Acoustical Studies Of Sediment Dynamics In The Surf Zone: Sandyduck'97

Alex E. Hay
Dalhousie University
Department of Oceanography
Halifax, N.S.
Canada B3H 4J1
Telephone: 902-494-665, FAX: 902-494-288, INTERNET: Alex.Hay@dal.ca
N00014-97-0482

LONG-TERM GOALS

The central goal of this project is a deeper understanding of the dynamic adjustment of mobile sandy sediments to fluid forcing in the surf zone at small (1cm to 10m) and intermediate (10m to 100m) horizontal scales. The effort is motivated by the dual need to develop more realistic models of fluid-sediment interactions in the nearshore zone, and for suitable *in situ* measurement techniques to make the observations necessary to adequately test the models. Of particular interest is the role of bedforms of different characteristic spatial pattern and scale in the local sediment flux and momentum balances.

OBJECTIVES

The overall objective of this project is to study bedform genesis, growth, migration, and decay, together with the associated fluid forcing and sediment suspension, in the natural surf zone. A key initial objective was to obtain a comprehensive set of measurements of bed adjustment through time, as a function of cross-shore position, and over a period of several months. This data set will provide a basis for determining cross-shore differences in response synoptically, and for differences in the response trajectories through time and between forcing events, over a suitably wide range of conditions.

APPROACH

The approach for the SANDYDUCK '97 experiment involved an array of state-of-the-art underwater acoustic sensors for high-resolution measurements of seabed topography, and fluid velocity and sediment concentration profiles through the wave-current boundary layer. The array comprised 5 instrumented frames deployed along a cross-shore line and along an alongshore line with 50-100 spacing between adjacent frames. Rotary fan and pencil-beam imaging sonars were mounted on each frame. Coherent Doppler Profiler (CDP) systems, augmented by Sontek ADV-O point velocimeters, were mounted on two of the frames. Ancillary sensors on each frame included pressure and temperature sensors, and electromagnetic flowmeters, and 2-axis tilt sensors.

The coherent Doppler system was developed with Dr. Len Zedel (Memorial University), with funds from ONR. Dr. Zedel and I continue to collaborate on this development. The

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rotary sonar system operates in master/slave mode, so that data from a number (up to 8) different heads may be acquired simultaneously. This was accomplished with custom electronics developed at Dalhousie prior to SANDYDUCK. Technical support for the Doppler and rotary systems is provided by Wes Paul (electronics and acoustics technologist) and Dr. Robert Craig (data acquisition and control software). Todd Mudge has been hired as a Research Assistant to help with the analysis of the acoustic data. The em flowmeters and pressure/temperature measurements were made by colleague Dr. Tony Bowen (Dalhousie University), as part of a separately-funded collaborative research project. David Hazen (electronics engineer) and Walter Judge (electronics technologist) provided additional technical support. Postdoctoral fellow Dr. Qingping Zou is participating in the analysis of the CDP data, providing theoretical analysis of the hydrodynamics. Postdoctoral fellow Dr. Diane Foster is collaborating with us on bottom boundary layer dynamics. Doctoral student Carolyn Smyth is playing a leading role is the analysis of the CDP data. Doctoral student Phil MacAulay is using acoustic images of the space-time structure of suspension for his thesis. Dr. J. C. Doering and his students are working with the ADV data. Other collaborations include Doctoral student Rebecca Beavers (Duke University) and Dr. Peter Howd (University of South Florida), on sediment fabric, and Dr. Tom Lippmann (Scripps Institution of Oceanography), on processes related to wave breaking.

WORK COMPLETED

Our SANDYDUCK experiment was highly successful. Approximately 250 GBytes of high-quality acoustic data were acquired continuously over a 77-day period from late August to early November. During the subsequent 11-month period, significant progress has been made in processing this large-volume data set.

We are almost at the point of generating final data products. The last remaining hurdle, now essentially overcome, has been to determine absolutely the attitude of the instrument frames (i.e. the tilt of the frame relative to gravity). This is essential prior to carrying out the next stages of analysis which require that the slope of the bottom, determined from the rotary pencil-beam sonar, be known. Determining the orientation of the pencil-beam images relative to gravity has been more involved than anticipated because of intermittent discrepancies in the measured direction of the sonar head. These problems are now resolved.

RESULTS

The SANDYDUCK data are rich in detail. At this point in time, the most accessible example results are of the bedform imagery, and Figures 1 and 2 provide an indication of the quality of these data. These Figures show the evolution of a meter-scale lunate megaripple over a 2-day period as it migrated toward shore.

