Distribution And Mechanics Of Nearshore Bedforms

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LONG-TERM GOAL

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 identify characteristic bedform patterns and their modes of evolution in the nearshore enviroment at Duck, North Carolina using side-scan sonar images obtained during the SandyDuck ‘97 experiment; to describe bedload transport over non-planar sediment beds, with particular application to megaripples; and to generate computer simulation models for evolution of nearshore morphology.

APPROACH

Side-scan sonar observations acquired in the surf zone during the SandyDuck '97 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. Identical image-processing techniques can be applied to results of bedform pattern simulations (Fig. 1).

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. Existing 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. Likewise, the model is ideal for studies of bedload transport over arbitrarily sloping beds, including avalanching processes occuring on angle-of-repose slopes (Fig. 2).

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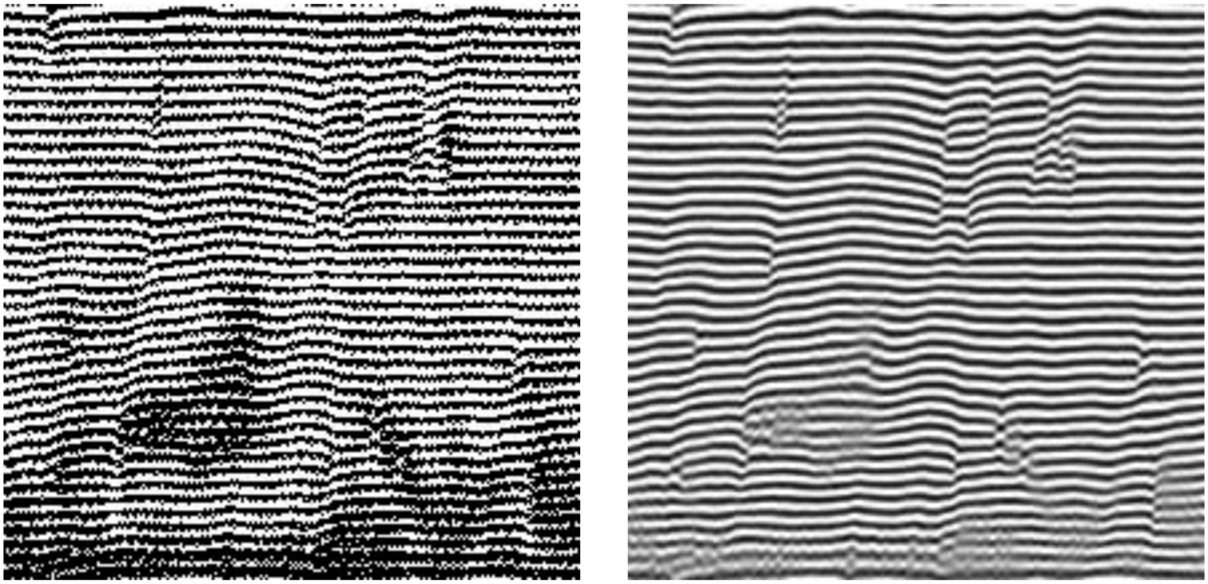

Figure 1. (left) Simulated ripples generated using a cellular automata model exhibits considerable high spatial frequency noise, which obscures underlying bedform imperfections. Imperfections form, migrate and coalesce; such imperfections define the boundaries of domains of topologically perfect bedforms. (right) Fourier transformation of the original image into frequency space and subsequent filtering reveals ripple patterns including imperfections and domains. Similar analyses have been carried out for SandyDuck sonar imagery.

WORK COMPLETED

Graduate student Peter Dickson completed mosaicking daily side-scan imagery from the SandyDuck experiment. He and E. Gallagher (NPS) confirmed correlation between sonar image intensity variations (for example, alternating light and dark ripple-like features) and actual variations in bed elevation derived from NPS sonic altimeters (Dickson, Gallagher and Drake, 1999). Correlation of sonar performance with wave climatology has been completed. Graduate student David Pierson has initiated principal component analysis of Dickson's imagery. Future work will map the distribution of bedforms and their orientation over the entire spatial extent of the SandyDuck experiment.

Graduate student Joe Calantoni (AASERT) used the 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).

