# Near Shore Wave Processes

Edward B. Thornton
Oceanography Department
Naval Postgraduate School
Monterey, CA 93943-5000
phone: (831) 656-284 fax: (831) 656-2712 email: thornton@oc.nps.navy.mil

Timothy P. Stanton
phone: (831) 656-3144 email:stanton@oc.nps.navy.mil

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http://www.oc.nps.navy.mil/~thornton/
http://www.oc.nps.navy.mil/~stanton/
http://www.frf.usace.army.mil/SandyDuck/SandyDuck.stm

## 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 near shore given the offshore wave conditions.

## OBJECTIVES

The interrelationship of wave-induced hydrodynamic and sediment processes over the vertical and morphologic processes at the bed are measured and modeled. The primary mechanism for changes in moment flux that drive near shore hydrodynamics is due to the dissipation by breaking waves, the processes of which are poorly understood. To improve our understanding of breaking waves, the dissipation associated with bubble injection is measured along with the velocity fields over the vertical. Bottom boundary layer measurements are obtained to determine bottom stress and dissipation. Sediment transport is measured in response to the measured mean longshore and cross-shore currents, wave velocities and induced stresses. The small-scale morphology, which acts as hydraulic roughness for the mean flows and perturbs the velocity-sediment fields, is measured as a function of time and over large areas to examine cross-shore and alongshore variation.

## APPROACH

Vertical distributions are measured throughout the water column of 3-component mean, wave-induced and turbulent velocities, bubbles, and sediment concentrations. The 3-component velocity field is measured every 3.2 cm at 48 Hz over the approximate bottom 1 m with a downward looking 1.3 MHz bistatic coherent acoustic Doppler velocimeter, BCDV. The BCDV also infers the vertical profile of suspended sediment concentration every 1.7 cm over the bottom 1m from the acoustic backscatter intensity. In addition, the vertical profiles of the horizontal velocities are measured with an array of 8 electromagnetic current meters. A 2 m cross-shore array of six optical backscatter instruments measures

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the horizontal coherence length scale and advection. The small-scale morphology is measured locally with a x-y scanning altimeter. The small-scale morphology over the entire area is measured with an array of 7 sonic altimeters mounted on the back of the CRAB. Bubble injection and depth of bubble penetration are measured with a 3 m vertical array of 8 conductivity cells and acoustically with the BCDV in the bottom 1 m. Set-up is measured with a cross-shore array of 8 pressure sensors. During SandyDuck, the local sled measurements are placed in synoptic perspective using the continuously recording cross-shore array of pressure sensors to measure wave transformation and set-up, along with the current/wave sensor array of Elgar and Guza.

Process models for breaking waves, momentum mixing due to the interaction of longshore and cross-shore vertical mean profiles, and bottom shear stress enhanced by the form drag of bedforms and by turbulence of wave breaking are compared with observations. Both linear and nonlinear (Boussinesq) wave models are considered. In addition, the comprehensive Delft3D morphodynamic model developed by Delft Hydraulics is being assessed using NSTS and SandyDuck wave, velocity and bathymetry fields.

## WORK COMPLETED

The wave, velocity, void fraction, and small-scale morphology acquired during the intensive SandyDuck nearshore experiment 15 September- 31 October 1997 are being analyzed. The bottom profile during this period consisted of a well-defined outer bar and a short inner bar, bar terrace or at times no bar. The waves during the intensive 6 week experiment were unusually mild, with only one major storm

Analysis and data processing tasks have focused on three areas:

1.) Vertical profiles of mean longshore and cross-shore velocities

2.) Sediment suspension and net fluxes using the BCDV backscatter-based sediment concentration profiles and three component velocity profiles to estimate stress and strain associated with sediment suspension events.

3.) Void fraction profiles in a surface-following coordinate system using the conductivity cell and EM current arrays in the mid- and upper- water column and the BCDV backscatter and velocities in the lower 50cm. The overlapping, but complimentary, range of turbulence and void fraction covered by these sensors is being exploited to define the water column turbulence and the influence of breaking waves.

4.) Accessing Delft3D nearshore model for adoption as the Navy surf model.

