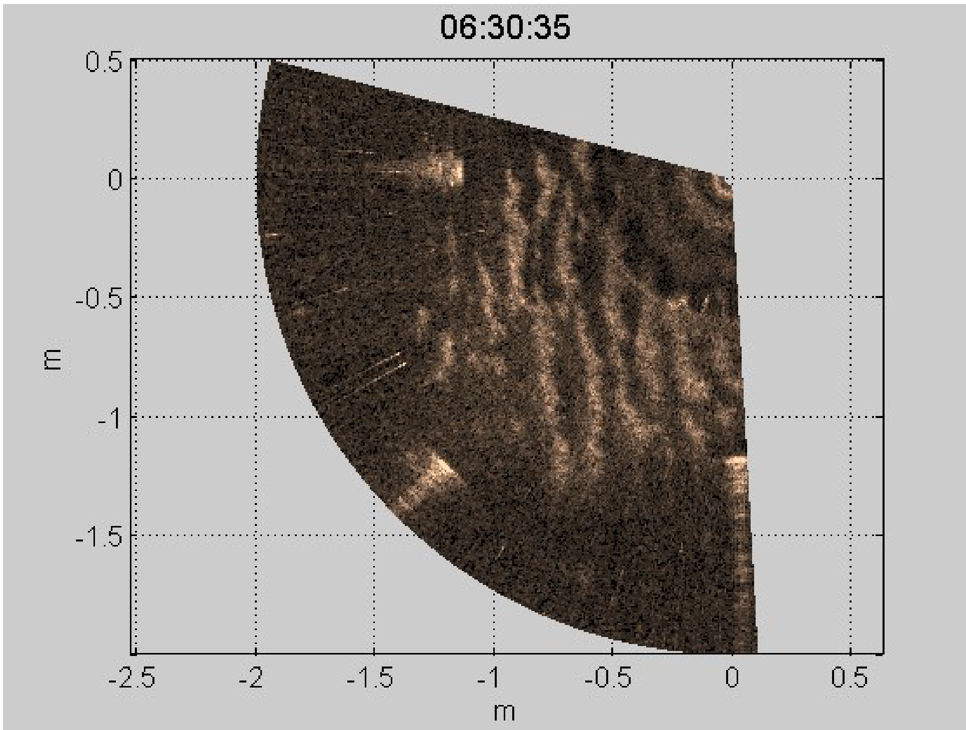

Figure 3: Sonar image showing linear ripples after 43 minutes of oscillation with maximum oscillatory velocity of 24 cm/s, and wave period of 8 s. Current is 6 cm/s. Image is average of two scans. Brightness corresponds to intensity of backscatter (brighter = stronger backscatter). Bright lines show ripple crests. The three brightest spots are legs of the instrument frame.

We extracted dominant and average bedform wavelength and orientation from the sonar data using 2-D Fourier transforms (FFTs). The results will allow us to investigate ripple evolution and to compare ripple wavelengths, orientation, and three-dimensionality produced by the different run conditions.

