Surf and Swash Zone Hydrodynamics

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http://www.maths.bris.ac.uk/~madhp Peregrine's home page.
http://www.coastal.edu/~ias Svendsen's homepage (8 reprints available)
http://www.wldelft.nl/sasme/sasme.htm The home page of the SASME project.

LONG-TERM GOALS

Improve understanding of the hydrodynamics of the near-shore motions on beaches, with particular reference to the zone where the incident waves break, form surf, and run-up on the beach to give a fluctuating shoreline. This includes the waves and currents that the breaking waves, surf and run-up generate together with necessary details of the motions beneath the waves. Particular attention is directed to improving theoretical models of these motions.

OBJECTIVES

The main topics for study are:
(a) the turbulence generated by breaking waves and bores. A rational, non-empirical, approach to modelling unsteady spilling breakers and bores is a major target.
(b) the modelling of surf in the presence of co-existing long waves.
(c) improved, and perhaps simplified, modelling of the swash zone.
(d) understanding the currents, eddies and long waves generated by the incident waves, especially for irregular non-uniform waves over non-uniform bed topography.

APPROACH

This grant is to enhance cooperation between the P.I.s and their respective groups in working towards the above goals. The P.I.s meet each other each year and their more junior associates can make extended visits to each other's institution. In both groups the emphasis is on developing mathematical models through to practical numerical programs, including significant interaction with field and experimental results.

WORK COMPLETED / RESULTS

After the unsatisfactory experience with the numerical shallow-water code AMRITA, Dr. Bokhove has developed and tested several numerical shallow-water codes for time-domain modeling of breaking waves in the surf zone. Since breaking waves are modeled as bores or discontinuities in the surf zone and since these bores are mathematically similar to shocks in gas dynamics, the newly developed codes are based on modern, higher-order shock-capturing algorithms in gas dynamics. While initial tests are promising, the zero-depth moving shoreline boundary condition is still

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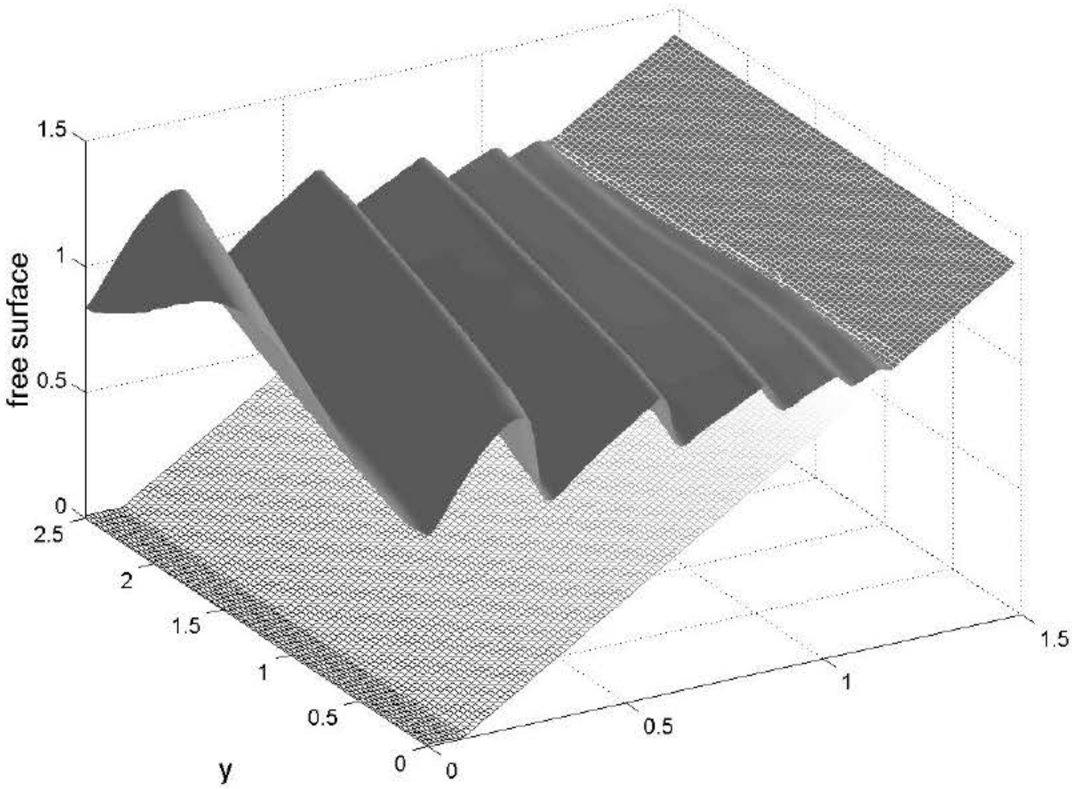
awaiting improvements. The generation of a long-shore currents by obliquely incident waves through potential-vorticity anomaly generation was succesfully supported by numerical simulations (Figure 1), but as a consequence of a simple implementation of the numerical shoreline boundary condition, the second peak in the current established by Stokes drift in the swash zone (e.g. Brocchini and Peregrine 1996) although clearly visible is insufficiently resolved.



