Ambient Noise Measurements and Inversions in Coastal and Continental Shelf Waters

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LONG-TERM GOALS

The long-term goals are to quantify and model the production of ambient noise by breaking waves in the open ocean and the surf zone. The origin of the $f^{5/3}$ dependence of wave-induced noise power on frequency, and the relationship between noise level and surface wave energy dissipation are of particular interest.

OBJECTIVES

The short-term objective was to acquire simultaneous measurements of the numbers and sizes of bubbles formed immediately beneath breaking waves and the ambient noise generated by waves in an open ocean experiment. This field study was the third in a series of deployments to study ambient noise generation and air entrainment processes by whitecaps.

APPROACH

The underlying approach combines field observations of wave-induced bubbles and ambient noise in the top meter of the marine boundary layer with models for wave noise generation. The field studies are organized around a bubble plume sensing system, consisting of an optical bubble counter, a depth sensor, a hydrophone and an underwater video camera. The plume sensing system is mounted on a surface-following frame tethered to Flip, providing a stable deployment location 20 to 40cm below the ocean surface. The scientific personnel responsible for the field measurements at SIO are Drs. Grant Deane and Dale Stokes. Drs. David farmer and Svein Vagle at the Institute of Ocean Sciences, BC are collaborators in the experiments, and have deployed Doppler sonars and acoustical resonators to measure surface wave activity and the more diffuse concentrations of bubbles that occur 1m or more below the ocean surface.

WORK COMPLETED

In February 2000, a three week field study on the RP Flip took place approximately 100 miles west of Point Conception. The central sensor system was an optical bubble counter and a co-located hydrophone to simultaneously measure bubble size distributions and ambient noise generated by whitecaps. A standard set of meteorological sensors were deployed along with an underwater video

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camera to monitor the gross features of wave-induced bubble plumes and a nested hydrophone array to monitor ambient noise. The experiment was undertaken in collaboration with David Farmer and Svein Vagle from the Institute of Ocean Sciences, BC, who deployed, amongst other systems, a sector scan sonar and two Doppler sonars to monitor whitecap formation, the surface gravity wave field and Langumir circulation. The experiment was successful, and a dataset of the bubble characteristics and noise generation associated with whitecaps was obtained.

A preliminary analysis of the bubble and noise data from the cruise has been completed. The average creation rate of bubbles inferred from the evolving size distribution measurements was incorporated into a model for ambient noise generation to calculate the emission spectrum from individual whitecap events. The resulting spectrum has been compared against the noise measured by the hydrophone co-located with the optical bubble counter.