## RESULTS

The spatial distribution of the mean cross-shore flow (undertow) over a barred beach is examined with field data obtained during the DUCK94 experiment (Garcez Faria et.al., 2000). The vertical structure of the undertow is modeled using a turbulent eddy viscosity closure and includes the important effects of wave breaking (described using the roller concept) and convective acceleration of the current. Other than a more realistic description of observed turbulence variations, a depth dependent eddy viscosity (compared with a constant) does not improve the agreement between predicted and observed undertow profiles. The effects of using different boundary conditions is investigated by extending the formulations of Stive and Wind (1986) and Svendsen *et al*. (1987) to include random waves by ensemble averaging over the wave height distribution. The contribution of breaking wave rollers to the surface mass flux can be of the same order, or greater than the contribution associated with the organized wave motion. The largest discrepancies between model predictions and observations occur over the sand bar, where the mass transport of the breaking waves appears to be underestimated.

Vertical profiles of velocity and sediment concentration were measured from a mobile sled at cross-shore locations spanning the surf zone during SandyDuck (Figure 1). A stack of eight, 2-component electromagnetic current sensors spanned 0.2 to 2.5m above the bed, while Bistatic Coherent Doppler Velocity Profiler (BCDV) measured three-component velocities at 1.6 cm resolution over the bottom 30cm. Estimates of the kinetic energy dissipation rates through the water column below breaking waves are made based on spectral levels of velocity fluctuations measured by the EM current sensors, assuming isotropy and the existence of an inertial subrange under the highly episodic surface wave forcing. These dissipation rate profiles allow the turbulent stresses and effective eddy viscosity profiles to be estimated. Comparisons are made with shear production estimates in the bottom boundary layer using the BCDV data. Bottom shear stress is estimated based on logarithmic fits of the mean currents in the bottom boundary layer. The effect of the surface wave-breaking on near-bed stresses is examined.

The Delft3D nearshore hydrodynamic model is assessed by comparing model output with data from comprehensive nearshore NSTS and Duck field experiments. The breaking wave description for Delft3D is based on the Battjes and Janssen (1978) breaking wave dissipation formulation. The flow component of Delft3D solves the depth averaged Navier-Stokes equations for non-steady flow resulting from tidal, meteorological forcing and time-variant mean wave conditions. Measured data include a range of wave heights and periods from both near-planar (Torrey Pines and Leadbetter beaches in California) and the barred Duck beach (Delilah and Duck94 experiments). Reducing the number of model free parameters is investigated with model performance quantified using a variant of the Brier Score Method to determine model skill. The Battjes and Stive (1985) parameter calibration of the Battjes and Jannsen (1978) model is recalculated and parameter space extended to include the low slope Pacific swell wave conditions and the breaking waves over barred bathymetry at Duck (Fig. 3). Rms wave heights are predicted with less than 8 percent error using the new calibration. Using the predicted wave heights as input to the current module, the longshore currents are predicted with less than 30 percent error (Fig 2 as an example).

## IMPACT/APPLICATIONS

On the basis of Delft3D hydrodynamic model comparisons with comprehensive nearshore field data acquired over two decades funded in all or part by ONR, it is recommended the U.S, Navy adopt Delft3D as their new standard surf model.

## TRANSITIONS

It is recommended on the basis of comparisons with comprehensive nearshore field data that the Delft3D hydrodynamics model be adopted by the U.S, Navy as their standard surf model.

## RELATED PROJECTS

1. Collaborative modeling of a turbulent wave boundary layer perturbed by an undulating bottom is being performed by Paulo Blondeaux, Giovanna Vittori and Piero Scudura from the University of Genoa through a NICOP program.

2. We participated in COAST3D with combined funding from NSF, ONR and NICOP.

3. Collaborative modeling and data comparisons of breaking waves using Boussinesq equations is being performed by PhD students at the U of Quebec under co-direction of Barbara Boczar-Karakiewicz and myself.

4. Results of process modeling obtained on this project are being applied to nearshore modeling efforts under the following programs: Surf Model (ONR), Modeling Wave Dissipation within the Wave Boundary Layer (ONR), and Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore (NOPP).

