Ambient Noise Measurements And Inversions In Coastal And Continental Shelf Waters.

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LONG-TERM GOAL

The long-term goal is to quantify and model the production of sound by breaking waves in the open ocean and the surf zone. Sound production on both of these regions is associated with the formation of plumes of bubbles within and beneath breaking wave crests, and the studies described here share the goal of relating breaking wave activity to bubble formation and ambient noise generation.

OBJECTIVES

The first objective was to conduct an experiment in the surf zone to study the transmission and reception of acoustic communications signals and the influence of environmental factors, such as wave-induced bubble clouds and surface and bottom scattering, on acoustic communications transmissions. In addition, the connection between patterns of air entrainment, bottom bathymetry and the wave number spectrum of the incident gravity wave field were studied.

The second objective was to obtain simultaneous measurements of bubble size distributions and ambient noise generated by whitecaps in the open ocean. The overall objective here is to develop a detailed understanding of the connection between surface wave activity and ambient noise generation.

APPROACH

The Near Shore Acoustics Network Experiment

The Near Shore Acoustic Network Experiment (NSANE) was a field experiment conducted during May 1999 in the surf zone immediately north of Scripps Pier to study ambient noise, and the transmission and reception of acoustic communications signals. There was a strong emphasis on understanding the relationship between environmental factors, such as wave-induced bubble clouds and surface and bottom scattering, and transmissions. The experiment was a collaborative effort between scientists and engineers from Woods Hole (WHOI), the Coastal Systems Station (CSS), the Institute of Ocean Sciences (IOS), Datasonics and Scripps Institution of Oceanography (SIO). The SIO component of the experiment consisted of providing logistical support in the deployment and recovery of all environmental monitoring and signal transmission equipment, the collection of environmental data sets, and producing the draft Categorical Exclusion (CATEX) required for authorized underwater sound transmissions. The SIO systems deployed consisted of a 10-element pressure array to measure the gravity wave field, a blimp-mounted video camera to monitor patterns of wave breaking and an optical instrument to measure bubble size distributions beneath breaking surf.

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SeaBubble 99.

SeaBubble was an open-ocean experiment supported by the FP Flip from April 5th to April 11th, 1999 to measure ambient noise production simultaneously with bubble size distributions and bubble formation mechanisms beneath breaking waves during a storm. David Farmer and Svein Vagle from the Institute of Ocean Sciences, BC also participated in the experiment, and supplemented the SIO measurements with upward-looking Doppler sonar measurements of the surface wave field and background bubble layer, and acoustical resonator measurements of the near-surface bubble size distributions. A single storm event was encountered, providing 40 knot winds and significant surface wave activity.

WORK COMPLETED

The Near Shore Acoustic Network Experiment was completed successfully. A total of 22 acoustic and environmental systems provided by IOS, WHOI, Datasonics, CSS and SIO were deployed and recovered in the surf zone and near shore region between 6-21 May, 1999. The SIO pressure array and overhead video data systems provided data on patterns of air entrainment and their relationship to the incident wave field and bottom bathymetry. A model describing acoustic transmission through the surf zone has been developed and, in collaboration with David Farmer at IOS, coupled into an oceanographical model describing bubble advection and diffusion in the surf zone.

The SeaBubble 99 cruise was carried out as planned, and provided an adequate data set on simultaneous measurements of ambient noise generation and bubble size distributions in the upper ocean. Analysis of the acoustic data and its relationship to bubble formation processes is in the initial stages.

RESULTS

There have been three main results from the SIO component of the Near Shore Acoustic Network Experiment. The first is the collection and study of the data relating along-shore wave height variations, bottom bathymetry and patterns of air entrainment. The data provides convincing evidence that the development of breaking wave crests in two horizontal dimensions is related to the spatial interference structure of the incident wave field. This is a new result, and has important implications for ambient noise generation in the surf zone, and the distributions of bubbles that affect high frequency acoustics communications in very shallow water. The second result of this study has been the development of a coupled oceanographical acoustics model in collaboration with Farmer and Vagle at IOS, BC. The model is being used to study acoustic 'drop-outs' in the surf zone, a phenomenon whereby acoustic transmissions passing through the wave breaking region are completely blocked by absorption and scattering from clouds of bubbles generated by breaking surf. The final result is the development of a model for the travel time spread of acoustic transmissions through the surf zone. The model predicts travel time spread as a function of geometry and seafloor composition. Travel time spread is the delay between the direct arrival and delayed, boundary-reflected arrivals, and is an important parameter in the design of underwater acoustic telemetry systems. The theory has been compared with measured arrival time spreads and shows good agreement.

The main result of the SeaBubble 99 cruise to date has been the determination of the medium to large size distribution of bubbles in open-ocean white caps formed during and immediately after wave breaking. This distribution is important for models of wind-induced, low frequency ambient noise

generation. The large bubble size distribution during high wind speeds is also important for air-sea gas flux, and is currently being used in a related program to calculated bubble-mediated CO2 flux through the marine boundary layer.

IMPACT/APPLICATIONS

The acoustical models developed as part of the Near Shore Acoustic Network Experiment will be used to model modem performance in very shallow water, and should provide a useful tool for the design of channel equalizer algorithms.

RELATED PROJECTS

The SeaBubble 99 cruise was partially supported by the ARL research program, which provided the Research Platform Flip. The Near Shore Acoustic Network Experiment was partially supported by ONR's Ocean Engineering & Marine Systems Program, Award #N00014-99-1-0260.

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