Characterizing The Surf Zone With Ambient Noise Measurements

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LONG-TERM GOAL

The long-term goal is to utilize the underwater sound generated by breaking surf to characterize properties of the littoral zone environment such as beach slope and sea floor composition.

OBJECTIVES

The most recent objective of this program have been to develop an empirical model for surf noise based on an extensive data set collected as part of ONR's ARL program at the Marine Physical Laboratory.

APPROACH

The basis for the empirical surf noise model is a data set collected from an autonomous monitoring station deployed from July of 1997 through June 1998. The monitoring station was located 1m above the sea floor in 8m of water, 200m southwest of Scripps Pier, La Jolla and approximately 200m from the surf line. The surf-monitoring array consisted of 4 broadband hydrophones, which measured ambient noise, and a pressure sensor, which measured the height of surface gravity waves. Noise and wave height were recorded in nine-minute time segments, at a rate of one segment per hour. The recordings provide data through a wide range of incident wave fields and weather conditions, including several winter storms.

The ambient noise recordings need to be analyzed with some care as many biological and mechanical noise sources operate in the surf zone. Spectrograms of each of the roughly 7500 nine minute noise segments have been manually examined for sources of sound other than breaking surf. Approximately 1200 nine-minute noise segments were identified as being dominated by surf noise. Snapping shrimp and flow noise respectively set the upper and lower frequencies of the analysis, which are 1.5kHz and 50Hz.

Each of the nine minute noise segments that were identified as being dominated by surf noise were analyzed into octave band averages centered on 32Hz, 64Hz, 128Hz, 256Hz, 512Hz and 1024Hz. The octave band averages were then cross correlated against the measured environmental conditions, which included the RMS height and dominant frequency of the incident surface wave field, the speed and direction of the wind and the mean water depth, which varied with the tidal cycle.

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WORK COMPLETED

Acquisition and processing of the surf zone ambient noise set has been completed.

The segments of the data base dominated by surf noise have been analyzed and cross-correlated with simultaneously measured environmental parameters. The results are encouraging and suggest it should be possible to predict surf noise levels at different frequencies with reasonable confidence from the RMS wave height of the incident wave field.

RESULTS

Two significant results have been obtained so far.

The first is that the RMS wave height of the incident wave field is the most important predictor of surf noise level. This result is shown in Table I, which shows the cross-correlation analysis between the surf noise octave band averages and the measured environmental parameters. The correlation coefficients between noise level and RMS wave height exceed 0.82 for all of the frequency bands.

Secondary predictors of the surf noise level are 1) the mean water depth, which varies with the tidal cycle and 2) wind speed. The water depth is weakly correlated to the noise level because the range between the noise monitoring station and the line of breaking surf changes with the tidal cycle, causing a propagation-induced variation in the noise level.

	32Hz	64Hz	128Hz	256Hz	512Hz	1024Hz	Wave Height	Wave Freq.	Depth	Wind Speed
32Hz	1.00	0.97	0.95	0.89	0.85	0.86	0.95	-0.16	-0.18	0.34
64Hz		1.00	0.96	0.90	0.87	0.87	0.95	-0.19	-0.13	0.32
128Hz			1.00	0.95	0.91	0.89	0.94	-0.15	-0.19	0.30
256Hz				1.00	0.98	0.91	0.87	-0.19	-0.27	0.23
512Hz					1.00	0.95	0.83	-0.15	-0.31	0.28
1024Hz						1.00	0.84	-0.14	-0.29	0.39
Wave Height							1.00	-0.18	-0.09	0.35
Wave Frequency								1.00	-0.16	0.18
Depth									1.00	-0.13
Wind Speed										1.00

Table I. Cross-correlation values of the surf noise octave band averages with each other and the environmental parameters, which were RMS wave height of the incident wave field, average frequency of the incident wave field, mean water depth and wind speed.

An analysis of scatter plots show that the weak correlation between wind speed and noise level is caused by an additive component of noise when the speed exceeds 7m/s. Since this is also the speed at which white caps begin to form, the increase in noise level is probably caused by wind-induced wave breaking occurring in deeper water.

The second important result is the discovery that surf noise level scales roughly with the square of RMS wave height. This conclusion arises from an analysis of scatter plots of surf noise level with wave height. The analysis shows that the noise levels scale as H^n where H is the RMS wave height and n is a frequency-dependent constant ranging from 1.8 at 1kHz to 2.6 at 128Hz. The kinetic energy in the incident wave field per unit cross-sectional area of ocean surface scales as H^2 and we can conclude that the surf noise level scales roughly with the kinetic energy of the incident wave field. This suggests in turn that the proportion of mechanical energy converted to sound energy is approximately constant, independent of the amplitude of the incident wave field – a simple and intuitively appealing result.

TRANSITIONS

The measurement and deployment techniques developed during this and related surf zone studies are being used to support ONR 6.2 MCM studies in the surf zone.

RELATED PROJECTS

1. I have a collaborative program with Douglas Cato at the Defence, Science and Technology Organization, Australia to study inversion methods to determine seafloor parameters in shallow water. Data taken in May of 1997 during a joint cruise supported by DSTO in Spencer Gulf, southern Australia are being analyzed. Another cruise is planned for May of 1999.

2. David Farmer at the Institute of Ocean Sciences, British Colombia and I have a joint program to study the generation, advection and dissolution of bubbles in the surf zone and their affect on noise generation and acoustic propagation. We both participated in the February 1997 Scripps Bubble experiment and have follow-on experiments at Scripps Pier planned for 1999.

IMPACT/APPLICATIONS

The empirical surf noise model developed during this program has application to the prediction of surf noise levels in very shallow water. The model will also be used to support studies of the connection between breaking waves and ambient noise in the open ocean.

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