Spatial and Temporal Variability of Grain Size and Small-Scale Mophology

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LONG-TERM GOALS

We propose to test the hypothesis that heterogeneity of coastal subaerial and subaqueous morphology on many scales is correlated with heterogeneity in surface sediments, which influences the morphodynamic feedback.

OBJECTIVES

The specific objectives of this work are to:

- develop and integrate a suite of sensors for efficiently measuring morphology and surface sediment grain size distribution within the surf zone,
- obtain, modify, and evaluate ONR's surf zone crawler as a platform for nearshore measurements,
- test the sensors in the field and obtain measurements of the temporal and spatial variability of sediments and bedforms
- investigate heterogeneity of morphology in the context of the local sedimentological conditions.

APPROACH

Historically, it has been assumed by most nearshore models that beaches are uniform in grain size and relative smooth. Recent studies have found that this is not the case. Ripples and megaripples are observed to be ubiquitous (Nielsen 1981, Gallagher et al. 2003, amoung many others) and to depend on grain size (Ardhuin et al. 2002, Trembanis et al. 2004), cross-shore sand bar migration is better modeled when small changes in grain size are considered (Gallagher et al. 1998), grain size is observed to vary in and around beah cusps, rip current systems, ripples scour depressions and erosional hot spots (eg, Komar 1973, MacMahan et al. 2005, Murray and Thieler 2004, McNinch 2004). Here we hypothesize that heterogeneity of coastal seafloor morphology on many scales is correlated with

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14. ABSTRACT
We propose to test the hypothesis that heterogeneity of coastal subaerial and subaqueous morphology on many scales is correlated with heterogeneity in surface sediments, which influences the morphodynamic feedback.

15. SUBJECT TERMS

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heterogeneity in surface sediments, which influence the morphodynamic evolution. We are making measurements to test this hypothesis.

The first and second goals of this proposal are to develop a versatile suite of sensors to measure grain size and morphology and to modify a mobile, autonomous platform to carry them. This efficient measuring system could be deployed easily in many environments. Planned measurements include morphology (from a sonar array, a pressure sensor and KGPS), grain size (from a digital imaging system and a LISST), and flow conditions (from a current meter array). The digital imaging system ('eyeball') for measuring grain size is under development following the work of Rubin (2004). From the auto-correlation of digital images, information about the surface grain size distribution can be obtained quickly and inexpensively. The rest of the instruments will be purchased from reputable vendors, which includes modifications for installation on the crawler.

WORK COMPLETED

During the first year of the project significant progress has been made on the development of the eyeball digital imaging system. The prototype eyeball was developed and tested while Gallagher was on sabbatical in Monterey, CA in the fall of 2004. A small field test was conducted in Monterey. In May, 2005 we participated in a field experiment in England with the University of Plymouth, where the eyeball was tested alongside traditional sediment measurements. The results of laboratory and field tests of the instrument have been submitted for presentation to ICCE 2006 and are discussed below.

In addition, progress has been made with the crawler system. The crawler itself is still in the hands of the manufacturer who is working on the necessary modifications. The remainder of the instruments are being designed, developed and purchased at this time (current meters and KGPS have been ordered, the sonar array is being designed for the crawler and will be puchased by the end of the year, the control and data acquisition system for the crawler is being developed by a graduate student at UD). Thus progress is being made, but there are no scientific results to be reported at this time.

RESULTS

The prototype eyeball consists of a 5 megapixel, digital, Nikon D70 camera (purchased with a grant from Franklin and Marshall's faculty development fund), a macro lens with magnifiers, and an Ikelite underwater housing. The light and focus are fixed so the system is easy to handle and control by a diver, where the diver simply presses the glass against the sand and obtains uniform images. Following Rubin's (2004) technique, auto-correlation is run on the digital image and the correlation curve is compared quantitatively (via linear least-squares regression or interpolation) to correlation curves used for calibration to determine the sediment grain size and distribution. The calibration curves are generated by photographing sieved sand from the same location. The calibration process is time-consuming and makes the technique valuable only when many images are planned for high-resolution sedimentological surveys. A sample natural image from Del Monte Beach in Monterey, CA is shown in Fig 1 (left) and its corresponding autocorrelation curve (asterisks) and the required calibration curves are shown in Fig 1 (right).

