Fluid Sediment Dynamics In The Nearshore

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LONG-TERM GOALS

The long-range goals of my research are to improve our understanding of the processes and physical interactions responsible for beach morphology change and patterns of erosion and deposition in the nearshore zone.

OBJECTIVES

Over the last 5 years, four aspects of nearshore sediment transport have been emphasized: 1) small-scale sediment transport, with emphasis on the initiation and vertical distribution of suspended sediment by turbulence and characterization of bottom boundary layer flows; 2) the linkage between small-scale sediment resuspension and large-scale circulation flows (edge waves, shear waves and mean currents) which presumably lead to changes in nearshore morphology; 3) swash zone sediment transport; and 4) new technologies for measuring nearshore bathymetry.

APPROACH

The overall approach is to determine the fundamental relationships between fluid forcing and sediment response by conducting detailed field studies using instrumentation deployed within the surf zone, primarily within and spanning the bottom boundary layer. These measurements are used for direct sediment transport calculations, in addition to guiding development and evaluation of bottom boundary layer, fluid-sediment interaction models. Three beach environments have been investigated; 1) a steep, coarse grained beach (Gleneden, OR), an intermediate/reflective beach (Duck, NC), and a several high-energy dissipative beaches (San Marine, OR and Agate Beach, OR).

Realizing that the experimental context is always desirable but not always available, a new mobile survey system utilizing a jet-ski was developed to rapidly measure nearshore/surfzone bathymetry, providing the capability to monitor and conduct field investigations at a wide variety of beach sites.

WORK COMPLETED

Participation in the SandyDuck97 field experiment (http://www.frf.usace.army.mil) was the lead effort in FY97; reduction, quality control and storage of this considerable quantity of data in an mSQL database dominated efforts in FY98. Results of preliminary analysis on the cross-shore and longshore transport of sediment were presented at the American Geophysical meeting (Conley et al., 1998).

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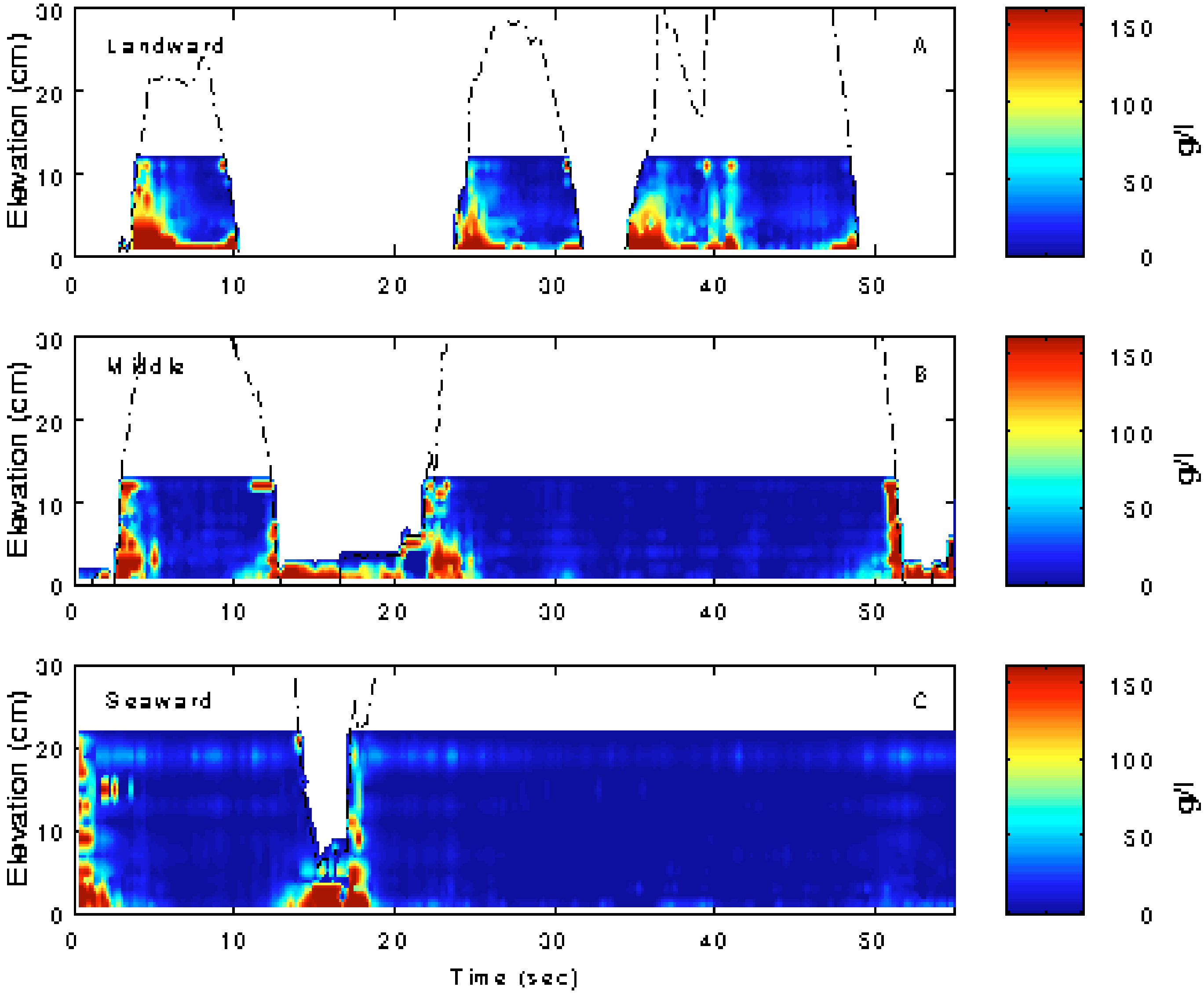

