Marine Physical Laboratory

Wave Breaking, Bubble Production and Acoustic Characteristics of the Surf Zone, SIO Component

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The objective of the research component reported here was to make long-term measurements of acoustic telemetry and channel probe signals propagated through the surf zone simultaneously with measurements of the shoaling surf, the clouds of bubble entrained by breaking waves and the nearshore circulation driving bubble advection. The purpose of these measurements was to: (1) statistically characterize the surf zone acoustic channel Doppler and time spreads, and acoustic drop-outs, in terms of the incident wave field and (2) make sufficiently detailed environmental and acoustic measurements to understand the deterministic coupling between the telemetry signals, the surface gravity wave field and wave-induced bubble clouds.

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Wave Breaking, Bubble Production and Channel Characterization of the Surf Zone, SIO Component

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LONG-TERM GOAL

The long-term goal of this research is to develop predictive models of acoustic modem performance in the surf zone. The main environmental factors limiting modem performance in this region are boundary reverberation, surface waves and wave-induced bubble clouds that absorb and scatter the acoustic signals. In order to understand and predict modem performance for a range of beach types and wave field conditions, the coupling between modem telemetry signals and environmental factors needs to be measured and modeled.

OBJECTIVES

The objective of the research component reported here was to make long-term measurements of acoustic telemetry and channel probe signals propagated through the surf zone simultaneously with measurements of the shoaling surf, the clouds of bubble entrained by breaking waves and the nearshore circulation driving bubble advection. The purpose of these measurements was to: (1) statistically characterize the surf zone acoustic channel Doppler and time spreads, and acoustic drop-outs, in terms of the incident wave field and (2) make sufficiently detailed environmental and acoustic measurements to understand the deterministic coupling between the telemetry signals, the surface gravity wave field and wave-induced bubble clouds.

APPROACH

The field work consisted of two experiments (the Surf Zone Acoustic Telemetry Experiments, or SZATE), conducted in the surf zone nearby Scripps pier at UCSD, La Jolla. The first experiment was a two month, long-duration deployment of acoustic and environmental sensors designed to statistically characterize the propagation of telemetry signals in terms of the incident wave field and distributions of wave-induced bubbles in the water column. The sensor geometry is shown in Figure 1. The numbered, black circles on the right hand side of the figure represent the pier pilings, and are spaced 9.1 meters apart. The source and hydrophones are indicated by red circles with the souce and reference hydrophone pair placed approximately 30 m south of piling 33. Seaward and shoreward hydrophones were maintained south of pilings 23 and 17 respectively in the swash zone. The hydrophone placement was chosen so that there would be periods of time throughout the experiment when waves broke between the hydrophones. The blue lines and squares indicate long-duration environmental sensors, which were deployed for the entire experiment.

