Wind Input, Surface Dissipation and Directional Properties of Shoaling Waves

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LONG-TERM GOAL

This project is a component of the Shoaling Waves Experiment (SHOWEX) - a multi-investigator, multi-institutional field study of shoaling surface waves that took place during the fall of 1999 off Duck, North Carolina. The overall goal of the program is to better understand the dynamics of wave evolution on the shelf, with the objective of improving wave prediction capability from the shelf break to the nearshore region. The work reported here is closely related to that of a group from the University of Miami (see Graber and Donelan, 2000).

OBJECTIVES

The scientific framework for SHOWEX is the equation describing the spectral evolution of wave energy as a function of fetch and duration. This expresses the rate of change of energy in each spectral band along a propagation ray as the residual of the sum of several "source" terms. The latter describe the rate of energy input from the wind, its transfer through the spectrum due to nonlinear interaction with other wave components, and subsequent dissipation (due to both breaking and the drag exerted by the bottom). The chief objective of SHOWEX is to develop better parameterizations of both propagation and source terms in the coastal ocean. The work reported here specifically addresses the dissipation of energy due to wave breaking, and its dependence on the wave spectrum, atmospheric forcing, and bathymetry.

APPROACH

We were responsible for measurements of the rate of kinetic energy dissipation in the near-surface waters carried out from an ASIS (Air-Sea Interaction Spar) buoy, and the SWATH vessel Frederick G. Creed. Simultaneous measurements of both the waves and meteorology were also obtained from both platforms (Graber and Donelan, 2000; Dobson, 2000). In particular, direct measurements of the wind input to the waves were carried out from the F.G. Creed. Other investigators in the program were responsible for measuring the kinematics of wave propagation, and the wave dissipation due to bottom friction.

WORK COMPLETED

During 1999-2000 we participated in the SHOWEX field effort, and have completed a first pass evaluation of the data. Field work consisted of: [1] deploying a vertical array of Acoustic Doppler Velocimeters (ADVs) on one of the ASIS (Air-Sea Interaction Spar) buoys to measure near-surface turbulence (generated by wave breaking); [2] operating a Pitot turbulence sensor on the SWATH ship Frederick G. Creed to measure near-surface turbulence in conjunction with measurements from the SWATH of the wind input to the waves (Graber and Donelan, 2000); [3] deploying a bottom-mounted ADCP close to the ASIS buoy to monitor current shear at greater depths. We discuss these in more detail below.

[1] The ASIS buoy is a rigid pentagonal array of short spars designed to follow long waves, thus permitting instruments to be positioned close to the interface (Graber *et al.*, 2000). We deployed 5 SonTek ADVs within the upper 4m of the water column on the "Bravo" ASIS buoy. These were sampled at 20Hz for 20 minutes at the start of each hour. Data were recorded for 24 days, with a data return during this period of close to 100%. Unfortunately, due to a combination of weather and ship availability, the scheduled battery refurbishment did not take place, and no data were obtained after 22 November, 1999. In addition to the near-surface shear (and possibly Reynolds stress), we also will analyze these observations to estimate the rate of turbulence kinetic energy dissipation from spectral levels in the inertial subrange (Lumley and Terray, 1981).

[2] For SHOWEX we developed a Pitot probe intended for use from the F.G. Creed while underway at speeds of 10-15 kts. A schematic of the probe and mounting details are given in Figure 1. Data were obtained continuously during each SWATH voyage, beginning with the 3rd cruise. Data recovery was close to 100%. The probe was intentionally designed to be short to avoid transverse vibrations in the desired measurement band of 10-100 Hz, and consequently the pressure transducers were located close to the sponson. However, our analysis of the probe's performance based on both at-sea measurements and calibration runs in Norfolk Harbor indicates that the flow blockage and distortion due to the hull can be modeled sufficiently well to correct the measurements for their effects (Thwaites *et al.,* 2000). The pressure signal was also contaminated by axial vibration of the probe (Figure 2). However, the contribution from this was highly coherent with the output of a co-located in-line accelerometer, and consequently could be filtered effectively (Thwaites *et al*., 2000; Soloviev, et al., 1999). Based on our work to date we estimate that the probe can resolve dissipation rates $O(10^{-8})$ W/kg and above.

[3] We deployed an ADCP on a bottom-lander close to the Bravo buoy discussed in [1] above, for the purpose of measuring the mean shear at depths below the ADV array on the buoy. The lander included a gimbal to level the ADCP, and was deployed contemporaneously with the buoy. Data was recorded through the end of the experiment in December with 100% recovery.

