551·46.018·1 : 532·29 : 535·33

Sea-wave Spectrum by echo-sounder

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1. Introduction

Nanda (1957) suggested a method of making a relative estimate of the standing crop in the ocean by studying the fluctuation of the echoes received on an echo-sounder. Taking the number of scatterers to be obeying Poisson distribution, it was shown that the average number of scatterers $\overline{N}$ is equal to $4/\overline{\alpha}^2$ times the mean square deviation of a series of values of log a/a_0 where $\overline{\alpha}$ is the average scattering coefficient per organism and a and a_0 are the received and transmitted amplitudes. Besides the density of standing crop in the ocean, the other factors which contribute to the fluctuation of the echoes are the changes in reflectivity of the ocean bottom, and the oscillation of the vessel due to state of the sea. The fluctuations of echoes for various stations give a relative estimate of the number of scatterers which scatter the sound waves (Nanda, paper on standing crop etc—*see ref.*), provided the contribution of the other factors can be allowed for or taken to be insignificant. Changes in reflectivity of ocean bottom are relatively less important bearing in mind the uniformity of the echo-sounder trace during the brief period of observations at any station, but when the sea is rough a considerable portion of the fluctuation will be due to the oscillations of the ship in the rough sea. In this paper the fluctuation of the echo-sounder amplitudes under rough sea conditions is studied with a view to estimate the sea-wave spectrum.

2. Observations

The data on the fluctuation of the echo-sounder intensities were collected by the senior author during the 'Downwind' Expedition in the South Pacific. The observations were taken both under calm and rough sea conditions. The data under calm sea conditions were analysed for estimating the relative density of the standing crop and discussed separately (*see ref.*). The data under rough sea conditions are used in this paper to study the sea-wave spectrum. The amplitudes of each of the received pulse and the corresponding transmitted pulse as recorded on a pen and ink recorder were read out. The ratio of these two amplitudes was calculated and the logarithm of these ratios were subjected to auto-correlation analysis.

3. Analysis

Auto-correlation function is given as $\Sigma x_i \; x_{i+l}/N$ where l is the lag in terms of the number of pulses and N is the total number of observations. Here x_i, x_{i+l} are deviations from their respective means. In our case, since the pulses were sent out at intervals of one second, l is also the time interval in seconds. By plotting the values of the auto-correlation function for different lags, we get the auto-correlogram. Every period in the original data is repeated in the auto-correlogram with the same period, but the amplitude of each period of the auto-correlogram is equal to half the square of the original amplitude (Kendall—*see ref.*). If we suppose our series to consist of a number of cyclic components plus a random component, then at lag zero, the value of the auto-correlation function is equal to the mean square deviation of the random component plus half the sum of the squares of the amplitudes of the cyclic components. At other lags the value of the auto-correlation function is only

TABLE 1

Date	26-1-1958	18-2-1958	24-2-1958
Time	1607	1700	0815
Latitude	25°18′S	03°37′S	15°37′N
Longitude	86°40·5′W	114°18′W	114°37·5′W
Mean square deviation of the logarithm of the ratio of received amplitude to transmitted amplitude	0·105	0·0475	0·0325
Mean square deviation of random component	0·0770 (72% of total)	0·031 (65% of total)	0·0189 (59% of total)
Mean square deviation of cyclic components = $\Sigma \frac{1}{2} A^2$	0·0280	0·0165	0·0136
Values for cyclic components: Prominent periods (sec)	18 6	5 17	16 12 3
Values for cyclic components: Mean square deviation	0·0040 0·0240	0·0106 0·0059	0·0011 0·0075 0·0050
Values for cyclic components: Relative amplitudes (proportional to sq. root of m.s.d.)	3 : 8	4 : 3	3 : 8 : 7
Wind speed	Light	10 knots	23 knots
Ship's speed	Ship stopped	Ship stopped	11 knots

due to the contribution from cyclic components. From the auto-correlogram the prominent periods were noted and the relative magnitude of the squares of the amplitudes of these were calculated. It was thus easy to determine the relative amplitudes of the cyclic components as well as the value of the mean square deviation of the random component. This value of the random component is expressed as a percentage of the total mean square deviation in Table 1. The periods thus determind in all cases passed the Walker's test of significance.

4. Discussion

It is evident from Table 1 that as the wind speed increases and the sea becomes rough, the contribution of the cyclic components to the total mean square deviation increases.

The analysis shows periods from 3 to 18 sec. The correlogram was constructed only upto a lag of 20 seconds. The data were insufficient for extending the correlogram beyond 20 seconds lag. Periods higher than 20 seconds may be present but one does not expect much amplitude for these since long period waves are not prominent in the open deep sea. The observations are not repeated at the same station.

As is evident,the observed spectra will not be exactly the same as that of the sea waves, but will reflect the response of the vessel to the waves. In fact we are analysing the movement of the ship due to the waves, which is of direct practical importance. Unfortunately the direction of wind with respect to ship motion was not recorded and so the effect of wind cannot be properly assessed.

REFERENCES

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