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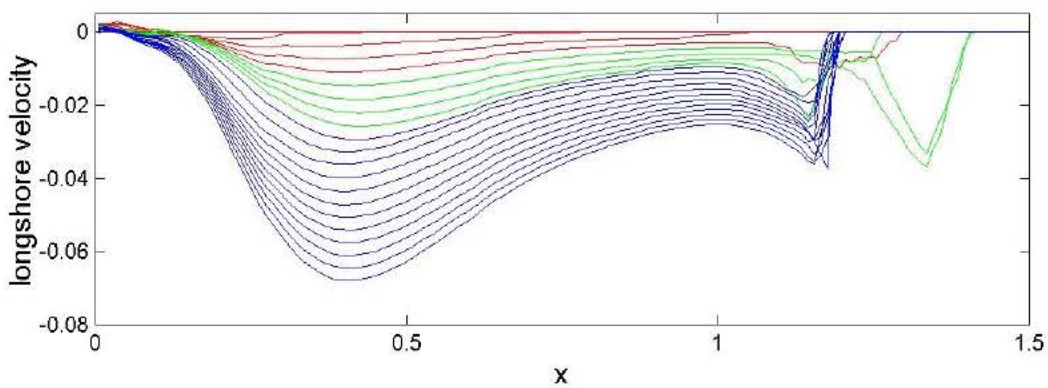

b)

Figure 1: a) A snapshot of obliquely incident shallow-water waves breaking or steepening is shown on a uniform beach. b) Accompanying longshore-averaged longshore current profiles during equidistant time intervals reveal the growth of the current through potential-vorticity anomaly generation. The initial flow is at rest and forcing is imposed at the offshore boundary (Bokhove and Peregrine 1999).

Following Ms Bird's visit to Delaware in July and August 1998, her Ph.D. studies have been vigorously pursued to a recent successful completion (Bird, 1999). The wider view of coastal wave topics that she gained from the visit was very helpful to this study that used accurate computations for a wide range of ‘irregular waves' and their evolution on a beach as they approached breaking. Two of the results are chosen for special mention.

1) When wave crests are in a solitary-wave type of regime a larger crest can overtake a smaller one. The resulting interaction leads to the combined crest at the middle of the interaction breaking much closer to the shoreline than would occur for the larger crest alone.
2) A wave group in intermediate to shallow water depth spreads out. Thus a sequence of wave groups can be expected to tend to merge. This is in fact found when three wave groups formed by modulating a wave train were calculated. However, when these waves were changed by a simple initial change of phase by π for the middle group, the evolution of the waves changed substantially. The three groups clearly retained their identity throughout the computation with no tendency to merge. We note that in studying both experimental measurements and field observations the wave phase is frequently neglected.

A research student, J.A.Santos, has made a theoretical study of the effect on edge waves of 'strong' changes in otherwise uniform coasts (Santos & Peregrine, 1998, 1999). This greatly extends our understanding of the propagation of low frequency waves along coasts. A feature of practical interest for experiment and for interpretation of field measurements was that local conditions can be affected significantly by a reflecting coast far offshore.

J. Veeramony, CACR, who visited Bristol under this project in May-June 1998, finished his PhD in March 1999 (Veeramony and Svendsen, 1999). In this work a Boussinesq model for breaking waves was developed. This model accounts for the effect of breaking in a hydrodynamically consistent way by determining the vorticity generated by the breaking. One of the main consequences is an ability to model not just the height and surface profiles of the breaking waves but also the particle velocities, the undertow and the radiation stresses in a physically meaningful way.

Work on the SHORECIRC (SC) nearshore circulation model has continued with the inclusion of the results for generalized dispersive mixing by Putrevu and Svendsen (1999), which essentially makes the SC model a fully 3D model. The model has been compared to laboratory measurement of rip currents and used extensively to study the mechanisms in such currents (Haas et al, 1999, Svendsen and Haas, 1999), the circulation around offshore breakwaters (Sancho et al 1999a), the effects of longshore variations in bottom topography (Sancho et al 1999b), and the generation of infragravity waves (Van Dongeren and Svendsen 1999).

