Bedform Dynamics and Mine Burial

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LONG-TERM GOAL

The generation and migration of bedforms on shallow-water sandy bottoms provide a mechanism whereby mine-like objects can become gradually buried. The ultimate goal of this work is to examine field data in order to develop a predictive understanding of coastal bedform statistics, bedform distribution, and the consequences of bedforms on the potential burial rates of bottom objects.

OBJECTIVES

The focus of the initial year of this project has been on the development of a framework for the problem and exploration of that framework with initial data sets.

APPROACH

As a bedform migrates past a mine, the mine will fall to the low point of the bedform trough before subsequently being buried by the passage of the following bedform crest. Thus, the statistics of mine burial are determined by the statistics of bed variability and the mine burial problem reduces to a problem of understanding the time evolution of the bottom profile envelope. If we define the bottom profile as $h(x, \tau)$, and the profile envelope as spanning from $h_{min}(x, \tau)$ to $h_{max}(x, \tau)$, then mines can sink to h_{min} and can feasibly be covered at any time by an envelope thickness, $D_{max}(x, \tau)=h_{max} - h_{min}$. ($\tau$

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14. ABSTRACT

The generation and migration of bedforms on shallow-water sandy bottoms provide a mechanism whereby mine-like objects can become gradually buried. The ultimate goal of this work is to examine field data in order to develop a predictive understanding of coastal bedform statistics, bedform distribution, and the consequences of bedforms on the potential burial rates of bottom objects.

15. SUBJECT TERMS

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denotes a time scale of slow evolution). When a mine is first seeded (τ=0), the envelope will have zero thickness. However, as megaripples, sand bars or any other profile features form and migrate, the thickness of the profile will grow with time in a way that depends on the overlying wave and current fields. If a mine has a vertical scale W (perhaps the diameter of a cylinder), then complete burial is possible once D_{max} exceeds W. At any subsequent time, the probability of burial depends on the statistics of $D = h - h_{min}$ as the bottom fluctuates through this envelope.

This framework is illustrated in Figures 1 and 2, using the example of beach profile data from Duck, NC. The upper panel of Figure 1, an example beach profile for 09/09/96 at a longshore location of y = 640 m, shows a typical realization of Duck bathymetry, with sand bars around x = 200 and 400 m. The lower panel shows 168 profiles collected during an eight-year period from 1991 to 1999. Together, these latter profiles describe a profile envelope within which any object would be buried by the above process. For example, at a cross-shore position of x = 200 m, the envelope spans almost 3 m, thus could potentially bury an object up to 3 m tall at times.