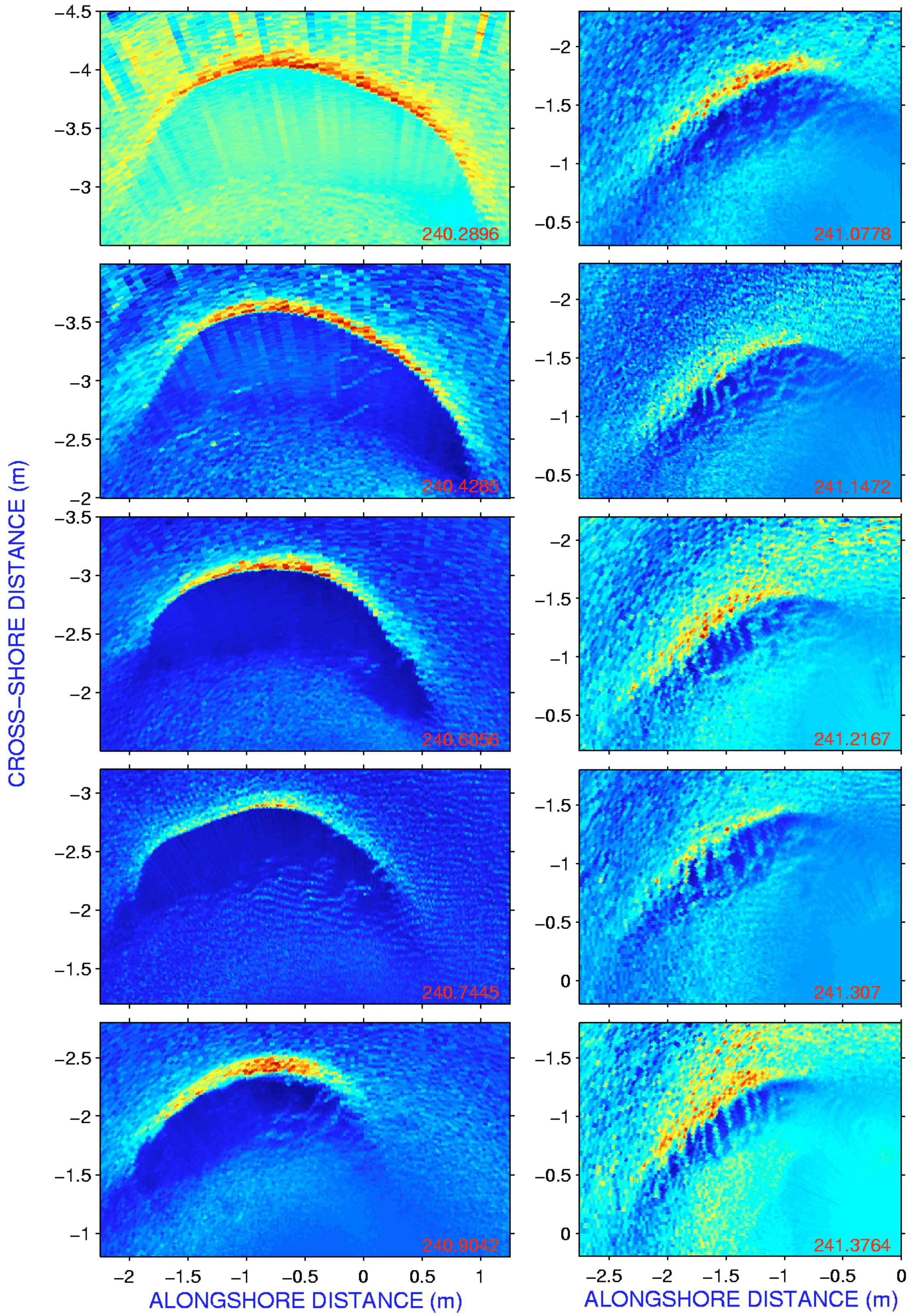

Figure 1: Fan-beam images of migrating megaripple.

Figure 1 shows the megaripple in plan view (offshore is toward the top). Dark blue represents acoustic shadow, and increasing acoustic reflection amplitudes are represented by the remaining colors from light blue to red. The images are separated by about 5h, with time increasing from top to bottom down the left column, and then down the right. For the farther distances seaward of the sensor (i.e. earlier times), the pit leading the shoreward facing crescentic (i.e. lunate) megaripple crest is not insonified (i.e. is in shadow). The structure of the surface of this pit becomes observable as the megaripple approaches closer to the sensor. The megaripple shrinks in size (horizontal scale at least) as it migrates.

Figure 2 shows the same megaripple, but as observed with the rotary pencil beam sonar, which provides bed elevation as a function of cross shore position along a single on-offshore line. The megaripple pit is the blue trench. The relief (crest-to-trough) is 20-30 cm, which is typical of these major features of the small scale topography at Duck.

