Wind Input, Surface Dissipation And Directional Properties Of Shoaling Waves

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LONG-TERM GOAL

This project is a component of SHOWEX - a multi-investigator, multi-institutional field study of shoaling surface waves. The long-term goal of this program is to better understand the dynamics of wave evolution on the shelf, and to improve predictive modeling capability there. The component we report on here is closely related to another one of the same name by a group at the University of Miami (see the 1999 Annual Progress Report by H.C. Graber and M.A. Donelan). The main SHOWEX experiment is scheduled for the fall of 1999 at Duck, N.C.

OBJECTIVES

Spectral wave models typically describe the evolution of wave energy or action as a function of fetch and duration. The rate of change of energy in each spectral band is the residual of the sum of various "source" terms describing the rate of energy input from the wind, the transfer of energy across the wave number spectrum due to nonlinear interaction with other wave components, and the dissipation (due both to wave breaking and to the drag exerted by the bottom. The data obtained in SHOWEX will be used to establish the evolution of the energy in the wave field from the shelf break to the nearshore region.

APPROACH

Measurements of wave height and direction, as well as meteorological forcing, and the near-surface rate of turbulent energy dissipation will be obtained from an array of three ASIS (Air-Sea Interaction Spar) buoys, and a SWATH (Small Waterplane Area Twin Hull) ship (Graber and Donelan, 1999). Other investigators in the program are responsible for measuring wave dissipation via breaking and bottom friction, as well as providing additional measurements of wave evolution.

We are responsible for near-surface turbulence measurements from the ASIS buoys and the SWATH ship, and for ADCP current profiling in the vicinity of one of the buoys.

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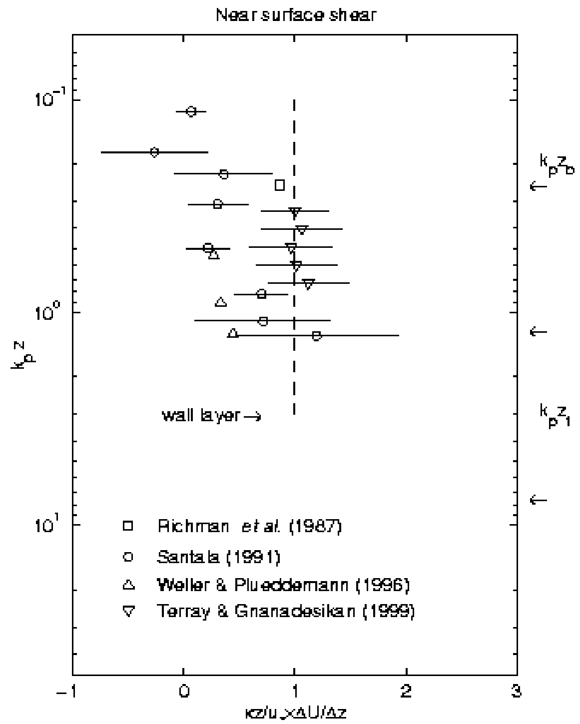
WORK COMPLETED

We spent 1999 preparing for the upcoming SHOWEX field work. In connection with this effort we [1] carried out a pilot deployment of three ASIS buoys last spring in the Gulf of Mexico (in collaboration with Graber *et al.*); [2] developed a pitot-static probe to be used from the SWATH ship F.G. Creed to measure turbulence close to the surface; and [3] reviewed existing measurements of near-surface shear under waves. We briefly discuss each of these below.

[1] The ASIS buoy is a pentagonal array of short spars designed to follow long waves, thus permitting instruments to be positioned close to the interface. In 1998 we constructed two new ASIS buoys as part of this program (additional discussion, as well as a photograph of an ASIS buoy deployed at sea, is contained in our contribution to the 1998 ONR Annual Report, and in the manuscript Graber *et al*., 1999). These new buoys, together with an existing ASIS, were deployed for close to two months this past spring in the Gulf of Mexico as part of a remote sensing experiment (for details see this year's annual report by Graber *et al.*), which served as a pilot deployment for SHOWEX. The buoys performed well and we had excellent data return. These measurements are currently being analyzed.