Mean grain size is estimated from the curves in Fig 1 by interpolating the points on natural curve between the calibration curves at each pixel offset and then averaging. Mean grain size for two samples from Del Monte Beach measured by the eyeball (dashed) and traditional seiving (solid) are shown in Fig 2. Similar to Rubin's (2004) findings, the eyeball is very reliable in estimating mean grain size.

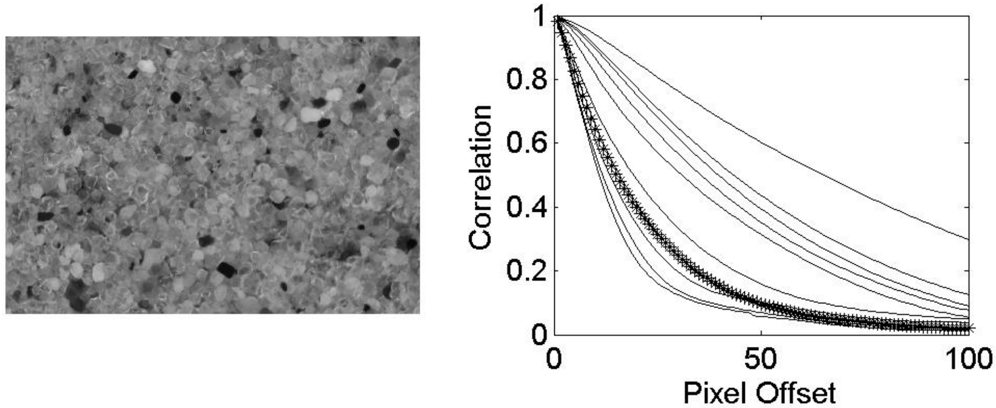

Figure 1. Example image of natural sand sample (left panel). Right panel: autocorrelation curve (asterisks) from image on left and calibration curves (thin lines) corresponding to .125 mm (bottom line), .18, .25, .3, .425, .6, .71, .85, 1.0 and 1.4 mm (top line). [Correlation curves fall off from a value of 1 at 0 pixels offset to close to 0 for large pixel offsets. Curves for largest grains fall off slowly, curves for smallest grains fall off quickly. The natural curve, being a combination of all grains, falls off at an intermediate rate.]

Estimates of sediment distribution are also shown in Fig 2, where the thin lines represent sediment distribution estimates from different photos of the same sample. When all estimates are averaged, the distribution from the eyeball (circles) is quite close to that from sieving (asterisks). As a further test of the eyeball's ability to estimate sediment distribution, mixtures of known sands were made in the laboratory. The bimodal distribution of sediment (50% by weight 0.25mm sand and 50% by weight 0.85 mm sand) was reproduced reasonably well by the eyeball with the exception of the small anomolous peak at 0.5mm (Fig 3). This may be owing to the occlusion of large grains by small grains, resulting in the appearance of an intermediate grain size. It may also be an anomoly of the analysis. Data from this and other artificial mixtures are being analyzed to evalute the capabilities of the eyeball.