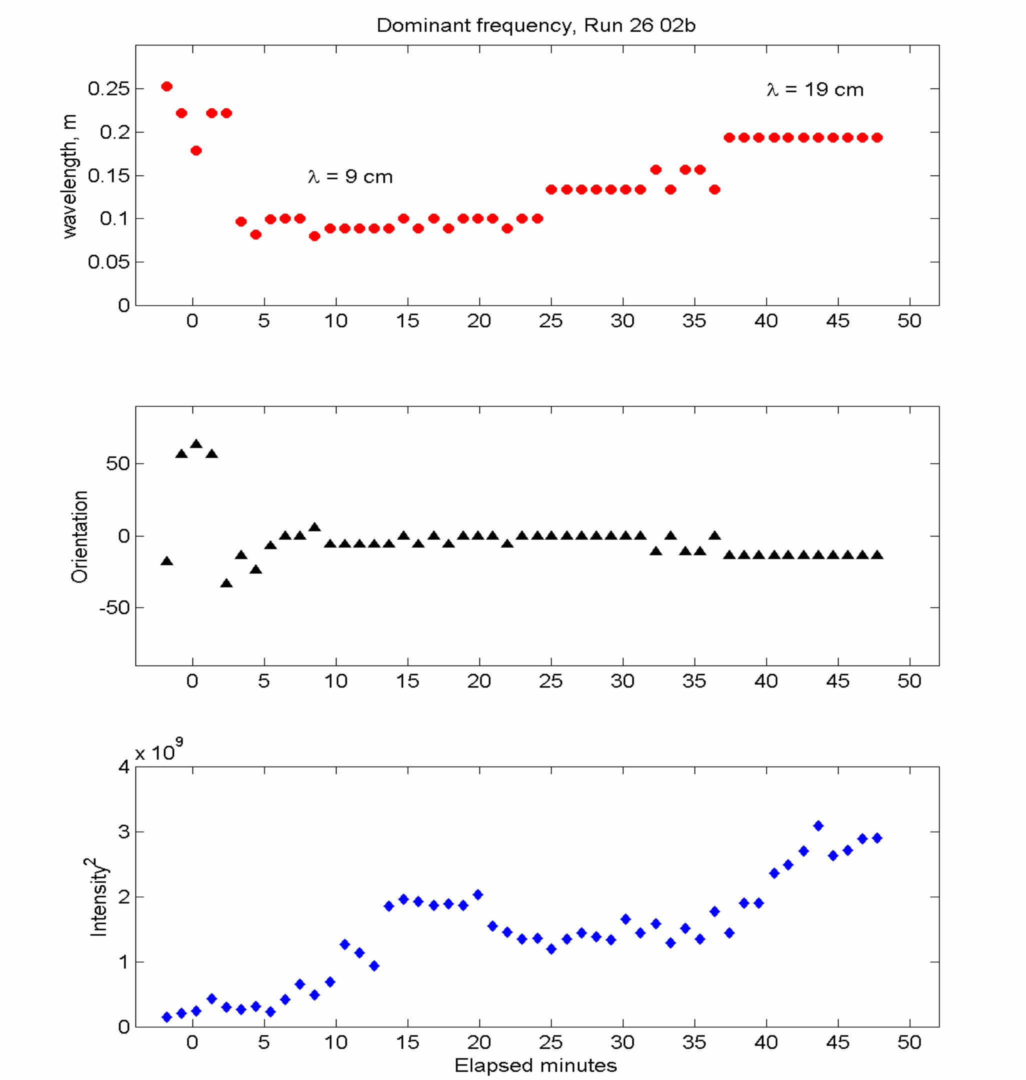

Figure 4: Evolution of ripple wavelength (top panel) and orientation (middle panel) during an experimental run. Bottom panel shows the energy in the highest-energy (dominant) frequency component of the 2-D Fourier transform. Coherent ripples appeared after about 5 minutes, and doubled in wavelength over the next 30 minutes. Wave/current conditions same as Figure 3.

Field experiment (SAX04)

The field experiment was heavily influenced by Hurricane Ivan, which passed through the region approximately one week prior to our deployments. A schematic of the instrumented tripod designed to measure the small scale morphology and sediment characteristics of the seabed is shown in Figure 5. The inner shelf exhibited patches of fine sediments and highly variable ripple morphology. The mid-shelf contained primarily two-dimensional large wave ripples that were formed in medium to coarse sand and shell during Hurricane Ivan. Figure 6 shows the bed sediment camera system used to characterize the surficial sediment. Figure 7 illustrates the ripple wavelengths typical on the mid-shelf following the passage of Hurricane Ivan.