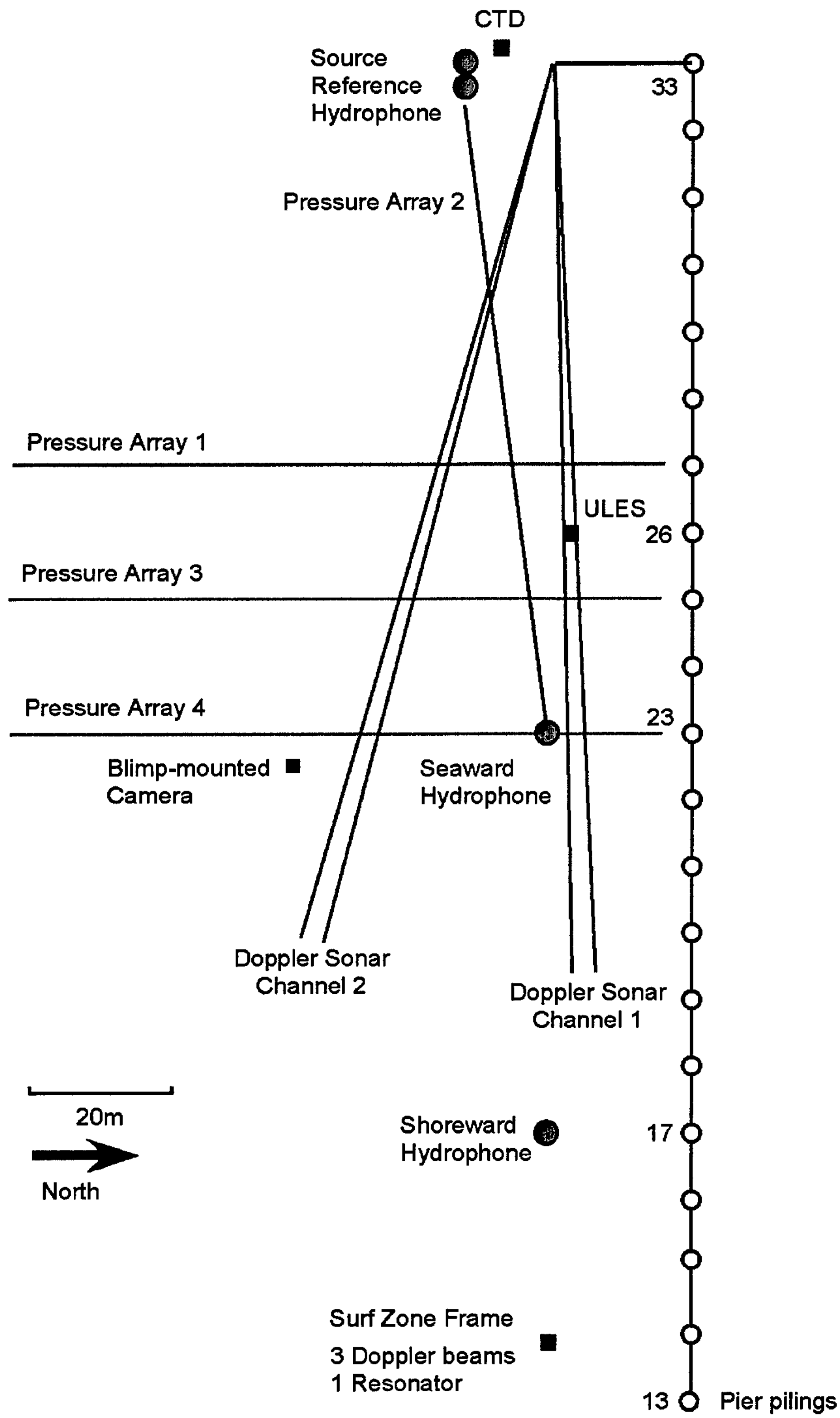

Figure 1. The experiment sensor geometry. Acoustic systems are shown in red, long-duration environmental sensors are shown in blue and short-term sensors are shown in indigo. The black circles on the right hand side of the figure represent the pier pilings.

The indigo lines and squares indicate environmental sensors that were deployed for a week or so during the short-duration experiment (described later). The long-term environmental sensors included a 10-element pressure array strung out between the source and seaward hydrophone to record the incident wave field, and 2 horizontally-oriented IOS Doppler sonar beams and an IOS upward-looking echo sounder (the ULES) provided by David Farmer to characterize bubbles clouds and near-shore circulation.

The long-term experiment, designed for a statistical characterization of the acoustic channel properties, was complemented by a short-term deployment to study the deterministic relationship between wave breaking dynamics and the formation of transmission path blockages associated with wave-induced bubbles. The short-term experiment lasted approximately 2 weeks and consisted of the environmental sensors indicated by indigo squares and lines in figure 1. The three pressure arrays oriented in the along-shore direction and the blimp-mounted camera made the measurements necessary to related the details of wave breaking and large-scale patterns of air entrainment to the local bathymetry. The instrument labeled CTD made velocity measurements in two horizontal dimensions in addition to recording water depth, temperature and salinity. The surf zone frame held an IOS acoustical resonator and three IOS high-frequency Doppler sonars deployed by David Farmer to measure the fluid turbulence and bubble entrainment during wave breaking.

WORK COMPLETED

Both the long-term and short-term experiments have been completed successfully. The details of the data obtained are described below.

RESULTS

The main product of the long-term deployment are tapes of channel probes and telemetry signals transmitted through the surf zone. Eighteen minutes of signal were transmitted every two hours for 56 days, yielding a total of 672 transmission segments, or a little over 200 hours of data. Of the 56 recorded tapes, 42 contain data from both hydrophones. The harsh surf zone environment resulted in multiple cable failures on three separate occasions and 12 of the recordings contain data with only one operational hydrophone. The main environmental sensors, which were the along-shore pressure sensor array and the two horizontally oriented Doppler sonars, characterized the rips and along-shore currents, the shoaling gravity wave field and the clouds of bubbles entrained by breaking waves.

The SZATE experiments were a success. Sufficient acoustic probe, telemetry and environmental characterization data now exists to statistically characterize acoustic channel drop-outs as a function of incident wave field, and study the deterministic formation of channel blockages by bubbles.

IMPACT/APPLICATION

The performance of acoustic modems in the surf zone is compromised by the presence of wave-induced bubbles in the breaking region. The bubbles can extend through the entire vertical extent of the water column and cause acoustic drop-outs that persist for minutes. This research provides the basic observations necessary to understand and model this process, in addition to channel delay spread and frequency shifts caused by reverberation from the sea floor and surface gravity wave field.

TRANSITIONS

This research has resulted in a determination of the basic acoustic channel properties necessary to design front-end equalizers for modems operated in the surf zone. The incorporation of this information into operational devices is an on-going process (contact: J. Preisig and L. Fritag).

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