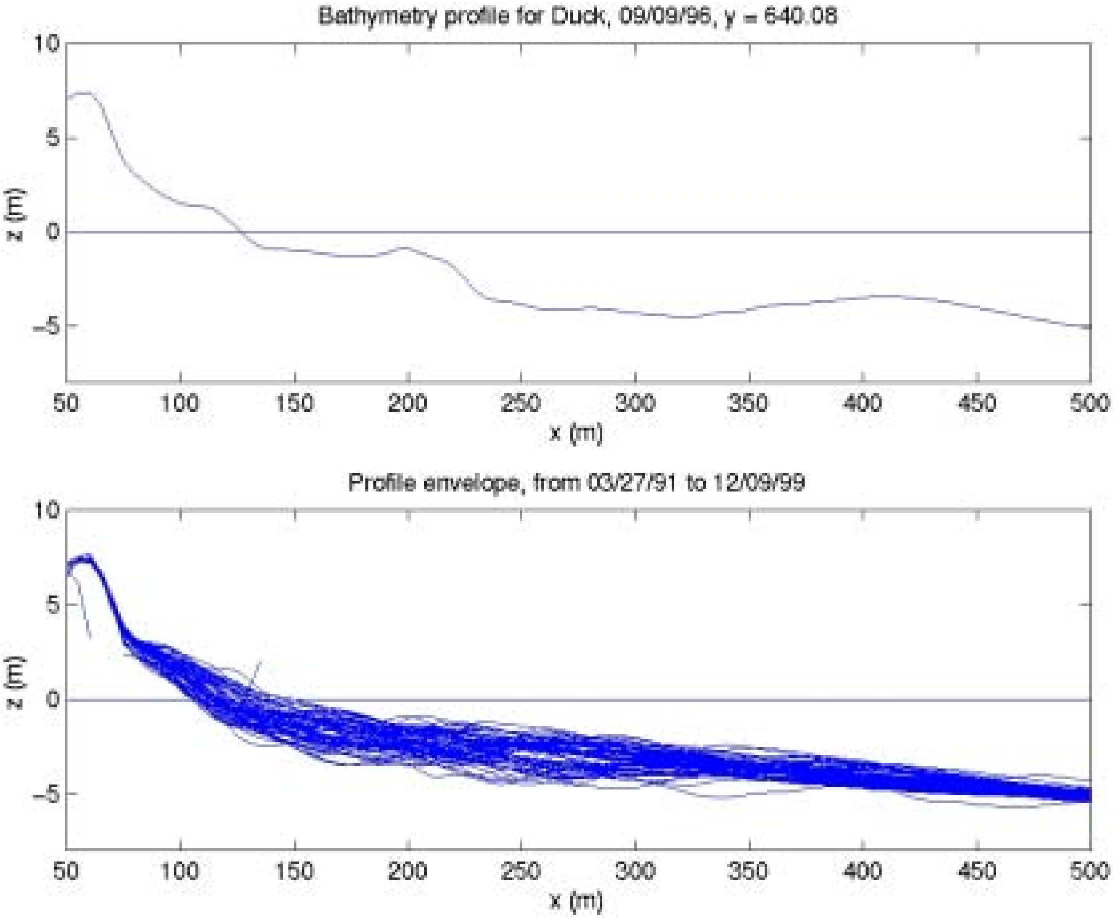

Figure 1: Upper panel: Example beach profile at Duck, NC showing sand bars around x=200 and 400 m. Lower panel: 168 profiles at Duck, NC from between 1991 to 1999, showing the envelope of natural profile variability.

The growth of the profile envelope at x=200 m is illustrated in Figure 2. It can be seen that the envelope grows to a 2 m thickness in less than one year. Within this growing envelope, D fluctuates in a way that would bury and unbury any mine-like objects.