Figure 1. Contour plots of suspended sediment concentration ($g\ l^{-1}$) in the swash as a function of time and height above the bed for 3 cross-shore locations from seaward (C) to middle (B) to landward (A), each separated by 7 m across the foreshore. The dashed line represents the time-varying water depth. High sediment concentrations are evident in the very toe of the uprush and the trailing edge of the backwash. The transition from low concentration levels associated with surf zone (C, blue), to high levels associated with the swash processes (B, A, red) occurs in a very short distance (~10 m).

Analysis and modeling of a swash zone sediment transport study on a steep beach resulted in the award of a Masters degree to Jack Puleo in 1998. Publication of the results are pending review (Puleo et al.).

RESULTS

The analysis results by J. Puleo provide an in-depth look at sediment resuspension in very shallow flows at the seas edge. The transition from "normal" surf zone suspension levels to the higher levels present in the swash occur over a very short, 5-10 m, cross-shore length scale (Fig. 1). Sediment concentrations are highest in the "toe" of the uprush and at the tail end of the backwash (Figs. 1 & 2).

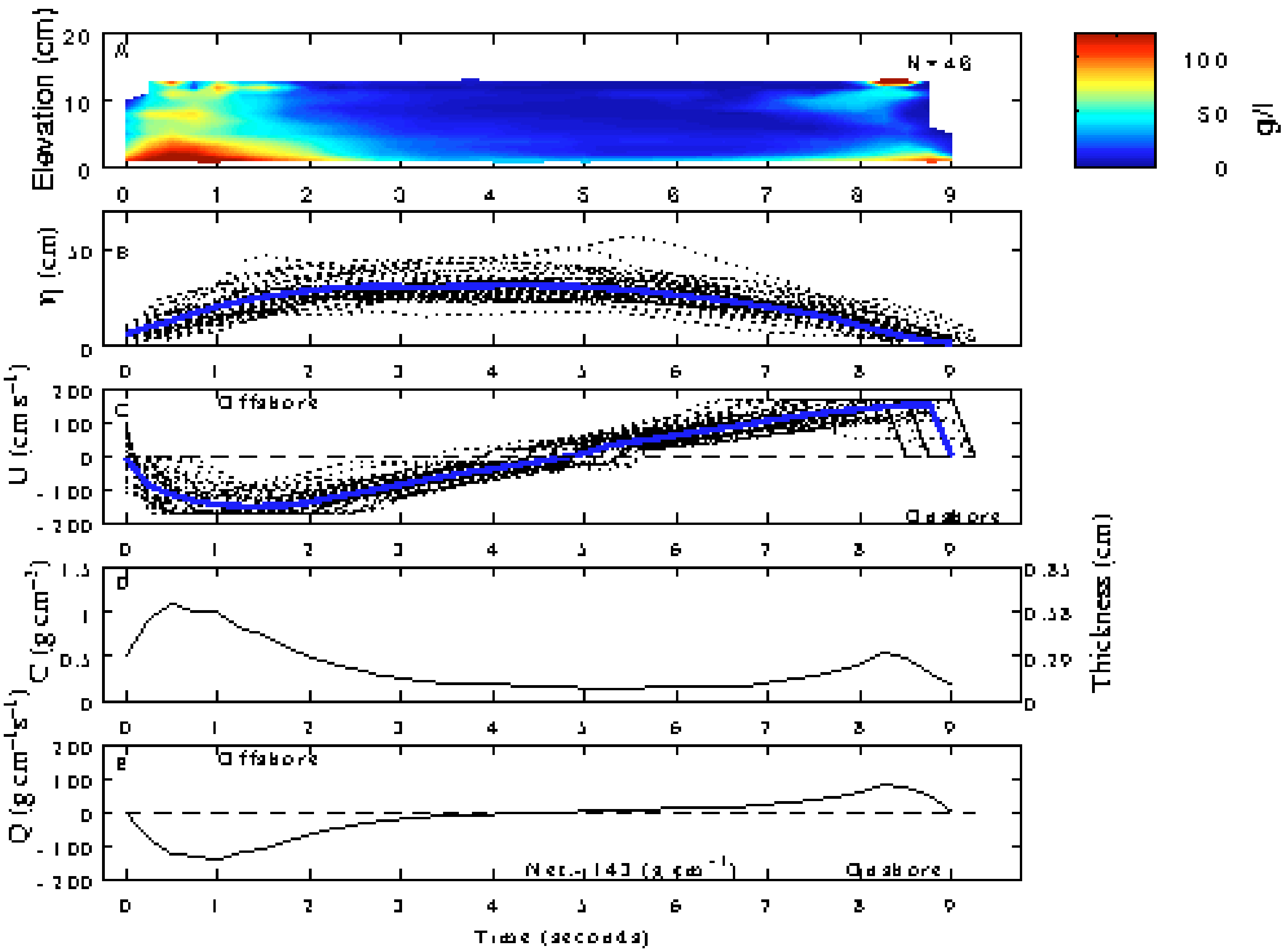

Figure 2. A 9 second duration swash uprush and backwash sequence. Dotted curves represent the 67 individual sequences which were used to calculate the ensemble average (blue curve). A) Contour plot of suspended sediment concentration (g l^{-1}) as a function of elevation above the bed; B) Sea surface elevation (cm); C) Cross-shore velocity (cm s^{-1}), negative values are directed onshore (uprush), positive values are offshore (backwash); D) Depth-integrated suspended load (g cm^{-2}) for the ensemble average over the sensor range; equivalent erosion depth of the seabed (right axis, cm); E) cross-shore suspended sediment flux gm cm^{-1} s^{-1}) obtained from the product of the ensemble-averaged velocity (C) and suspended load curves (D) assuming a depth-uniform velocity profile.

