Distribution and Mechanics of Nearshore Bedforms

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LONG-TERM GOALS

To understand the physics of sediment transport by waves and currents and to use that understanding to predict the evolution of nearshore bathymetry given the nearshore fluid-velocity field. A secondary goal is to interpret the environment of deposition and the offshore wave climate from the sedimentary record.

SCIENTIFIC OBJECTIVES

Objectives are to generate maps of bed roughness for the entire surf zone from sidescan sonar images and sonic-altimeter-derived bathymetry acquired at Duck, North Carolina during the SandyDuck '97 experiment; to theoretically describe and numerically model the substantial effects of fluid acceleration on sheet flow bedload transport in the surf zone; and to generate computer simulation models for evolution of nearshore morphology and other grain-scale sedimentary processes.

APPROACH

Side-scan sonar observations acquired in the surf zone during the SandyDuck97 experiment complement sonic altimeter profiles of bathymetry acquired by NPS collaborators E. Gallagher and E. Thornton. Side-scan sonar imagery offers complete areal coverage of the bed geometry and certain aspects of bed sedimentology but lacks quantitative measures of bed elevation. Sonic altimeter measurements, on the other hand, provide cross-shore profiles of bed elevation but lack areal coverage. Side-scan sonar performance in the surf zone can be evaluated by comparison of imagery and bathymetric data; furthermore, the complete areal distribution of bed roughness and orientation can be estimated by appropriately combining the data.

Discrete-particle models for bedload transport processes describe the motion of individual sediment grains subjected to fluid and body forces by integrating F=ma at small time steps. Our models predict transport rates, dispersion and sorting of grains having a distribution of sizes and densities. They are well-suited for describing transport processes in the swash and surf zones, where variations in particle properties may be large. The model is also well-suited for studies of other sea-bed phenomena, for instance, the penetration of impactors into the sea floor as described below. We continue to address fundamental problems concerning fluid-particle interactions within the discrete-particle modeling framework.

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WORK COMPLETED

Graduate student David Pierson developed a robust image-processing method for filtering noisy sidescan sonar images obtained in the surf zone (Figures 1 and 2). Pierson correlated bedform-geometry patterns, which are exhibited as variations in pixel intensity in the sonar images, with variations in bed elevation measured independently using sonic altimeters during the experiment by NPS collaborator E. Gallagher. Daily maps of bed roughness can be constructed for most of the surf zone throughout the SandyDuck97 experiment.