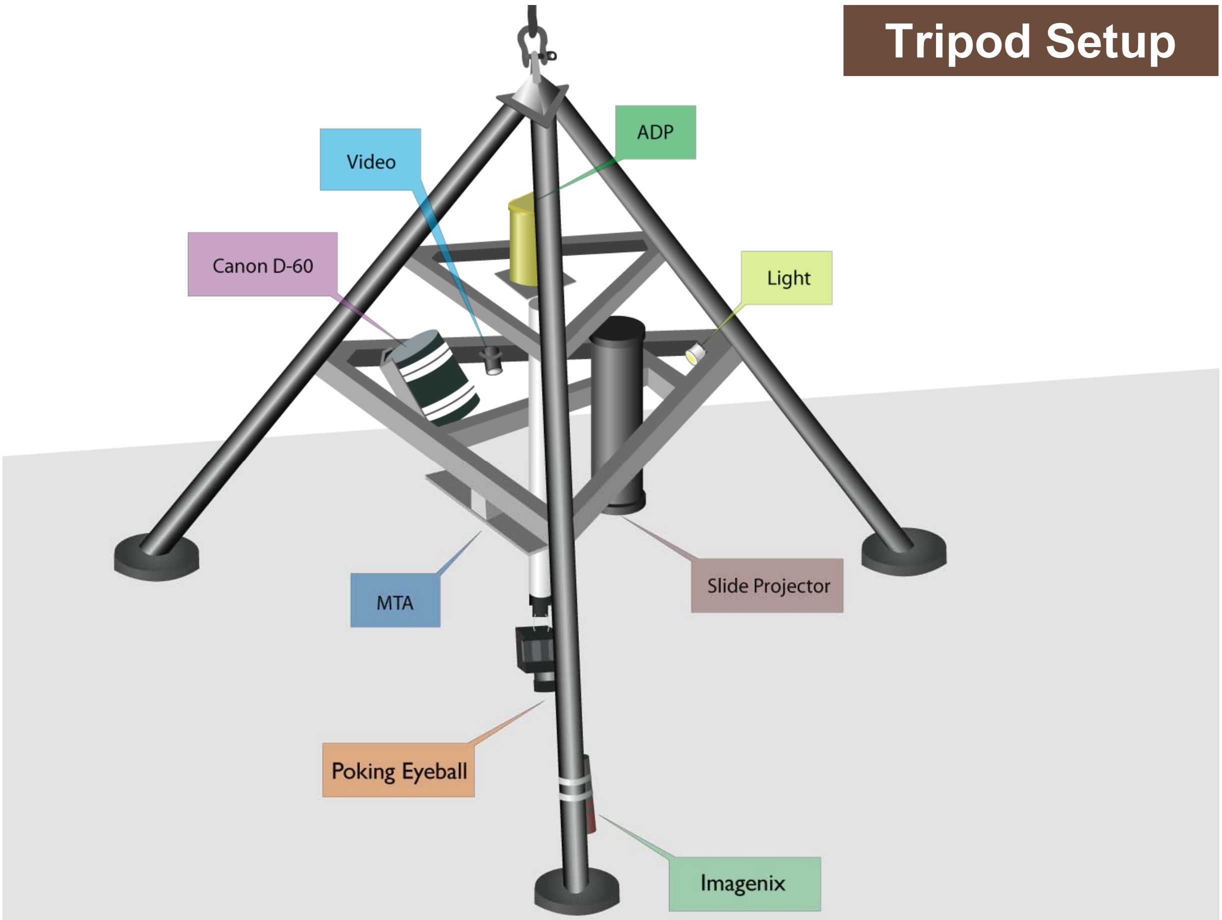

Figure 5: Schematic of tripod and instrumentation used to characterize the small-scale morphology and sediment characteristics of the seabed.