RESULTS

Analysis of side-scan sonar imagery and correlation with independent measures of bed geometry confirm ability of sonar imaging via conventional instruments in the surf zone under moderately energetic conditions. Specifically, useful sonar images are obtained when the sonar towfish is submerged at a depth below the mean sea surface at least twice the significant wave height for a wide range of sea-state conditions.

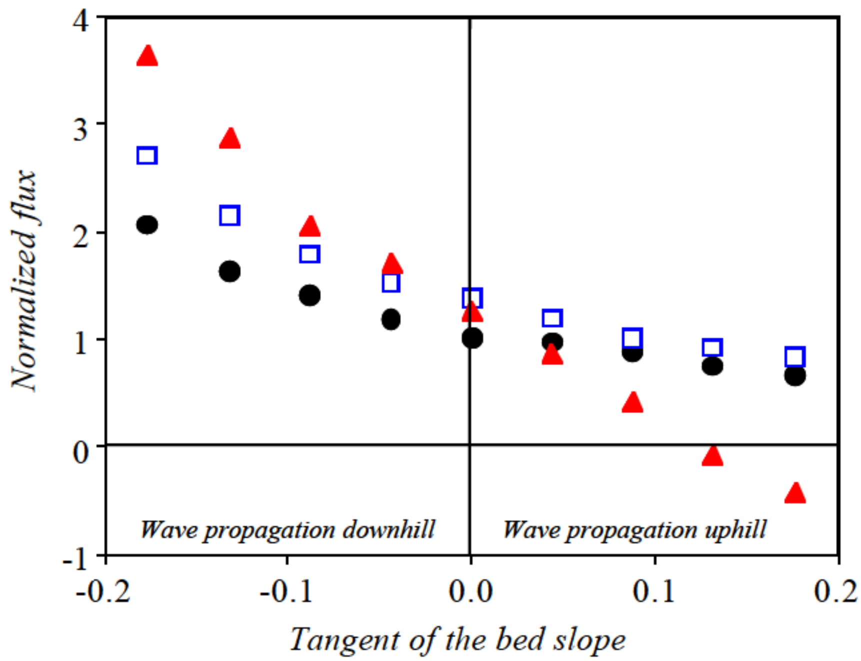

Figure 2. Variation in bedload flux with slope for waves propagating both upslope, in the direction of the dry beach, and downslope or offshore. The fluxes are normalized by the flux for an unbroken wave (circles) over a horizontal bed (zero slope). An equilibrium bed slope at a slope of about 7 degree is obtained only for a sawtooth-shape waveform (triangles), in direct contradiction to energetics-based bedload transport models. Such models predict an equilibrium bed slope of zero under these conditions. Furthermore, the fluxes under all waveforms are a linear function of bed slope only for slopes less than about 7 to 8 degrees; at higher angles the bedload flux is a strongly nonlinear function of bed slope.

Discrete-particle simulations suggest that bedload flux is proportional to the cube of the fluid acceleration, in addition to the velocity-cubed term suggested by numerous investigations. Calantoni and Drake (1999a;b) showed that discrete-particle simulations predict a strongly nonlinear relation between bedload flux and bed slope, in direct contradiction to predictions of energetics-based models for bedload transport (Bagnold, 1963; Bowen, 1980; Bailard and Inman, 1981).

IMPACT/APPLICATION

SandyDuck field work will provide a significantly enhanced synoptic picture of surf zone bed geometry for use by other SandyDuck investigators. Performance characteristics of side-scan sonar in the surf zone may have important applications in nearshore operations. Discrete-particle simulation results have increasingly called into question fundamental assumptions in energetics-based models for sediment transport; in particular, application of such models in the highly unsteady nearshore environment appear to require addition of a term proportional to the cube of the near-bed fluid acceleration.

RELATED PROJECTS

SandyDuck '97 side-scan sonar studies were performed in collaboration with ONR investigators E. Gallagher and E. Thornton. Additional side-scan and shallow seismic geophysical studies in the Duck vicinity, supported by the Army Research Office, Terrestrial Sciences Program, provide geological context useful for this work and other ONR-supported work at the Duck, North Carolina Field Research Facility. Discrete-particle simulation studies are partially supported by a National Ocean Partnership Program grant for "Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean."

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