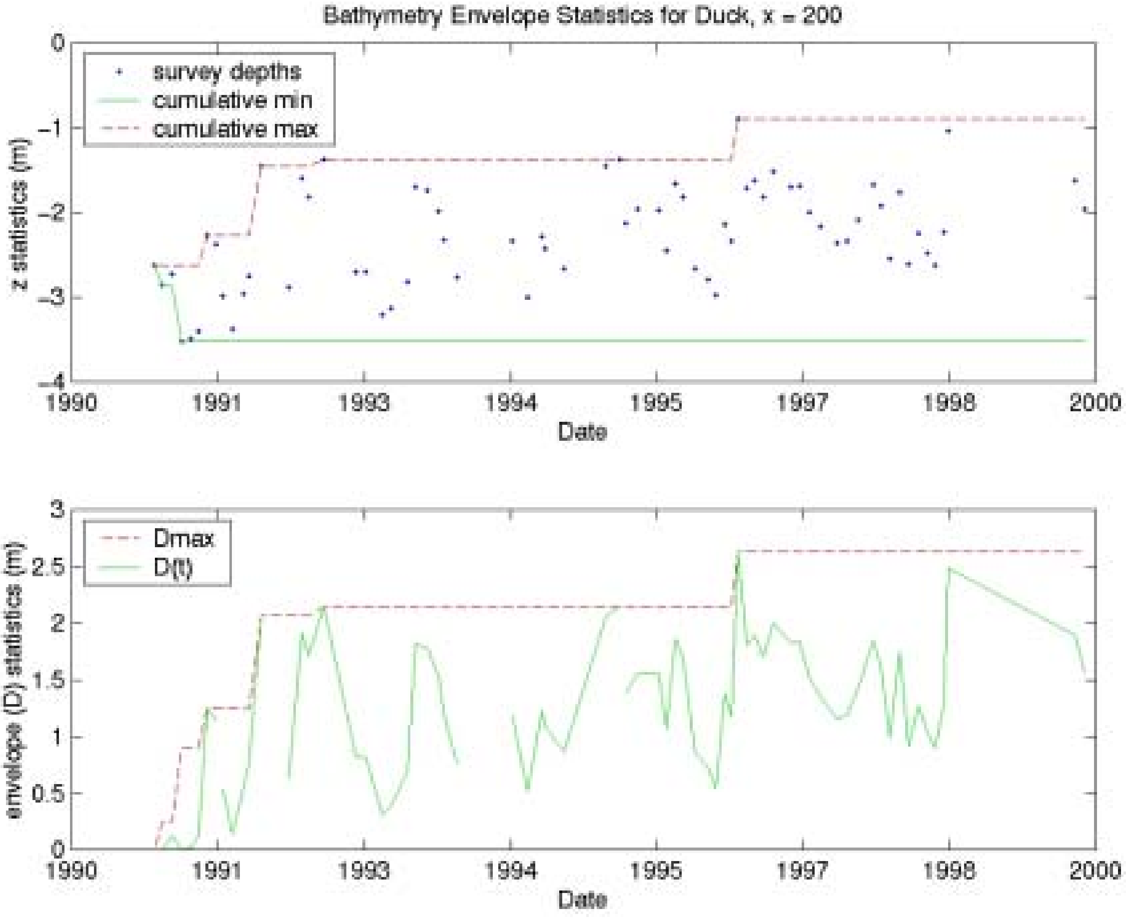

Figure 2: The time variability of bed from Figure 1 at cross-shore location x=200 m. Upper panel: The original data points (dots) are shown as well as the developing cumulative minimum (dashed line) and maximun (solid line) depths. Lower panel: The development of the envelope width, D_{max} (dashed line) and the instantaneous envelope, D (solid line) are shown.

Functional forms will be developed for the bed profile growth and for the statistics of D, given a history of the available wave energy. Data from a large number of profiles and based on a suite of possible start times, t_0, will be used. This methodology will also be applied to time series of small-scale bottom variability (ripples, megaripples, etc.) collected at a number of sites by stationary sonar altimeters, scanning altimeters and video imaging of the bed.

In addition, the spatial distribution of the bed envelope statistics is being examined. Sonar altimeters mounted on an amphibious vehicle (CRAB) are used to measure the spatial distribution of bottom

roughness and its variability. A cross-shore profile from the SandyDuck (Sep-Oct 1997) experiment is shown in Figure 3a. As in Figure 1, sand bars are located at about x=180 and 310 m. However, smaller scale megaripples (expanded in Figure 3b) are also resolved in this unique data set.
A profile of the root mean square (RMS) roughness was calculated (Figure 3c) by estimating RMS variations over 10 m lengths of bed. Profiles of this type were estimated over the 500 m x 700 m survey area for 1 month.