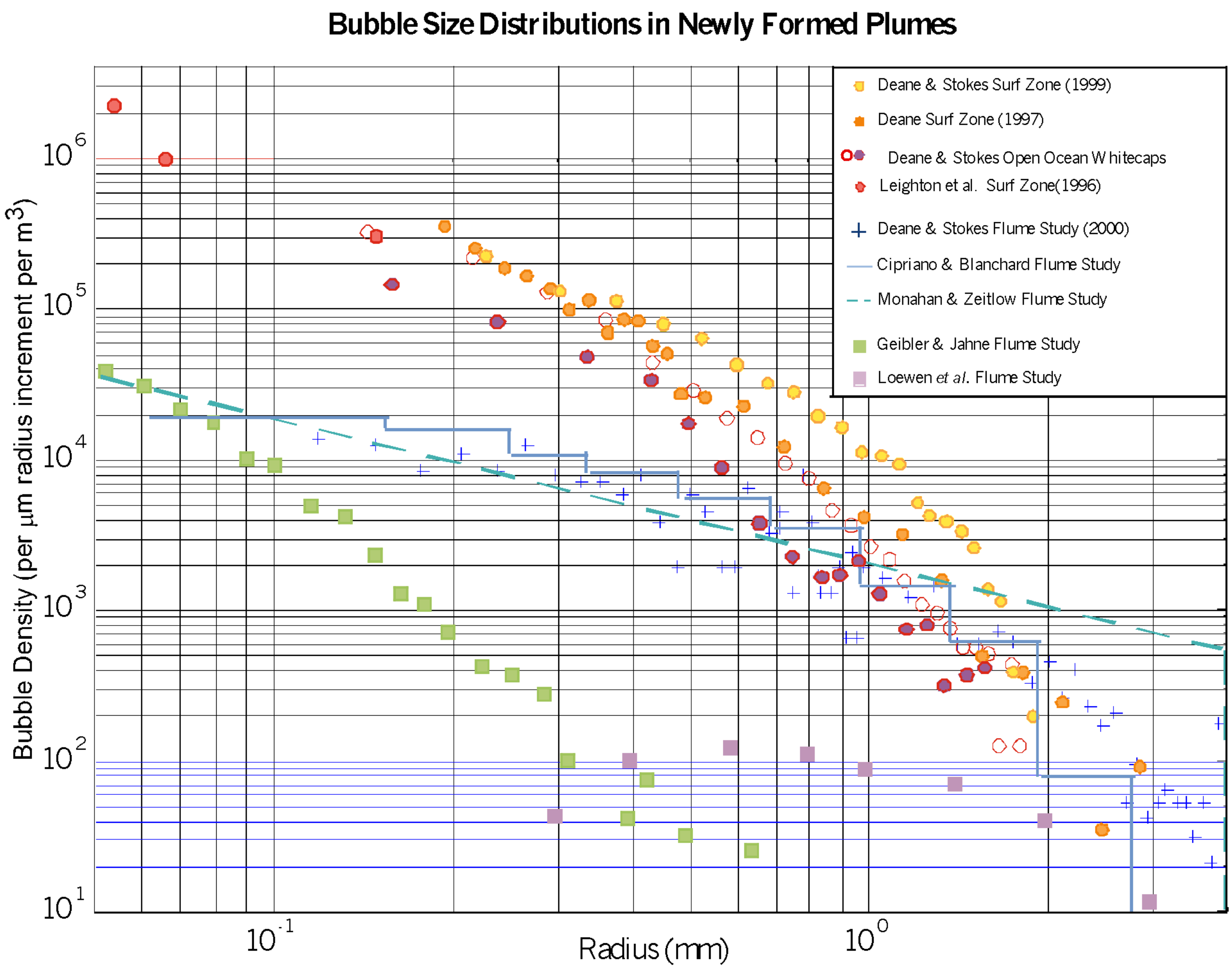

Figure 1. A collection of bubble size distributions obtained from the SeaBubble experiments, surf zone studies and laboratory studies. Significant differences between the laboratory and open ocean distributions exist for bubble radii less than 500 microns.

RESULTS

Significant results have been achieved within both the experimental and modeling efforts. The February Flip cruise (SeaBubble 2000), along with a similar cruise in April of 1999 (SeaBubble 99), has provided a comprehensive dataset of the bubble and noise characteristics in the top meter of the ocean's surface during 25 to 35 knot winds. This is a unique dataset with significance for ambient noise modeling, acoustical scattering at the ocean's surface, ocean color during wave breaking and air-sea gas transfer. The optical bubble measurements show the temporal evolution of the bubble size distribution inside the white cap through the high void fraction (> 1%) phase of the bubble plume formation. Figure 1 shows a collection of bubble size distributions taken from the SeaBubble cruises, the surf zone and flume studies. The bubble size distributions observed in the open ocean differ significantly from those measured in salt water flume studies with an order of magnitude or more bubbles being present with radii less than 500 microns. The similarity between the size distributions measured beneath breaking surf and breaking waves in the open ocean suggests that the surf zone can be used as a real-world natural laboratory for studying bubble plume physics. The differences between the flume study results and the open ocean size distributions show that care must be taken when scaling laboratory studies to ocean phenomena.

A first order model for the noise radiated by a forming whitecap based on the bubble size distribution measurements from the SeaBubble dataset has been developed. Figure 2 shows a comparison of the model results with the measured noise power spectrum for a selected breaking event. The comparison is quite favorable, showing a similar spectral level and shape. An important feature of the noise model is that it includes the shielding effect of the growing population of acoustically quiescent bubbles on sound radiated by bubbles formed within the whitecap. The favorable agreement between the measured and modeled spectra indicate that the origin of the $f^{-5/3}$ dependence of wave-induced noise power on frequency is associated with this screening mechanism.

IMPACT/APPLICATIONS

A potential future impact of this research is the development of models for the generation of bubbles due to wave breaking, and the impact of those bubbles on acoustical absorption and scattering at the ocean surface. If the link can be made between noise generation and wave energy dissipation, then it will also be possible to remotely monitor air entrainment rates by measuring ambient noise levels.

TRANSITIONS

The bubble plume studies described here have implications for the propagation of sound through the surf zone, where wave-induced bubble plumes strongly absorb and scatter telemetry signals. The techniques developed to measure dense bubble plumes and the bubble size distribution information obtained are being used to develop models of modem signal propagation through the surf zone.