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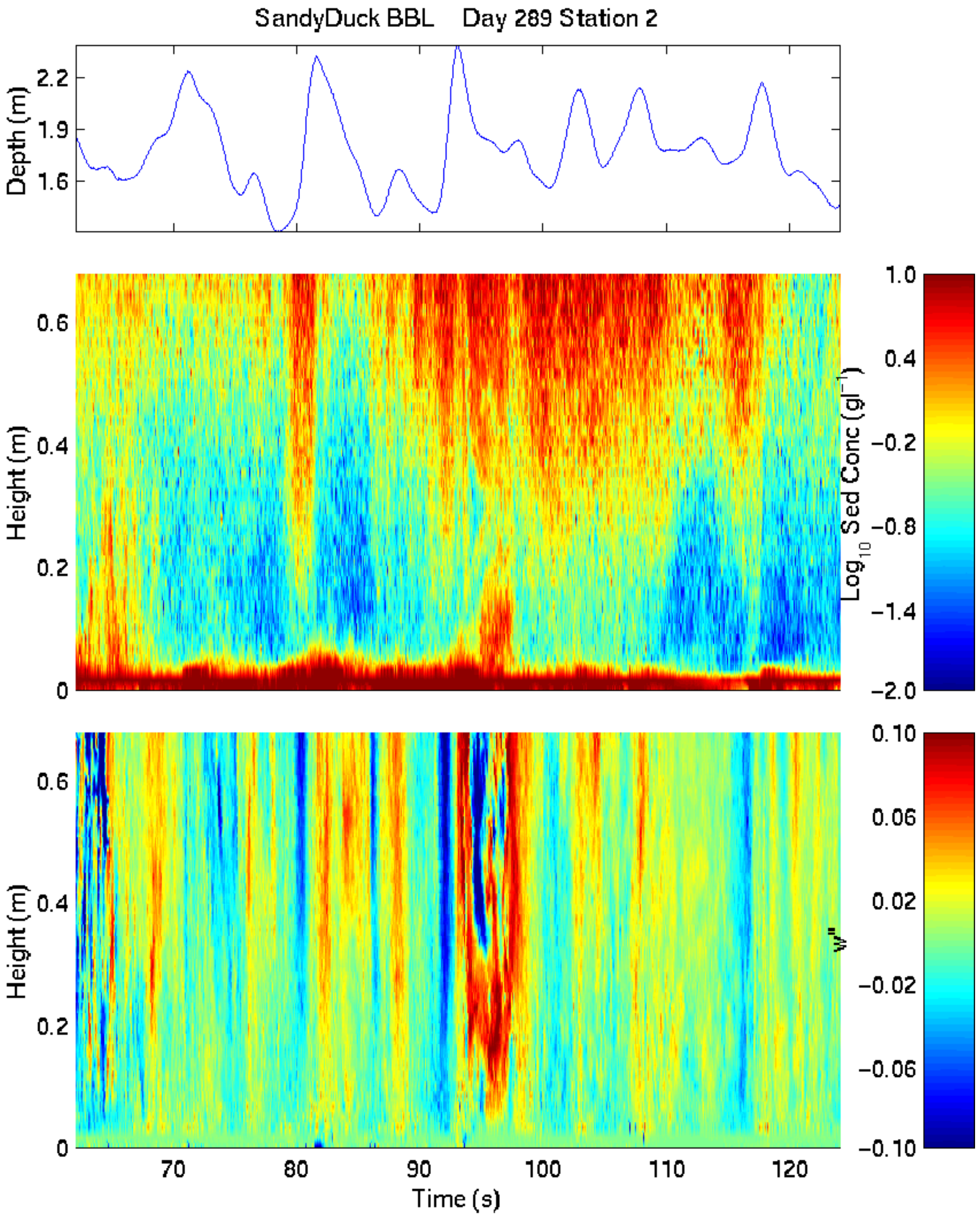

***Figure 1: Timeseries of near bed response to wave breaking in the trough during SandyDuck on yearday 289. The upper panel is surface elevation, the middle panel is backscatter intensity profile timeseries scaled to sediment concentration, and the lower panel is the turbulent vertical velocity profile timeseries. The backscatter timeseries shows the injection of bubbles from the a surface breaking event at t = 80seconds followed by a stronger event at t=90 seconds. The second event has a very vertical strong strain signature seen in the w'(z) profiles between t= 90 and t=100 seconds. The downward transport of stress associated with this strongly turbulent feature resulted in a large sediment suspension event starting at t=95 s.***