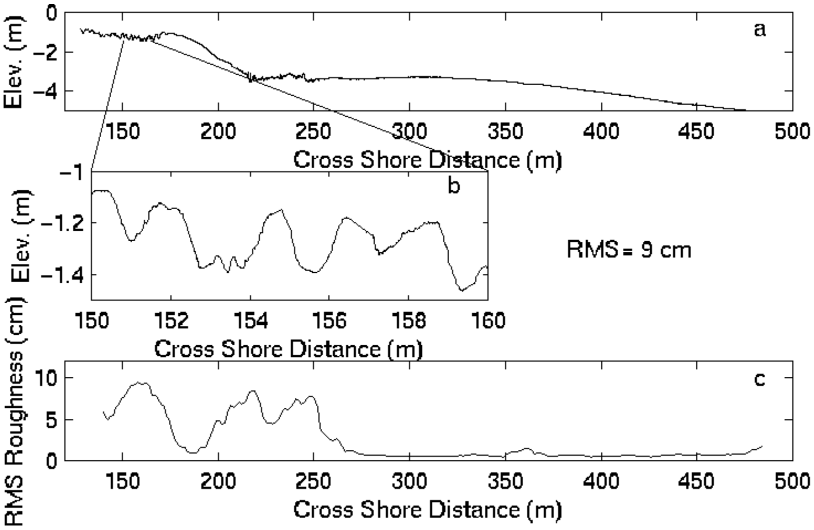

Figure 3. a) Example of a cross-shore profile from a single sonar altimeter with large bedforms in the trough (x=130-175 m). b) Example of a 10 m long section of Fig 3a (x=150-160 m). These data are demeaned and the root-mean-square is calculated to give the RMS roughness , which for this section on large bedforms is 9 cm and corresponds to the value at x=155m in Fig 3c. c) RMS roughness versus cross-shore location. The RMS is calculated of overlapping 10 m long sections (as in Fig 3b) to produce this RMS roughness profile from the depth profile in Fig 3a.

WORK COMPLETED

Much of this work is still in its initial research stages. A manuscript on the spatial distribution on bottom roughness in the nearshore has been submitted for publication.

RESULTS

Bed roughness in the nearshore is largest in shallow water (water depths < 2 m, usually inside the surf zone) (Figure 4). The spatial and temporal variability of the bed roughness is also largest inside the surf zone. This is likely owing to the high near-bed velocities from shoaling and breaking waves, breaking induced turbulence and the 3-dimensional circulation patterns and morphology in this region.

IMPACT/APPLICATION

The threat of mines has a huge impact on Naval operations. If mining is suspected, methods exist for search and identification for proud mines, but the potential existance of buried mines is of considerable concern. This work will help to quantify the process of mine burial by bottom bedform movement, and the expected time scales, probability and depths of burial.

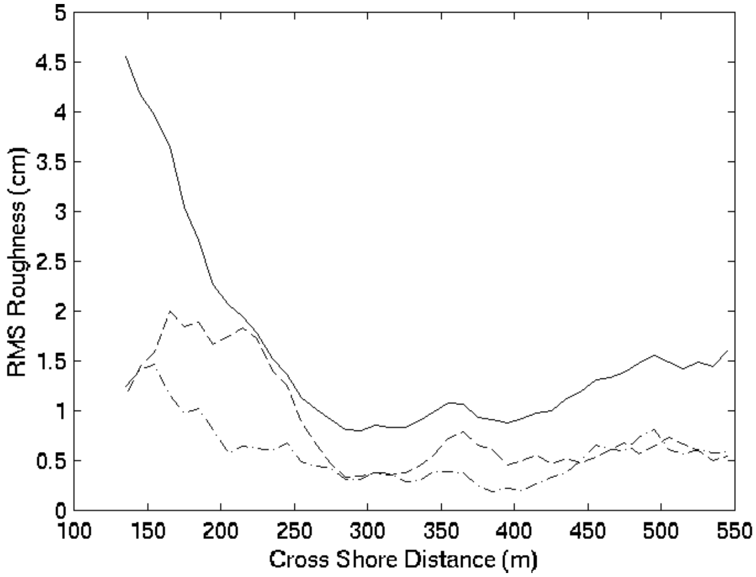

Figure 4: Time average, alongshore-average RMS bed roughness versus cross-shore distance (solid line). The dash-dot line is standard deviation of the time average and represents the temporal variability. The dashed line is the mean of the daily alongshore standard deviation and represents the mean spatial variability. [The RMS bed roughness decreases from about 4.5 cm (equivalent to a bedform amplitude of about 15 cm) at the shoreline to about 1 cm at x=250 m offshore (just offshore of the inner bar).]

TRANSITIONS

This work has not yet lead to any transitions.

RELATED PROJECTS

This work is part of the Mine Burial Program, a coordinated effort to study all processes of mine burial including impact and scour burial.

REFERENCES

PUBLICATIONS

Gallagher, E.L., E.B. Thornton and T.P. Stanton. Sand bed roughness in the nearshore. Submitted to J. Geophysical Research.