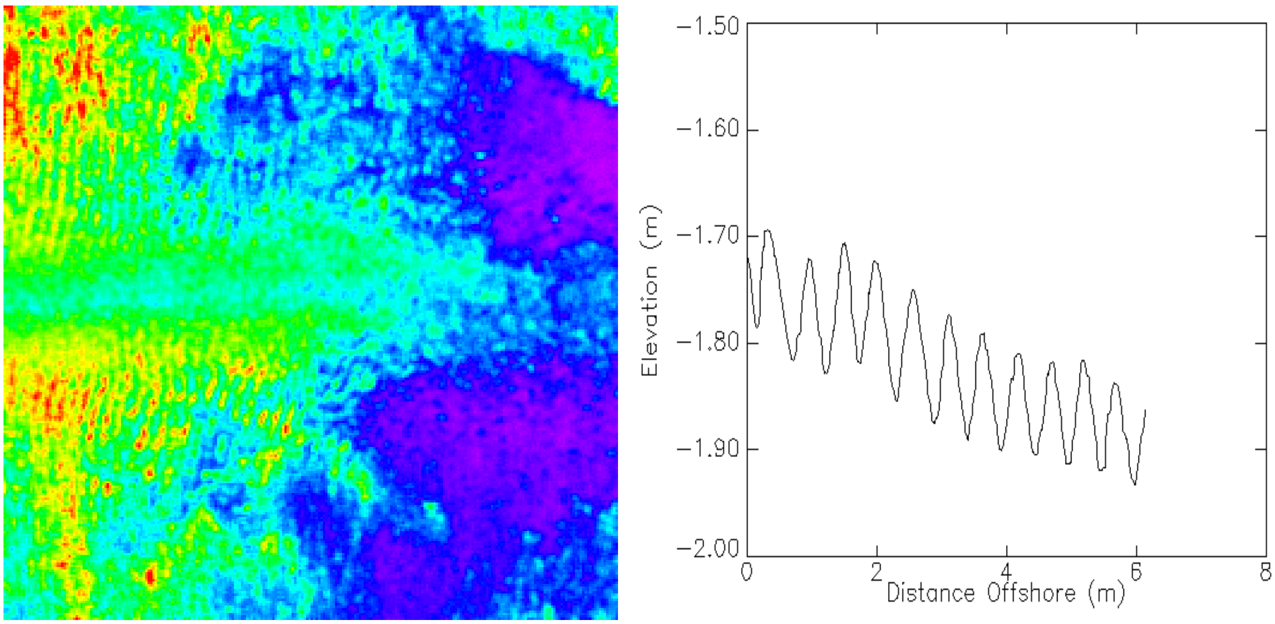

Figure 1. (left) Surf-zone sidescan image from Duck, NC displays well-developed bar-trough megaripples in water depths of 1.5 to 2 m. North at the top, offshore to the right. Images depict a 25.6 m x 25.6 m area (256x256 pixels at 0.1 m/pixel). Hot colors (red/yellow) correspond to high acoustic backscatter. Uniform grain-size-distribution observed independently at these cross-shore locations at Duck imply that backscatter variation is due primarily to bedforms. Horizontal line bisecting each image is the path of the 3-wheeled CRAB survey platform. (right) Example of high-resolution bathymetry from NPS sonic altimeter used to correlate bed roughness on sidescan images. Megaripples shown are from the left-hand side of the sonar image.

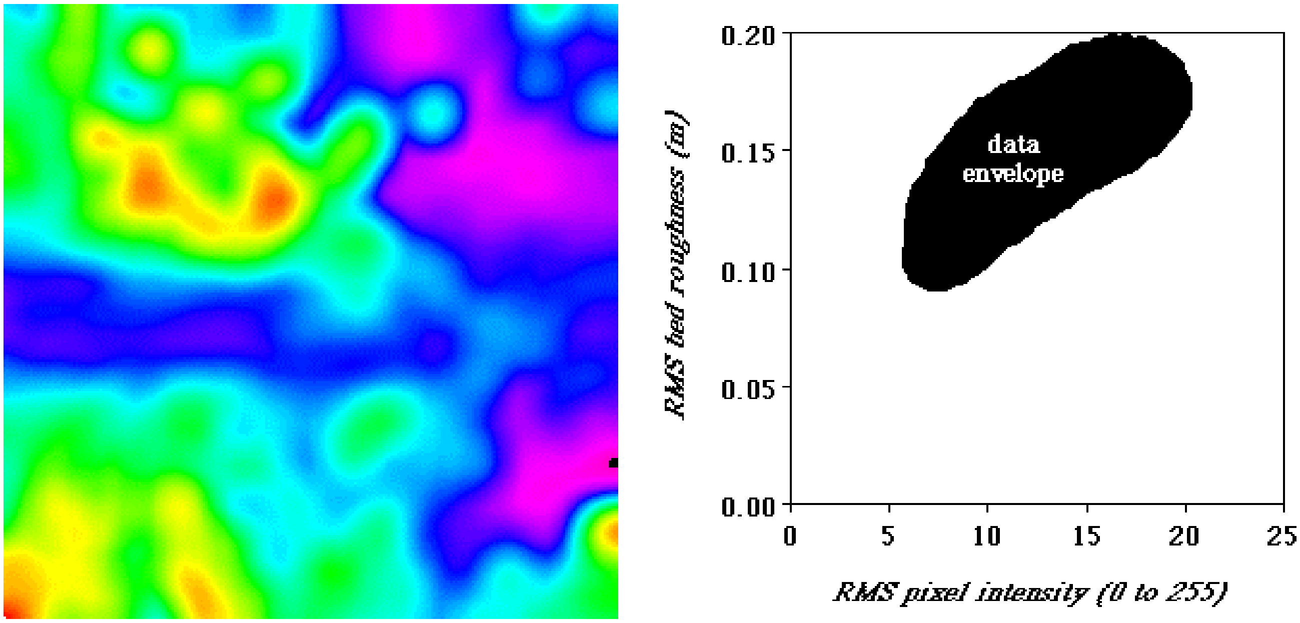

Figure 2. (left) Root-mean-square pixel intensity for 2-m-square bins. Hot colors indicate high rms pixel intensities and large rms bed roughness. (right) Approximately linear relationship between rms bed roughness from sonic altimeters and rms pixel intensity from sonar images.

Graduate student Joe Calantoni (AASERT) used a discrete-particle simulation model for bedload transport to study sheet flow transport of coarse sand under a variety of typical nearshore conditions, including broken and unbroken waves; bed slopes; and a distribution of particle sizes (Calantoni and Drake, 1998a,b; 1999a,b). Calantoni developed a model that describes the effects of fluid acceleration on bedload transport under sheet flow conditions in terms of the fluid impulse, which can be calculated from commonly available near-bed velocity measurements (Drake and Calantoni, submitted). Generality of the discrete-particle model allows application to such problems as simulation of sea-bed penetration studies. Figure 3 compares impact of spherical impactor in physical experiments conducted by D.Goodnight (unpublished data) with discrete-particle simulations.