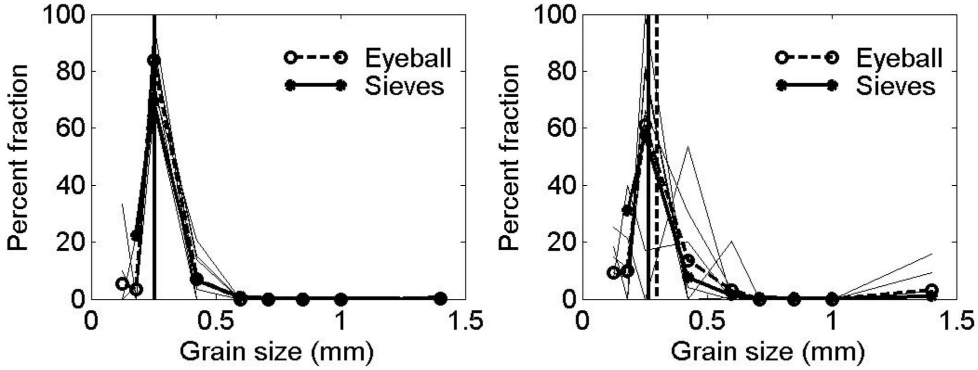

Figure 2. Two examples of mean grain size (vertical lines) and grain size distribution (lines with symbols). Dashed line are estimated from the eyeball and the thick solid lines are measured with seives. The thin lines are eyeball distributions estimated from individual photographs, the thick dashed line with circles is the mean of all the thin lines. Data in the left panel is from above the high tide line at Del Monte Beach, Monterey, CA. The photo and data in Fig 1, provided one of the thin lines in the left panel. Data in the right panel is from sand collected from a shoal between rip channels exposed at low tide also at Del Monte Beach. [In both panels, the two techniques agree well and show a mean grain size and a peak in the distribution at about .25-.3 mm. The mean grain size on the high beach (left) from the two techniques is only different by .005mm. On the low tide shoal (right), the mean grain sizes from the two techniques differ by 0.04mm.]

The eyeball was taken to Sennen, Cornwall, England in May to participate in a cross-shore sediment transport experiment being conducted by colleagues at the University of Plymouth (they contributed some travel money for this project). Univ. Plym. was making measurements of waves, currents, sediment transport, bed changes, ripples and sediment grain size (via traditional sample collection for laboratory analysis). Cross-shore surveys were conducted daily with the eyeball alongside the traditionl sediment measurements and profile surveys. Mean grain size estimated with the eyeball is shown in Fig 4 compared with measured mean grain size for two example surveys (May 9 and 19, 2005). Although there are differences between the two measurements, both techniques get estimates that are approximately the same and both exihibit the similar variabiliy. In addition, the larger scale trends are similar, with the grain size staying about the same across the profile on May 9 (left) and increasing slightly across the profile on May 19 (right). It should be noted that the traditional sampling collected sand from the top 3 cm of the bed, while the camera measures the top layer of grains only. Data of this sort, as well as grain size distribution estimates will be compared carefully to evaluate the eyeball.

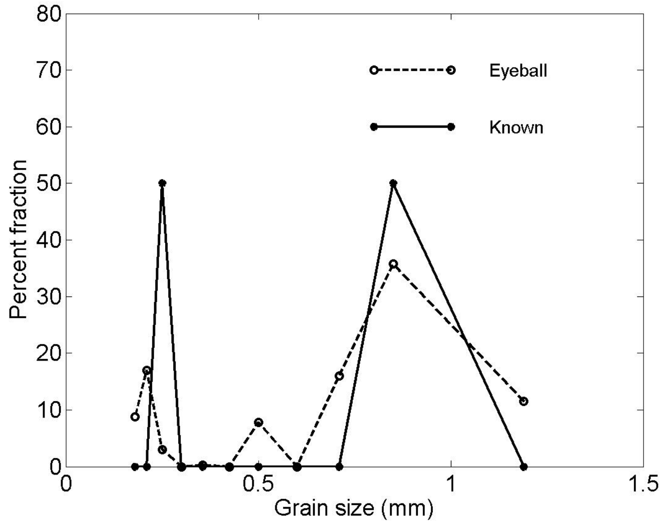

Figure 3. Grain size distribution of a bimodal mixture (50% by weight 0.25mm sand and 50% by weight 0.85 mm sand) of sand from Sennen, England. The solid line with asterisks represents the known distribution and the estimate from the eyeball is shown by the dashed line with circles. [The distribution from the eyeball has two peaks in the correct location, reasonably reproducing the bimodal distribution. However, the eyeball gives a small third peak at 0.5mm.]

A number of interesting morphological phenomena were observed at Sennen and surveyed with GPS, the eyeball, and traditional sediment sampling. Beach cusps occurred and changed during the 3 week long experiment. The macrotidal beach had a coarse, steep forshore and a broad low tide terrace. On the low tide terrace, megarriples were frequently observed. These features were all sampled and this excellent and opportune data set will serve to test both the eyeball and the underlying scientific hypothesis.