However, suspended sediment concentrations in the uprush and backwash have considerably different vertical structure. The uprush suspended load being distributed over the water depth and the backwash suspended load showing strong vertical gradients, suggesting very different fluid dynamics. Figure 2, panel D, shows that the net transport over an incident wave swash cycle is shoreward. This begs the question of why beaches don't continually prograde? How does beach material get off the beach face? The answer probably lies in interactions with the lower frequency, "infragravity," band swash runup. The answer to these questions are a source of continuing analysis.

IMPACT/APPLICATIONS

The insight gained from the swash zone sediment transport study will be used to guide future investigations. A new, portable survey system will allow the investigation of nearshore bathymetry on larger horizontal spatial scales and on a wider variety of beach types (from reflective to dissipative) than previously attainable.

TRANSITIONS

The surf zone bathymetry survey system has been duplicated and is presently being used by the Littoral Remote Sensing program to provide ground-truth bathymetry measurements for wave-shoaling studies which attempt to infer bathymetry using video or other EO observations of surface wave shoaling characteristics (J. Dugan, Arete'). Jack Puleo has found gainful employment with NRL/Stennis working on a 6.1 Foreshore Sediment Transport study (K.T. Holland, PI).

RELATED PROJECTS

The bathymetric survey systems are in use by the State of Washington in a study of coastal erosion jointly funded by the USGS and the Washington State Dept. of Ecology (Cote et al., 1998, http://www.wa.gov/ecology/sea/swce/index.html).

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