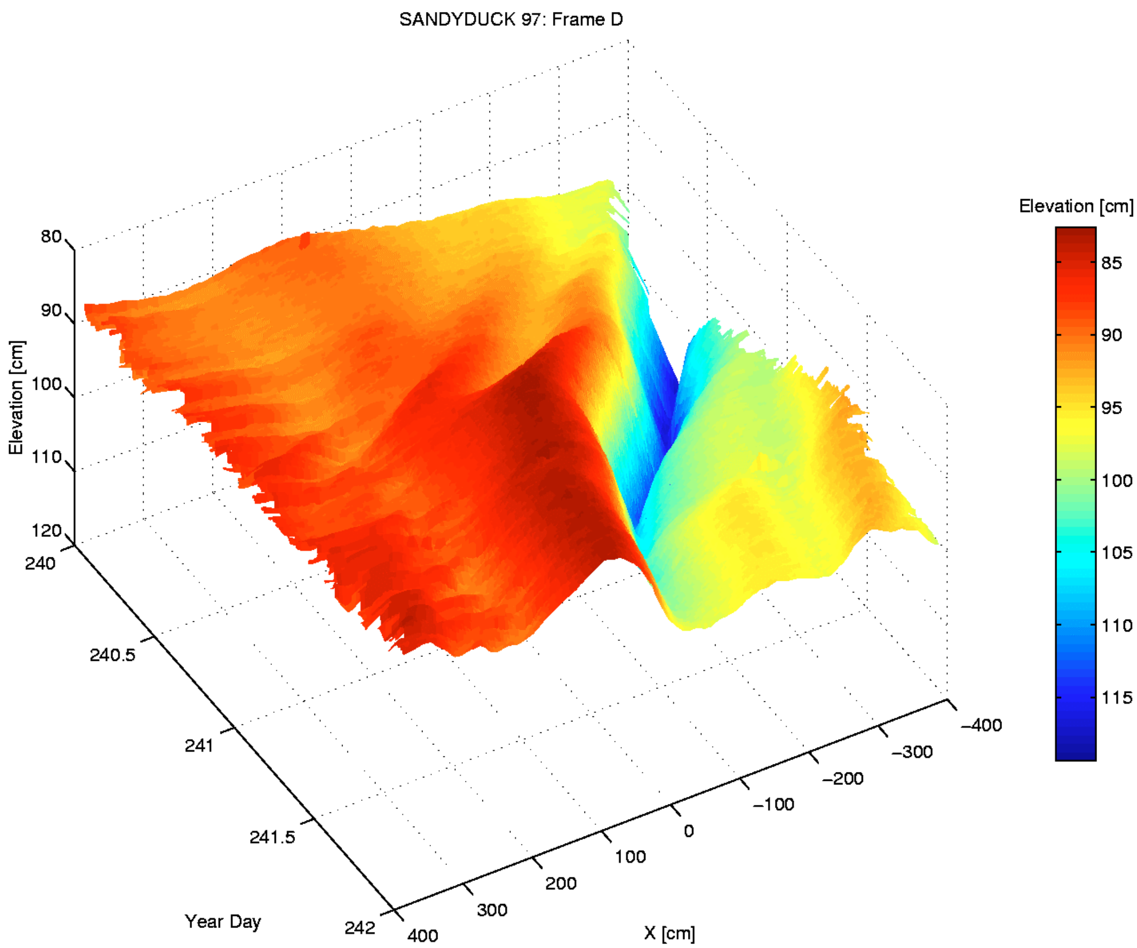

Figure 2: Time-space surface of bed elevations (from rotary pencil beam data) for the migrating megaripple in Figure 1. **X** is the cross-shore coordinate, positive onshore.

IMPACT

In the SANDYDUCK'97 experiment, we demonstrated that it is possible to make long-term observations of nearshore fluid-sediment interactions with sophisticated measurement systems on a continuous basis at a number of cross-shore locations. The data set is of high quality and, because of the combination of Doppler profilers, the 3-dimensional seabed imaging systems, and the 3-month's duration, it is also unusually comprehensive. During the next several years, it can be anticipated that, through comparisons of these results with model predictions, significant new insights into mobile bed dynamics in the surf zone will result. In addition, the successful performance of the acoustic remote sensing array throughout SANDYDUCK for a wide range of surf zone conditions opens up a variety of new possibilities for these kinds of instruments in future nearshore dynamics experiments.

TRANSITIONS

Numbers of groups world-wide are making use of our advances in the use of acoustics for the sediment transport studies, including our recent introduction of rotary imaging sonars for bedform measurements (see Hay and Wilson, 1994).

RELATED PROJECTS

A significant benefit to this project was provided by a grant from the Natural Sciences and Engineering Research Council (NSERC) of Canada to Dr. Alex Hay (Principal Investigator), and Co-Investigators: Dr. Tony Bowen (Dalhousie University), Dr. J. C. Doering (University of Manitoba) and Dr. Len Zedel (Memorial University of Newfoundland), which covered most of our field costs during the SANDYDUCK'97 experiment .

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Zedel, L., and A. E. Hay. 1998. A Coherent Doppler Profiler for High Resolution Particle Velocimetry in the Ocean: Laboratory Measurements of Turbulence and Particle Flux. J. Atmos and Ocean. Tech. (in press).