[2] During SWADE we made subsurface turbulence measurements from the F.G. Creed while underway at speeds of a few knots (Drennan *et al*., 1996). We were constrained to operate at such low speeds because of our use of surface penetrating wire gages to measure wave height. During SHOWEX, wave height will be measured non-invasively from above using an array of laser height gages, thus permitting operation at high speed. To measure near-surface turbulence from the Creed while underway at speeds of 10-20 Kts, we have developed a pitot-static tube that will be attached to the port sponson. The probe includes a temperature sensor, as well as accelerometers to measure vibration. We expect that this sensor will permit estimation of turbulence velocity over 1-2 decades of inertial range wave numbers.

[3] We will also make measurements of near-surface shear and turbulence profiles during SHOWEX using a vertical array of SonTek acoustic Doppler velocimeters (ADVs) deployed on an ASIS buoy. As an aid in specifying the locations of these instruments, we reviewed existing observations of current shear under waves. The results, which turned out to be interesting, are shown in Figure 1, where we have plotted the downwind shear normalized by the corresponding wall-layer result as a function of non-dimensional depth (based on the wave number of the dominant waves, k_p). Although the data show considerable scatter, shears closer the surface tend to be smaller than those below. The data shown in the figure were selected from times where stratification was considered to be negligible. Note that shears exceeding a wall-layer were not observed. The profile data of Santala (1991), taken on the Northern California Shelf during the "Shelf Mixed-Layer Experiment", SMILE, extend closest to the surface. We have plotted a subset of those observations (taken over several months) which had roughly the same wind and wave conditions, over depths where stratification was negligible. The solid line is the result of a low order turbulence closure model of the kind recently proposed by Craig and Banner (1994) that includes a downward flux of kinetic energy at the surface (Terray *et al*., 1999). By contrast, models in which mixing is driven by a surface stress and wave-current interaction produce velocity profiles that are sheared close to the surface, and well-mixed below.



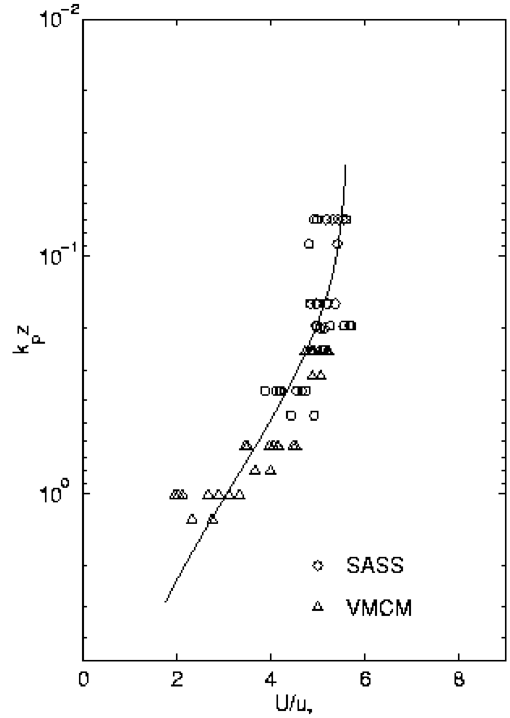


Fig. 1 Compilation of downwind/downwave shear measured in several experiments. The shear has been scaled by the corresponding wall-layer result, and the depth by the wave number of the dominant waves (see Terray et al., 1999a). Stratification in the water is believed to be negligible for the data shown here..

Fig. 2 Downwind current measured by Santala (1991) using acoustic travel-time (SASS) and propeller-type (VMCM) current meters. The current has been scaled by the friction velocity at the surface, estimated from the wind stress. The solid line is the output from a low order turbulence closure model (Terray et al., 1999a).

RESULTS

The work described above has produced the following results:

[1] We have established, by means of a pilot experiment using the same configuration, that the ASIS buoys should perform well during SHOWEX. The response of the ASIS was previously characterized in Graber *et al*., (1999).

[2] We have developed a pitot-static tube for measuring turbulence during SHOWEX from a SWATH ship moving at high speed.

[3] A review of previous observations suggests that the current shear close to the surface beneath waves is reduced relative to a wall-layer. We have shown that this behavior is quantitatively consistent with a model based on a low order turbulence closure (Terray *et al*., (1999a).

[4] We have continued our earlier work on the use of conventional ADCPs to measure wave height and direction in coastal-depth waters. Recent results were presented at the *6th IEEE Working Conference on Current Measurement,* (Terray *et al*., 1999b).

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