NEARSHORE WAVE PROCESSES

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LONG-TERM GOALS

Long-term goals are to predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the nearshore given the offshore wave conditions.

SCIENTIFIC OBJECTIVES

Predict the vertical distributions of velocity and stress, and associated sediment transport and morphologic changes due to waves and currents in the nearshore, including breaking waves.

APPROACH

The vertical distributions throughout the water column of 3-component mean, wave-induced and turbulent velocities, bubbles,and sediment concentrations were measured during the SandyDuck nearshore experiment using an instrumented sled. The 3-component velocity field was measured every 5 cm over the lower 1 m with a unique downward looking 1.2 MHz bistatic coherent acoustic Doppler velocimeter (1.6 cm resolution at 48 Hz) and every 8 cm in the upper water column with a unique upward looking 300 KHz bistatic coherent acoustic Doppler velocimeter (8 cm resolution at 48 Hz). In addition, the vertical distribution of the horizontal velocities was measured with an array of 8 electromagnetic current meters. The advection of sediments and their coherence length scales were measured with a 2 m cross-shore array of 7 optical backscatter instruments. The small-scale morphology, which acts as hydraulic roughness for the mean flows and perturbs the velocity-sediment field, was measured from the sled with a newly developed x-y scanning altimeter, and with an array of 7 sonic altimeters mounted on the back of the CRAB. The primary mechanism for changes in moment flux, which drives the nearshore dynamics, is due to the dissipation of wave energy by breaking, the processes of which are only poorly understood. To improve our understanding of breaking waves, the dissipation associated with bubble injection and depth of bubble penetration were measured with the two acoustic systems (1.2 MHz looking down and 300 KHz looking up) and with a 3 m vertical array of 8 conductivity cells to measuring void fraction (amount of air in the water). An important component of the cross-shore sediment flux is due to the cross-shore mean flow (undertow), which is forced by wave set-up/down; the set-up was measured with an array of 14 manometers and 8 pressure sensors. Undertow is an

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integral measure of the turbulent Reynolds stresses and wave radiation stresses over the vertical and acts as a check for the detailed velocity measurements. The data are being compared with models developed under this program and in collaboration with other groups (see below).

WORK COMPLETED

We participated in the SandyDuck nearshore experiment conducted at the U.S. Army Field Research Facility, Duck, North Carolina. Measurements were obtained throughout the 6-week intensive measurement period from 22 September to 31 October 1997. The bathymetry during this period consisted of a well-defined outer bar and a poorly defined inner bar, bar terrace or at times no bar. The bathymetry was quite different from that of previous years and was not anticipated in the experimental design. The waves were unusually mild during this period, with only one major storm. The mobile sled allowed the measurements to be adapted to the profile, and advantage was taken of the milder wave conditions to study wave boundary layers in deeper water simulating waves on the inner shelf.

RESULTS

The longshore current maximum observed in the trough of the barred beach during DELILAH is not well predicted by present theory. The simplest longshore current models balance cross-shore changes in the alongshore wave momentum (radiation stress) with the alongshore bottom shear stress. Waves break over the bar, reform in the trough and again break on the foreshore. Wave breaking results in changes in the radiation stress predicting two maxima, one over the bar and one at the foreshore. This does not agree with the observed current maximum in the trough. A number of mechanisms have been investigated, which are described in a series of papers to explain the observed longshore currents, including:

Reniers, Thornton and Lippmann (1997) show that even for the seemingly alongshore uniform bathymetry during DELIlAH, small variations create alongshore pressure gradients of first order importance. Using scaling arguments, they show that for small alongshore changes in bathymetry, a quasi-3D dynamics model is appropriate. The cross-shore set-up is first calculated at various alongshore locations from which the alongshore pressure gradient forcing is calculated, and shown to be a dominant forcing mechanism in the trough where changes in the cross-shore radiation stress are a minimum.

Faria, Thornton, Soares and Stanton (1997) show the vertical profile of longshore current is well described by a logarithmic profile for strong longshore currents during Duck94 (0.98 mean linear correlation coefficient for all profiles). Equating the bottom shear stress determined from the log profile with a quadratic bed shear stress formulation, bed shear stress coefficients, Cf, were calculated. Measured Cf values varied by an order of magnitude across the surf zone, and were found to be proportional to the measured rms bed roughness as measured by a sonic altimeter mounted on the CRAB.

Faria, Thornton, Stanton, Lippmann, Guza, and Elgar (1997) compared the cross-shore distributions of mean longshore currents observed during the DUCK94 experiment to predictions of a quasi three-dimensional nearshore circulation model. The model includes forcing due to breaking waves described using the roller concept (Lippmann and Thornton, 1997), alongshore wind stress, cross-shore advection of mean momentum of the alongshore current, and a full non-linear bottom shear stress with a variable bed shear stress coefficient, Cf, constrained by observations. Contributions from the alongshore wind stress are mostly evident offshore and over the inner trough of the sand bar due to the relative increase in the wind force to wave force ratio as wave forcing decreases over these regions. The advection of the momentum of the longshore current by mean cross-shore currents is shown to improve the agreement with observations within the surf zone, O[10] percent. The use of a non-linear bed shear stress formulation with a variable Cf is shown to improve model/data comparison O[20] percent, compared to the use of a constant Cf. The largest overall improvement with observations is obtained by incorporating the roller stress contribution, O[50]percent.

IMPACT/APPLICATION

The largest improvements for modeling of mean longshore currents, starting with the simple Thornton and Guza (1986) formulation of balancing the radiation stress gradient with the bottom shear stress, and comparing with data acquired during DUCK94, was found to be: 1) O[50} percent improvement by incorporating a roller stress contribution (Lippmann and Thornton, 1997); 2) O[20} percent improvement by including a variable non linear bottom shear stress formulation; and 3) O[10] percent improvement by including the momentum mixing by the advection of the longshore current momentum by the mean cross-shore currents.

RELATED PROJECTS

A number of collaborations were established during the SandyDuck field program. The vertical and cross-shore structure of mean currents in the nearshore are being analyzed in collaboration with Bob Guza and Steve Elgar. The research is integrated with ongoing funding by the Waves BAA initiatives "Wave surface and bottom boundary layers in the nearshore", with Thornton, Stanton and Lippmann and "Nearshore circulation on variable bathymetry " with Svendsen, Thornton, Dalrymple, Putrevu and Oltman-Shay,. Enrico Foti of Catania University, Italy, is visiting for 6 months funded by NICOP in collaboration with Paolo Blondeaux. He is comparing boundary layer models with data acquired during SandyDuck. Ad Reniers, of Delft University and Delft Hydraulics, was also funded by NICOP in collaboration Huib DeVriend to participate in the SandyDuck experiment and collaborate in data analysis and model comparisons.