REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* OCT. 2001	2. REPORT ~~DATE~~ TYPE Final	3. DATES COVERED *(From - To)* 3/1/99 - 9/30/01

4. TITLE AND SUBTITLE

Modeling Beach Morphology Changes Coupled to Incident Wave Climate and Low Frequency Currents

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-99-1-0398

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)

James T. Kirby

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Center for Applied Coastal Research
University of Delaware
Newark, DE 19716

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research

10. SPONSOR/MONITOR'S ACRONYM(S)

ONR

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT

Approved for Public Resease, distribution is unlimited.

20020920 052

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This work is intended to provide a process-based model for predicting nearshore large scale bedform evolution over day to week time scales, as a first step to bridging the gap between short-time physical predictions and longer time (annual and longer) predictions based on parameterized physics. This gap is still immense, and will only be closed with (1) the advent of both faster computers and with (2) the ability to access local sediment transport formulations applied over reasonably long time scales. We are mainly concerned with the second aspect of this problem.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			James T. Kirby
UL	UL	UL	UL	8	19b. TELEPONE NUMBER *(Include area code)* 302-831-2438

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI-Std Z39-18

Modeling Beach Morphology Changes Coupled to Incident Wave Climate and Low Frequency Currents

James T. Kirby
Center for Applied Coastal Research
University of Delaware
Newark, DE 19716
phone: (302) 831-2438 fax: (302) 831-1228 email: kirby@udel.edu

Grant Number: N00014-99-1-0398

http://www.coastal.udel.edu

LONG-TERM GOAL

My longterm goal is to develop physics-based models to predict nearshore morphology changes, and to test the models against available field data.

OBJECTIVES

The objectives of the present project are to:

1. Incorporate a sediment transport and bed morphology capability in the wave-induced circulation model of Özkan-Haller and Kirby (1997, 1999)
2. Use the resulting model to study the growth to finite amplitude of bottom perturbations on initially longshore-uniform planar or barred beaches
3. Use the model to investigate the evolution of three-dimensional bed features under specific wave conditions, in comparison to ARGUS video results for the Duck FRF site.
4. Begin the development of an instantaneous sediment transport capability (on a wave by wave basis) in the Boussinesq model of Wei et al (1995).

APPROACH

Our approach is to use a robust numerical code for the modeling of 2D or quasi-3D wave-driven nearshore circulation as the basis for computing the local wave-averaged sediment transport rate and the resulting evolution of nearshore morphology. The model results will be limited in accuracy by both the accuracy of input wave information and by the accuracy of the local sediment transport model. By using data from the FRF ARGUS station and related wave information from in situ pressure gage arrays, we seek to determine whether the model will reproduce qualitative shifts in overall bed geometry which have been observed to correlate with shifts in wave conditions (Lippman and Holman, 1990).

WORK COMPLETED

We have incorporated a sediment transport formulation and bed morphology calculation into the nearshore circulation model of Özkan-Haller and Kirby (1997, 1999), and have begun to use the model to study evolution of large amplitude bed forms in river environments as well as the nearshore environments. The study of river environments has proven to be a useful intermediate step, as it has allowed us to test the robustness of the computational model before concentrating on the accuracy of the sediment transport formulation after waves are included. River environments provide striking examples of large amplitude bed features, including alternating bar configurations with strong shock-like structures. We have begun an evaluation of the long-term behavior of various unstable bedform patterns, whose linear stability analyses have been described in the literature (Falqués et al, 1996; Schielen et al, 1993). Work on extending the model to incorporate a Bagnold-Bailard-Bowen type model for wave-induced transport is underway.