Graduate student Chris Thaxton modified the surf-zone wave model RBREAK (e.g., Kobayashi and Wurjanto, 1992; Raubenheimer *et al.*, 1995) to incorporate sediment-tranport relationships derived from Calantoni's discrete-particle simulations, as a first step in a longer-term effort to model nearshore evolution with NOPP collaborators J. Kirby, I. Svendsen and others.

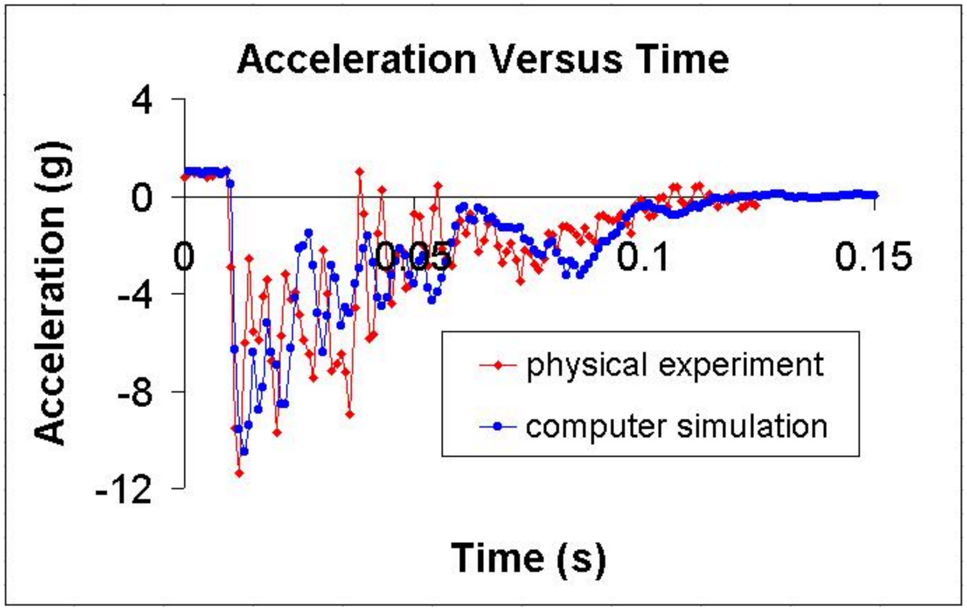

Figure 3. Discrete-particle simulation of physical experiments using a steel ball impacting a bed of plastic beads in air. Velocity of the 2.4-cm-diameter steel sphere impactor is 2.8 m s^{-1}. Cellulose-acetate plastic target spheres have 0.6 cm diameter and density of 1.31 g cm^{-3}. Simulation accurately captures the deceleration peak; however, the physical impactor decelerates with distinctive oscillations, which are believed to result from oscillations of the slender, rigid rod attached to the impactor. The simulated spherical impactor is an unconstrained, freely-rotating sphere.

RESULTS

Sea-bed roughness maps provide considerably greater spatial resolution than localized observations of roughness typically obtained in the surf zone. Such maps are essential input for modeling surf-zone circulation. Quantitative measures of roughness anisotropy are also produced by the analysis; when shore-parallel ripples are present such anisotropy can be considerable.

Discrete-particle modeling allows detailed grain-scale understanding of bedload transport processes difficult or impossible to study in the field. Simulations of sheet flow transport under asymmetric broken waves characteristic of surf zone bores reveal the importance of fluid acceleration (Drake and Calantoni, submitted), in addition to the steady components of nearshore circulation observed to accompany bar migration offshore.

IMPACT/APPLICATION

Sidescan sonar images from SandyDuck97 field work are used to generate areally extensive bed-roughness maps. Such maps display significant spatial variation in both the cross-shore and alongshore directions at Duck, which is a nominally two-dimensional beach. Roughness maps are thus essential for modeling surf-zone circulation and resultant nearshore evolution. Fluid-acceleration effects on sheet flow bedload transport in the surf zone, which are not addressed in extant models, dominate when steady currents are small. Incorporating a new term in sediment-transport models to account for acceleration will greatly improve ability to predict, for example, onshore bar migration under lowenergy conditions in the surf zone. Continued fundamental development of discrete-particle modeling capabilities will aid studies of sea-floor geophysical properties for a variety of applications.

RELATED PROJECTS

Discrete-particle simulation studies are also supported by a National Ocean Partnership Program grant for "Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean." SandyDuck '97 side-scan sonar studies were performed in collaboration with ONR investigators E. Gallagher and E. Thornton.

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PUBLICATIONS

Drake, T.G. and Calantoni, J., Discrete-particle model for sheet flow sediment transport in the nearshore, submitted to Journal of Geophysical Research, August 2000