IMPACT/APPLICATION

Understanding the morphodynamics of sedimentary environments is important for recreational, economic, and military reasons. This work will help to shed light on the importance of grain size on sediment transport and will help elucidate whether variations in grain size are important to or even drive changes in morphology in many coastal environments. In addition, the development of a suite of instruments on an amphibious ROV has the potential to revolutionize measurement in the coastal zone.

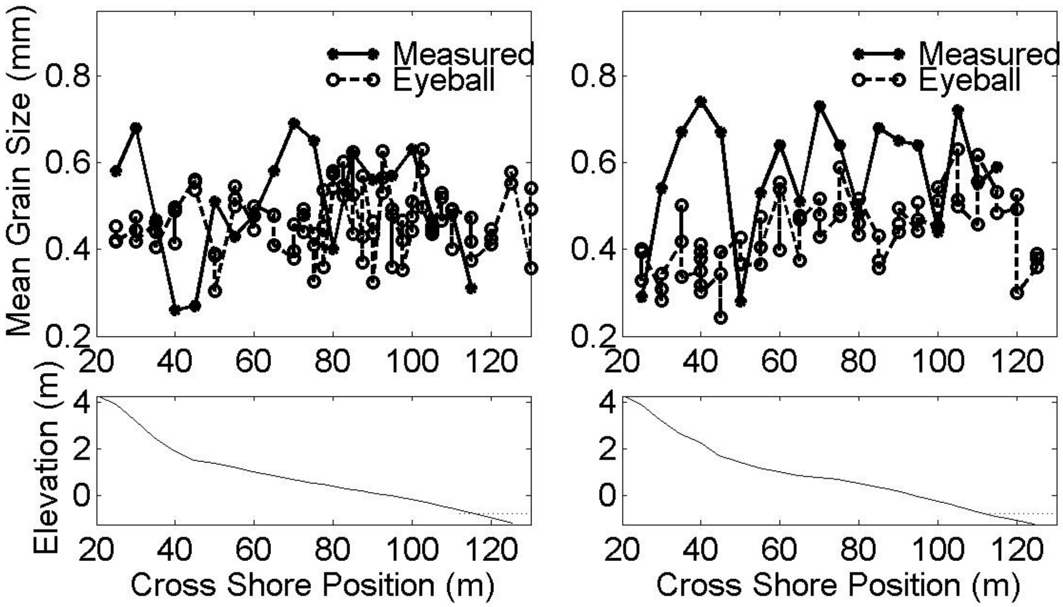

Figure 4. Mean grain size measured with sieves and estimated with the eyeball both plotted versus cross shore position (top panels). Data are from May 9, 2005 (left) and May 19, 2005(right) at Sennen, England. Bottom panels: cross shore profile of the beach at Sennen. Dotted line shows approximate low tide level, and because this beach has a tide range of 5 m, this sampled area is submerged at high tide. Note that there are three eyeball samples at each cross shore location. [Mean grain size ranges from 0.3-0.6 mm and both techniques compare well, although both are highly variable.]

TRANSITIONS

This work has not yet lead to any transitions.

RELATED PROJECTS

This work also is being supported by an ONR DURIP award to Dr. MacMahan at University of Delaware.

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PUBLICATIONS

Abstracts and Presentations

Gallagher, E.L., J. MacMahan, P. Russell, G. Masselink, N. Auger. Grain Size from Digital Images and Morphological Variability. Abstract submitted to the 30th International Conference on Coastal Engineering, 2006.

Gallagher, E.L. The Eyeball: Estimating Sand Grain Size With Digital Images. Invited presentation, Woods Hole Oceanographic Institution, July 15, 2005.

Gallagher, E.L. The Eyeball: Estimating Sand Grain Size With Digital Images. Invited presentation, University of Delaware, September 27, 2005.

Peer-reviewed Publications

This work has not yet lead to any publications.