RESULTS

Results to date have concentrated on calculations based on sediment transport modeling for slowly varying unidirectional flows, as pursued in Falqués et al. (1996) for coastal environments, or by Parker (1976), Colombini et al (1987), Schielen et al (1993) and others for river environments. In particular, we have concentrated recently on the evolution of alternate bars in river environments. The growth of these bars as a bed instability has been understood as a linear instability process since Parker (1976), and Colombini et al (1987) showed in a next-higher-order correction that the bar crests could become oblique to the channel sides. However, it has long been understood from observations that alternate bars can grow into very large amplitude structures with very abrupt, down-channel facing depth increases, taking on a shock-like appearance. Examples in Chang et al (1971) serve as a guideline for testing. An example from our own numerical work is illustrated in Figures 1 and 2. Figure 1 illustrates the evolution of a single along-channel wavelength of a nearly-fastest growing linear perturbation in a channel 200 m wide and 5 m deep. In these figures, along-channel is oriented up the page. The initially sinusoidal bars shown at $t = 0$ take on an oblique character and evolve into shock-like structures fairly rapidly, by $t = 9hr$ as illustrated on the rightmost panel. Figure 2 illustrates the continuation of this process at much later time, where the shock structure has equilabrated and is propagating along the channel. Depths in the scour holes immediately downstream of the bar crests can be twice the initial unperturbed channel depth.

Features such as these show up in a wide range of test calculations with a variety of sediment transport formulations and channel geometries, and thus are likely to self-organizing features to some degree. However, the quantitative accuracy of the morphology predictions here is almost certainly dependent on the chosen sediment transport relation as well as the limitation to depth-integrated 2-D hydrodynamics.

The model has subsequently been applied to coastal beaches in two scenarios. In the first, we have used a formulation similar to that employed by Falqués et al (1996), in which

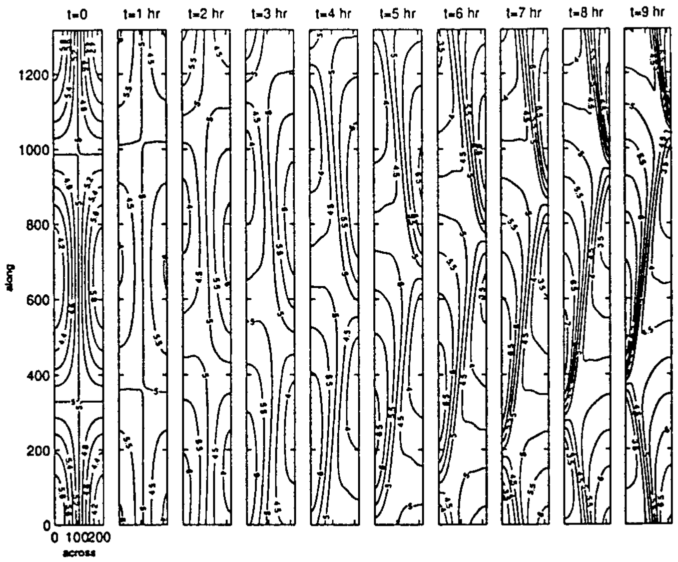

Figure 1: Initial growth of a sinusoidal alternating bar in a sloped channel. The initial bar configuration is based on linear perturbation analysis and has an along-channel length slightly longer than the fastest growing mode. Initial channel depth is 5 meters, and labelled contours are depths in meters.

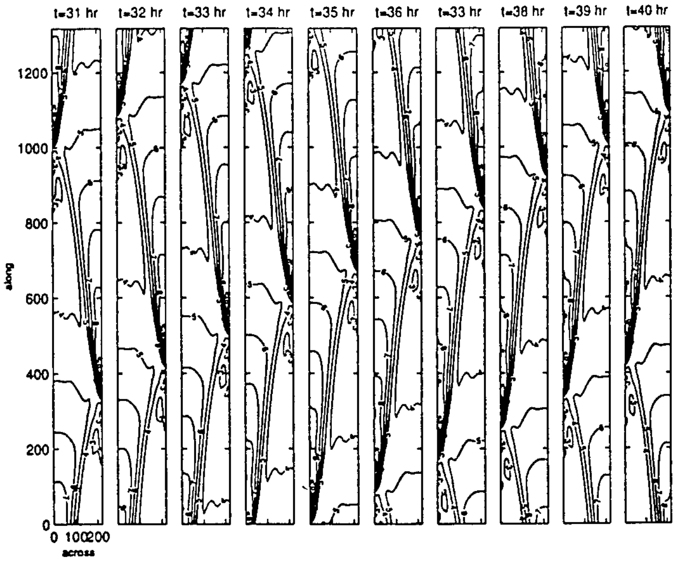

Figure 2: Later stages of alternating bar evolution, showing equilibration and along-slope migration of bars. Note deep scour holes immediately downstream (or up-page) from bar crests, as well as the steadiness of the zig-zagging shock-like structures in the bed.