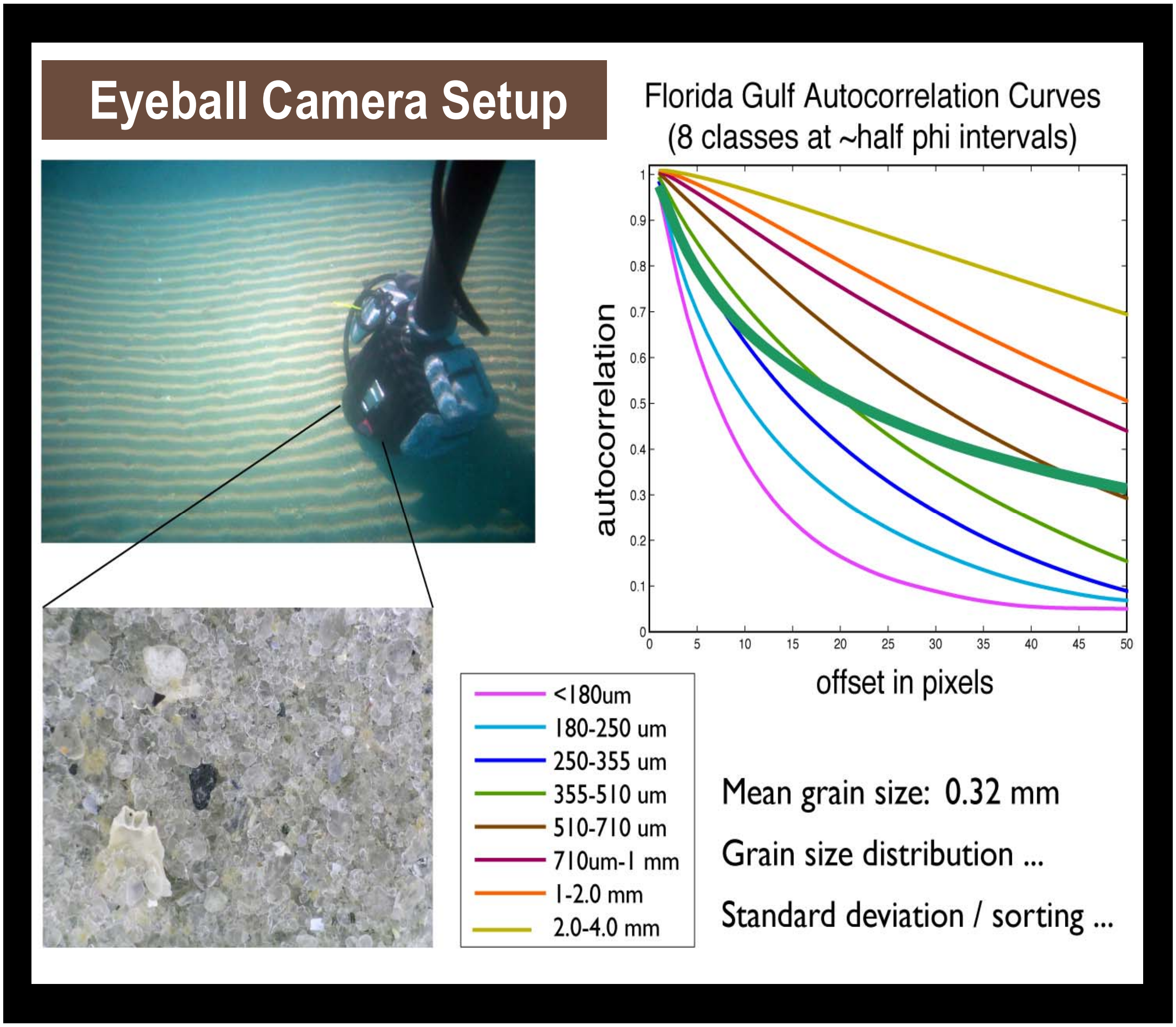

Figure 6: The bed sediment camera obtains a high resolution digital image of the seabed sediment and uses a correlation analysis technique to estimate the mean sediment grain size.