Personnel exchanges 1998-99

Name	Position	Visit dates	Home institution	Place of visit
M.Brocchini	Professor	Jan.- Feb. 1999	U. of Genoa	CACR
O.Bokhove	Res. Associate	July 1999	Bristol Univ.	CACR

WORK IN PROGRESS

Dr. Bokhove continues to develop the numerical shallow water code and with emphasis on the generation of unsteady currents such as eddies and rip currents.

In work with Maurizio Brocchini on averaging over strong turbulence at a free surface, two papers are near completion and a study is being made with a simple splashing model to give insight into closure approximations. He has also made progress in introducing frictional terms into the Brocchini & Peregrine (1996) model for averaging over the swash zone.

A research student, Michael Patterson, funded by the U.K. Natural Environment Research Council (NERC) is studying of waves over porous beaches with emphasis on coarse sediment where the porous flow is at high Reynolds number. Attention is now being focussed on the moving shoreline where we have identified two different regimes of motion. This is a combined experimental and theoretical study.

A reference version of the SC-model is nearly completed with an associated extensive user manual. The plan is to make this model available to the scientific community. Development and analysis of the model performance also continues under the project "Modelling of Nearshore Wave, Current and IG-Wave Motion" and the NOPP project "Development and verification of a comprehensive community model for physical processes in the nearshore ocean"

IMPACT/APPLICATIONs

In all areas mentioned under OBJECTIVES major improvements in modelling are sought.

(a) At a wave-resolving scale the improvements in modelling two horizontal dimensions now give a capability to investigate many features due to thre-dimensional wave fields or bed topography.

(b) Wave averaged models at present neglect the swash zone. However, it has special significance as the land-sea boundary and as an area where sediment erosion or deposition are important. The development of averaged models for the region gives a valuable tool.

(c) present the best models for the surf zone include 'rollers' to model the breakers. The parameters describing these rollers are obtained from best fits to data. We aim to gain sufficient understanding of the hydrodynamic feedback between the foot and crest of a breaker such that a more deterministic model that includes breaker initiation, merging and decay can be created.

(d) Quantification of the changes of circulation and generation of vorticity by bores gives a new and simpler way of assessing currents from observation of the wave field, in addition they promise new insights into horizontal mixing and transport properties of the surf zone currents.

RELATED PROJECTS

Several of the twelve other groups in the SASME project cooperate with Bristol. This includes contacts with experimental groups e.g. at the Universities of Cantabria, Edinburgh, Florence, and Plymouth. Similar interactions occur with those running complex computer programs (e.g. Danish Hydraulic Institute [DHI], and Delft Hydraulics).

Interactions occur between Delaware and the groups conducting hydrodynamic field experiments at Duck, North Carolina (Scripps, Naval Postgraduate School, Oregon State University and others). Close interaction continues between Delaware and the researchers at NorthWest Research Associates (Putrevu, Oltman-Shay) and with DHI in Denmark.

At Bristol, in addition to the SASME project Peregrine also has:

1) just completed project funded by the U.K.'s Defence Evaluation and Research Agency (DERA), including Reading University, to study the effects of surface currents on the patterns and breaking of surface waves with reference to remote sensing (Donato, Peregrine & Stocker, 1998). A major aim of obtaining three-dimensional unsteady nonlinear wave evolution of waves on a three-dimensional current filed was acheived. In particular, the most recent work has given especially interesting results that are likely to completely refocuss activity on the

interpretion of the surface wave fields that are modified by flow over submerged banks or moving bodies. It also helps this grant's area of study by giving a different view of the modelling of breakers and interpretation of their patterns.

2) Another MAST 3 project: Probabilistic Design of Vertical Breakwaters (PROVERBS) finished at the end of February 1999. Aspects of this project relating to porous berms and porous foundations of monolithic structures provided valuable insights for studying porous beaches. Papers arising from this project, which include Bristol authors are in course of publication: Wood & Peregrine (1999), Wood, Bruce & Peregrine (1999), Walkden et al (1999). Other impactr elated work is in porogress.
3) Peregrine has become associated with another MAST 3 project, OPTICREST, and has already found that data collected on a dike at Petten in The Netherlands and related experiments give interesting insights into the behaviour of a wide swash zone with a strongly non-uniform slope.

Related projects at Delaware are
The generation of Rip currents and circulation around coastal structures
PI: I. A. Svendsen, Sponsor: NOAA/Sea Grant
Modelling of Nearshore Wave, Current and IG-Wave Motion
PI's: I. A. Svendsen, J. Kaihatu, Sponsor: ONR
Hydrodynamics of the nearshore zone
PI's: Dalrymple, Kirby, Svendsen, Sponsor: ONR
Development and verification of a comprehensive community model for physical processes in the nearshore ocean.
PI: Kirby, Svendsen, (at UD, and others outside UD), Sponsor: NOPP

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