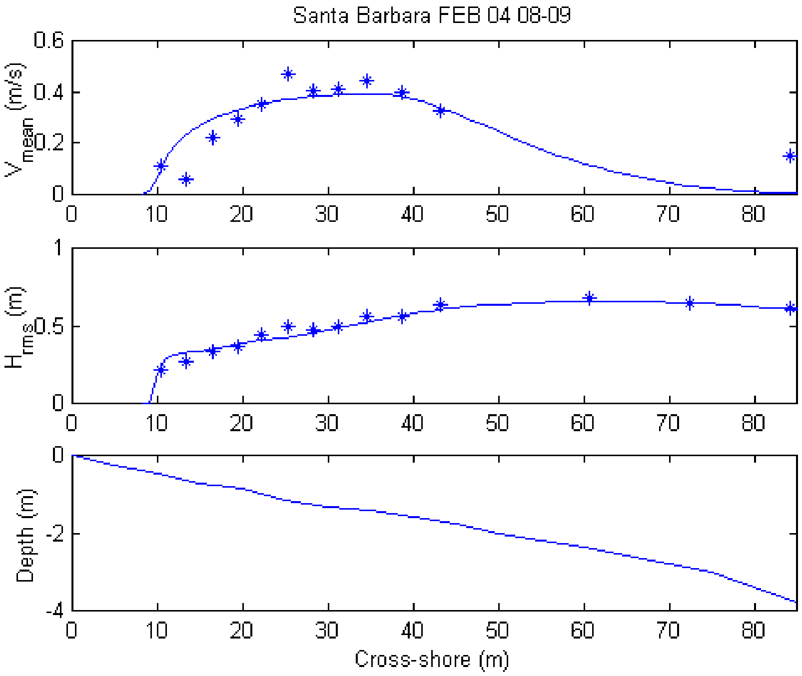

*Figure 2: Delft3D model compared with mean longshore current (upper panel), RMS wave height (center panel), with bathymetry in lower panel measured during NSTS experiment at Leadbetter Beach, Santa Barbara, California.*

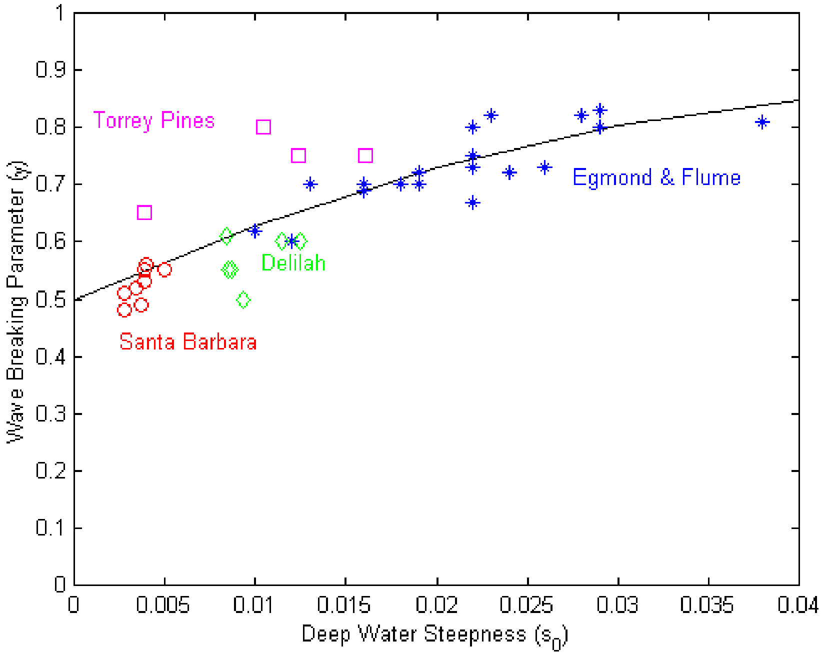

*Figure 3: Wave breaking parameter for Delft3D model as a function of deep water steepness extended to include NSTS data from Torrey Pines and Santa Barbara, California beaches and Delilah experiment at Duck, NC.*

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