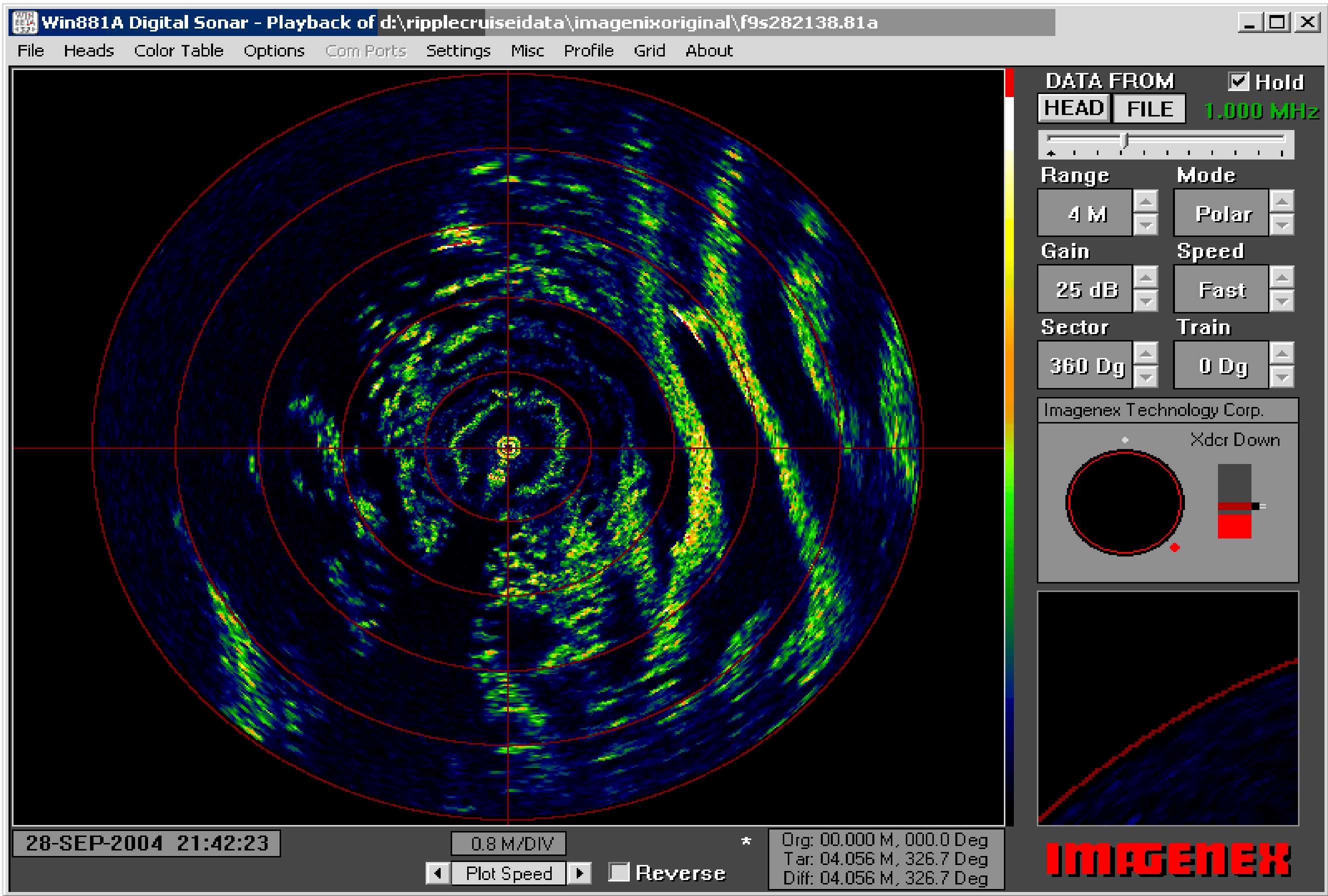

Figure 7: Rotating scanning sonar image of the seabed from approximately 40 m depth off Fort Walton Beach, FL after the passage of Hurricane Ivan in Fall, 2004.

IMPACT/APPLICATION

The connections between small scale and large scale sedimentation processes are important in order to develop a comprehensive understanding of nearshore sedimentation processes, and the ability to model bathymetric change. Our research provides new information on small-scale processes that will allow these connections to be discovered and verified.

TRANSITIONS

Our work on the small-scale dynamics of nearshore sediment transport will be applied in a related project (see below) to develop a general model for local sediment transport in the nearshore region.

RELATED PROJECTS

This project is closely related to the USGS project entitled: Coastal Evolution: Process-based, Multi-scale Modeling.