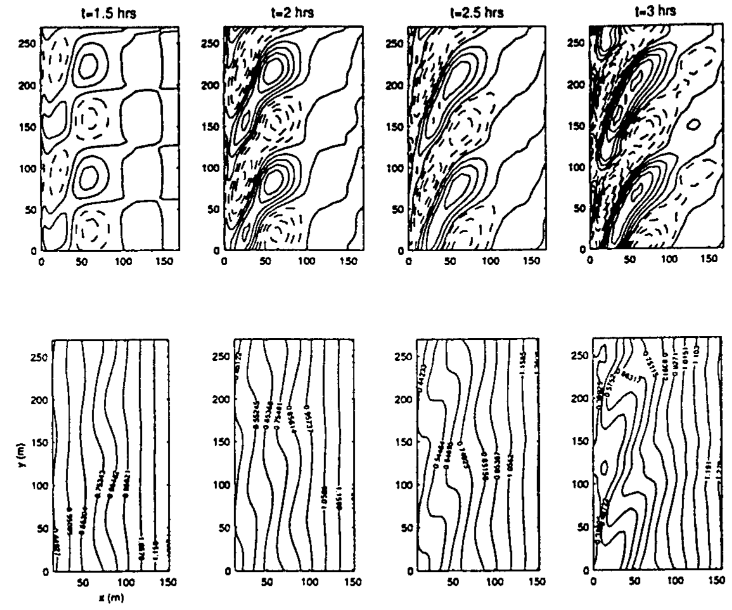

Figure 3: Initial growth of a perturbed bedform corresponding to a bed-surf instability described by Falqués et al (1996). Top panels shows contours of bed deformation relative to a planar beach. Lower panels show the total depth profiles.

sediment transport is driven primarily by the mean flow and wave-induced effects (such as cross-shore transport in the presence of a longshore current) are absent. Figures 3 and 4 show the early and later stages of growth of an initial perturbation similar in form to the predictions of the linear stability theory of Falqués et al. Initially, the growth of relatively well organized oblique bedforms is observed. This organized evolution does not persist in the present simulations, however, where the bed evolves further to a somewhat cuspate from with a hint of the formation of rip channels. Further interpretation of these results requires the application of a much more accurate wave model which accounts for wave-current interaction effects.

Work has also been started on performing similar simulations using the Bagnold-Bailard-Bowen transport formulation or more modern variants incorporating acceleration effects. At the end of this project, we are able to predict the formation of a storm bar under strong erosional conditions. This work is being continued in the context of the NOPP Nearshore Community Model project.

IMPACT/APPLICATION

This work is intended to provide a process-based model for predicting nearshore large scale bedform evolution over day to week time scales, as a first step to bridging the gap