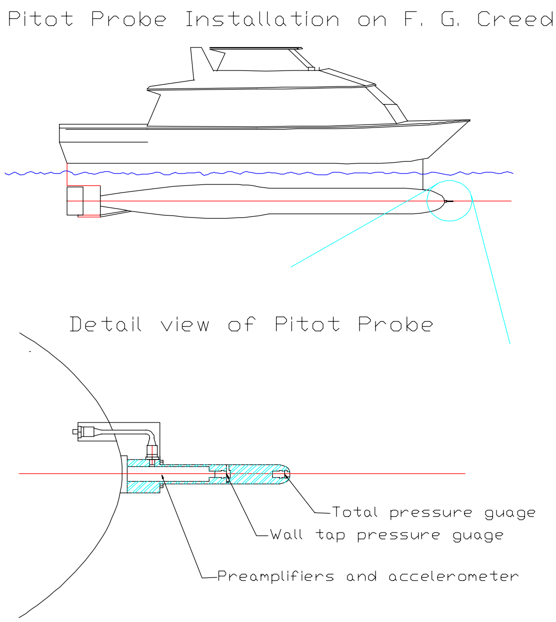

Figure 1: Side view of the F.G. Creed with a detail view of the pitot probe on the starboard sponson. The through-hull penetrator was vertically and laterally displaced (Thwaites et al., 2000).

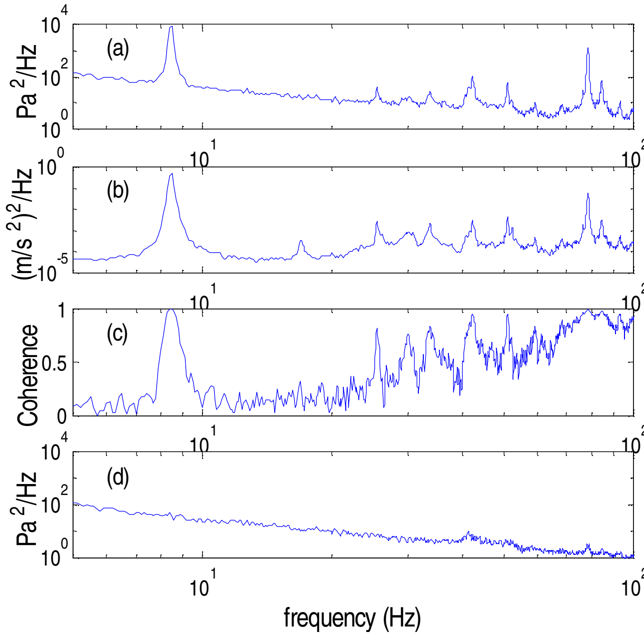

Figure 2: (a) Raw stagnation pressure spectrum, (b) axial acceleration spectrum, (c) coherence between pressure and acceleration, and (d) the pressure spectrum after removal of contributions coherent with the axial acceleration (Thwaites et al., 2000).

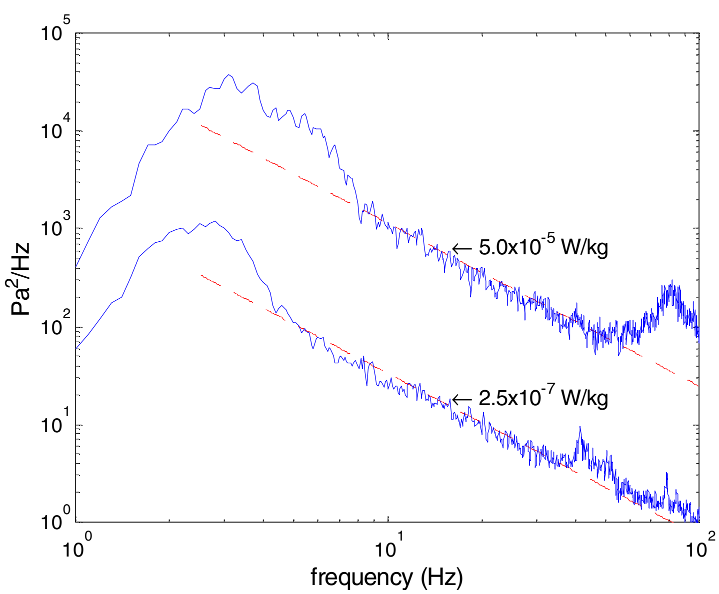

Figure 3: Stagnation pressure spectrum from Fig. 2(d). The dissipation rate in this case is estimated at 2.5×10^{-7} W/kg. For comparison we show a second pressure spectrum obtained under conditions of strong forcing (Thwaites et al., 2000) where the dissipation is estimated to be 5×10^{-5} W/kg.

RESULTS

The work described above has produced the following results to date:

[1] Demonstration that the Pitot turbulence sensor we developed for use from the F.G. Creed during SHOWEX provides interpretable measurements of near-surface turbulence (Thwaites *et al*., 2000).

[2] Acquisition of high quality observations of near-surface turbulence associated with wave breaking from (a) a vertical array of ADVs on a spar buoy, and (b) the Pitot probe deployed on the SWATH vessel F.G. Creed.

[3] Validation of the use of conventional ADCPs to measure wave height and direction in coastal-depth waters. Recent results were presented at Oceans 2000 (Strong *et al*., 2000).

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