RELATED PROJECTS

Two closely related projects are the Near Shore Acoustic Telemetry Experiment and the Surf Zone Acoustic Telemetry Experiment conducted in the surf zone adjacent to the SIO Scripps Pier. These experiments were designed to study the effects of boundary reverberation and wave-induced bubble absorption and scattering on acoustic telemetry signals.

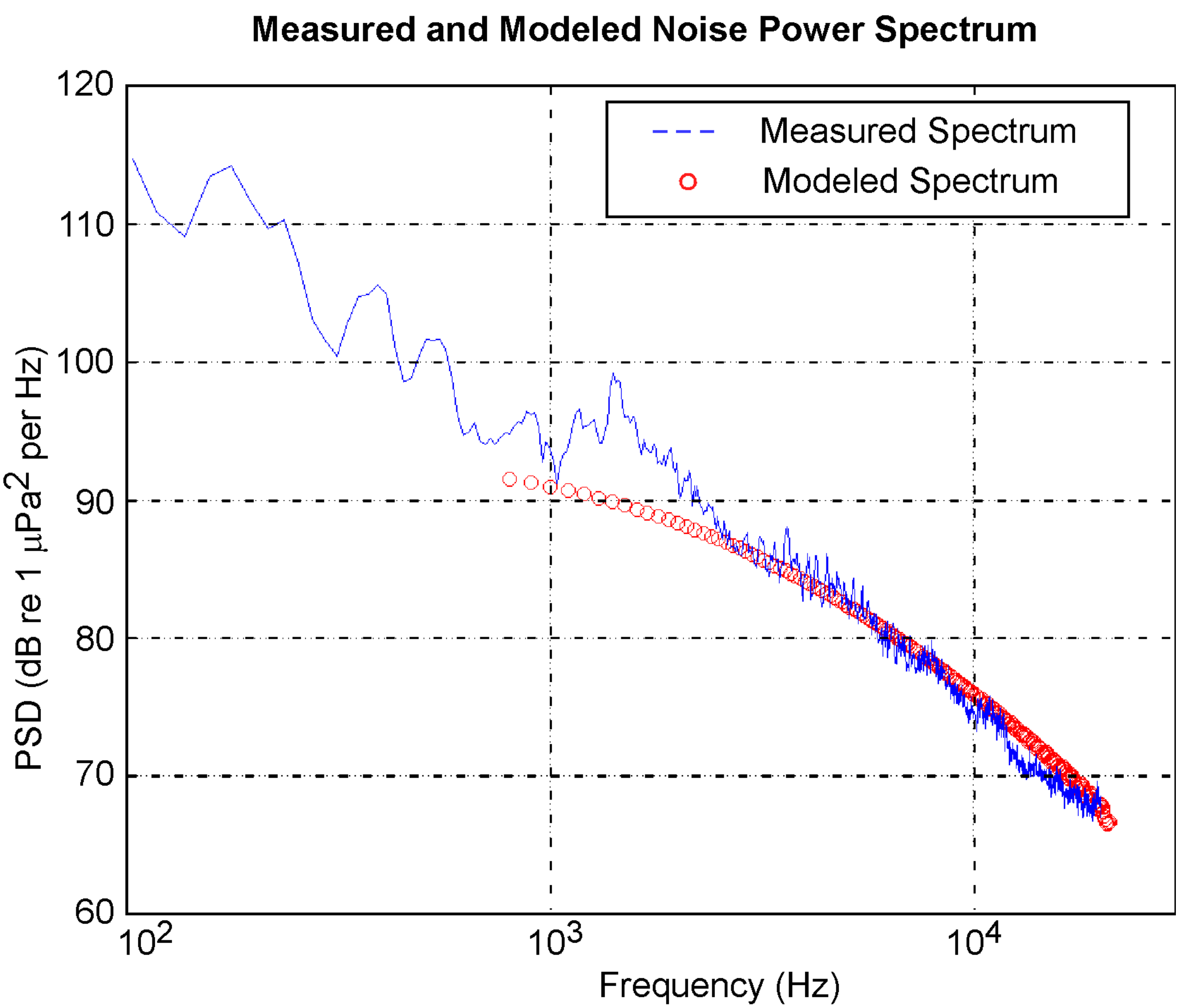

Figure 2. The measured and modeled wave noise spectrum for a single SeaBubble 2000 whitecap.

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