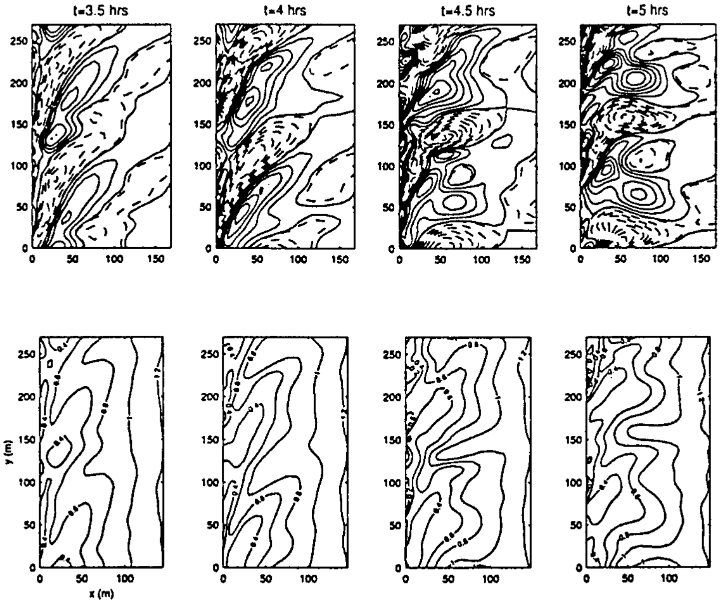

Figure 4: Later stages of nearshore bedform evolution, showing formation of a complex but somewhat cuspate bedform.

between short-time physical predictions and longer time (annual and longer) predictions based on parameterized physics. This gap is still immense, and will only be closed with (1) the advent of both faster computers and with (2) the ability to assess the accuracy of local sediment transport formulations applied over reasonably long time scales. We are mainly concerned with the second aspect of this problem.

TRANSITIONS

The work on morphology evolution conducted here will carry over directly into the seabed module work in the NOPP nearshore project. Tuba Özkan-Haller is working very closely with us, with model extensions and developments being shared by all investigators.

RELATED PROJECTS

(1) N00014-99-1-0490 "Prediction of the Low Frequency Wave Field on Open Coastal Beaches", H. Tuba Özkan-Haller, Univ. Mich. Tuba is directly involved in this work, and will be in principal charge of transitioning results on the morphology model here to NOPP models. We are also using her work on extensions to the wave driver portion of the hydrodynamic code.

(2) N00014-99-1-1051 (NOPP) "Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore Ocean", James T. Kirby et al, Univ. of Del. The work on morphology evolution done here will provide a foundation for work in this area in the NOPP project.

REFERENCES

Chang, H.-Y., Simons, D. B. and Woolhiser, D. A., 1971, "Flume experiments on alternate bar formation", *J. Waterway, Port, Coastal and Ocean Engrng.*, **97**, 155-165.

Colombini, M., Seminara, G. and Tubino, M., 1987, "Finite-amplitude alternate bars", *J. Fluid Mech.*, **181**, 213-232.

Falqués, A., Montoto, A. and Iranzo, V., 1996, "Bed-flow instability of the longshore current", *Continental Shelf Research*, **16**, 1927-1964.

Lippman, T. C. and Holman, R. A., 1990, "The spatial and temporal variability of sand bar morphology", *J. Geophys. Res.*, **95**, 11,575-11,590.

Özkan-Haller, H. T. and Kirby, J. T., 1997, "A Fourier-Chebyshev collocation method for the shallow wate equations including shoreline runup", *Applied Ocean Research*, **19**, 21-34.

Özkan-Haller, H. T. and Kirby, J. T., 1999, "Nonlinear evolution of shear instabilities of the longshore current: A comparison of observations and computations", *Journal of Geophysical Research*, **104**, 25,953-25,984.

Parker, G., 1976, “On the cause and characteristic scales of meandering and braiding in rivers”, *J. Fluid Mech.*, **76**, 457-480.

Schielen, R., Doelman, A. and de Swart, H. E., 1993, ”On the nonlinear dynamics of free bars in straight channels”, *J. Fluid Mech.*, **252**, 325-356.

Wei, G., Kirby, J. T., Grilli, S. T. and Subramanya, R., 1995, ”A fully nonlinear Boussinesq model for surface waves. I. Highly nonlinear, unsteady waves”, *J. Fluid Mech.*, **294**, 71-92.

PUBLICATIONS

Güngördü, O. and Kirby, J. T., 2000, “Evolution of large amplitude bedforms in a flowing stream”, presented at *AGU Fall Meeting*, San Francisco, December, 15-19. Abstract published in *EOS Trans. AGU*, **81**, 48, F679, 2000.