LOW FREQUENCY BOTTOM REVERBERATION IN THE NORTH EAST ATLANTIC AND MEDITERRANEAN SEA

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ABSTRACT

Measurements of bottom backscattering strengths have been made at a frequency of 2 kHz for grazing angles between 5 and 40 degrees in the NE Atlantic Ocean and Mediterranean Sea. A very simple model has been developed to explain some of the features of the results. The backscattered energy levels exhibit a peak at grazing angles of 30 degrees, a fact which has been attributed to the form of the Rayleigh reflection coefficient for the water-sea bed interface. The highest backscattered levels of about -16 dB were found in areas of Abyssal Plain in which the large scale bottom roughness was small, and levels were inversely related to bottom roughness. In addition the variation of backscattered energy with grazing angle was inversely related to bottom roughness.

INTRODUCTION

Measurements of bottom backscattering strength have been made at low grazing angles at 9 sites in the NE Atlantic and 3 in the Western Mediterranean at a frequency of 24kHz. Although measurements of bottom backscattering strength have been made by other people i.e. Burstein & Keane [1] in 1964 and Schmidt [2] in 1969, few have been at the low grazing angles reported here.

The equipment used to make the measurements consisted of a projector with known directivity and a vertical line receiving array giving a narrow vertical beamwidth. Both of the arrays were steerable in the vertical plane. 2 kHz pulses were transmitted and the returning signals recorded on a logarithmic level recorder. The backscattering strength of the sea bed was then calculated using the known parameters of the equipment and the distance to the sea bed at a given angle of steer. The results were plotted against grazing angle over the range 5 to 40^{o}.

RESULTS

The levels of backscatter varied between -16 and -40 dB with both grazing angle (η) and geographical location, and each of the plots exhibited a peak in backscattering level at $\eta \approx 30^{o}$. In order to simplify further analysis the data was combined into backscattering types by reference to the level at $\eta = 30^{o}$ and each then assigned a type number with low number representing high level. The result is shown in figure 1 for the four types, and figure 2 shows the relationship between type number and backscattering level at $\eta = 5^{o}$ and 30^{o}. The results in this form were then compared with the physiographic province types of Heezen, Tharp and Ewing [3] by reference to geographical location. The high levels of backscatter of type 1 were found by this means to come from abyssal plains and the lower levels from rougher areas.

A simple mathematical model which will not be described here, was then fitted to the data and permitted an estimate to be made of the bottom roughness in terms of the rms bottom slope of facets whose dimensions were large compared to the ensonifying wavelength. The fitted curves from the model are shown in figure 1 as the solid lines and they also exhibit the peak at $\eta = 30^{o}$, which in the model arises from the form of the Rayleigh reflection coefficient at the water and sea-bed interface. The values of rms bottom slope obtained for each type number are shown in table 1. It may be seen that the higher slopes

Backscatter Type No.	1	2	3	4
RMS Bottom Slope (degs)	4	7	6	9

TABLE 1

The relationship between rms bottom slope and backscattering type number

are to be found in areas of low type number which suggests that high slopes are generally to be found in areas of low backscattering strength. This is indeed the case and the relationship is shown graphically in figure 3 and is significant at the 5% level using a student t test.

Thus the results show that moving from a smooth abyssal sea bed to a rougher one with higher slopes produces a lower backscattering strength. This at first seems anomalous since intuition might lead one to think that a rougher surface should backscatter more energy. However the answer is to be found in the high critical angle for reflection at the water sea bed interface (about 30^{o}). At higher bottom slopes there is more chance of a particular scatterer presenting a grazing angle greater than the critical angle and also of multiple reflection occurring. Thus in rougher areas what is really happening is that more energy is being absorbed into the sea bed which is intuitively more acceptable.

CONCLUSIONS

Bottom backscattering levels have been shown to exhibit a peak at a grazing angle of 30^{o} in the range $0-40^{o}$, which has been attributed to the form of the Rayleigh reflection coefficient at the water sea-bed interface.

High levels of bottom backscatter (-16 dB) have been found in abyssal plains associated with low rms bottom slopes, and lower levels (-35 dB) with higher slopes in rougher areas. It is suggested that increased absorption in the sea bed in the rougher areas is the reason for this relationship. In addition there is less variation of backscattering strength among the types of sea bed at low grazing angles (15 dB at $\eta = 30$ and 10 dB at $\eta = 5$) and less variation with grazing angle in the rougher provinces (about 20 dB in abyssal plains and 10 dB in rougher regions over the range 0^{o} to 40^{o}).

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Application to Internal Waves

Range of scale sizes. Basic theory has a single scale size r_o. Internal wave spectrum covers a range of scale sizes. Can basic scattering theory be applied? Consider a wave-number spectrum $\sim \nu^{-n}$. Ratio of power in successive tenfold ranges of ν depends on n (Fig. 3)

n	ratio	range
2	1/10	b/a, c/b
1.5	1/3	" "
1	1	" "

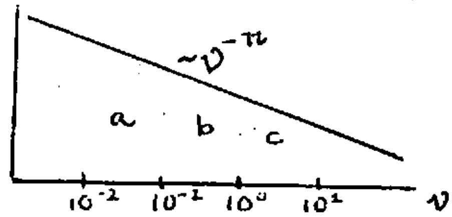

Fig. 3. Ratio of power in different wavenumber ranges

For $n \geq 2$ the theory is applicable since contributions from higher scale sizes are small.

Wave-number spectrum for internal waves. If $F(\nu_H, \nu_V, \nu_z)$ is the 3-D internal wave spectrum, the spectrum corresponding to $f(\xi, \eta)$ is $F(\nu_H, \nu_V, 0)$. Model spectra give $F \sim \nu_H^{-2}$, $\sim \nu_V^{-2}$ with horizontal scale $\nu_H^* \sim 1$ c/km, and vertical scale $\nu_V^* \sim 10$ c/km, i.e. elongated irregularities. The spectrum is observed to have a lower cut off at $\nu \sim 10^{-1}$.

Scattering strength of the irregularities. Are the internal waves weakly scattering, i.e. is $(\Delta\phi_c)^2 \ll 1$ for every scale size? We can get an estimate from the phase spectrum of an acoustic signal

$$\int \phi_c^2(\omega)\, d\omega = \int \phi_c^2(\nu)\, d\nu = C_o \int \nu^{-2}\, d\nu \qquad (11)$$

For typical ocean conditions $C_o \simeq 10$ rad^2.c/km/6/. This gives

$$\nu_H < 10^0 \text{ c/km} \qquad (\Delta\phi_c)^2 \geq 1 \text{ rad}^2$$
$$\nu_H > 10^0 \text{ c/km} \qquad (\Delta\phi_c)^2 < 1 \text{ rad}^2$$

Irregularities with $\nu_H < 10^0$ c/km can give strong scatter and the applicability of the theory is restricted.

Distance for intensity fluctuations to be produced $\quad k = 17\ \text{m}^{-1}$ i.e. 4 KHz

ν_o c/km	r_o m	$k r_o^2$ km	ϕ_c^2	Z_{fc} km
10^2	10	1.7	1	0.42
10^1	100	170	10	13
10^0	1000	170×10^3	100	400

For distances $z > 500$ km the scales with $\nu_H < 10^0$ c/km begin to produce amplitude fluctuations and there is strong scattering. Theory is restricted here but we can apply it without much modification in situations with $z < 500$ km.

Application to Cobb Seamount Experiment /6/, z = 20 km, 4 KHz.

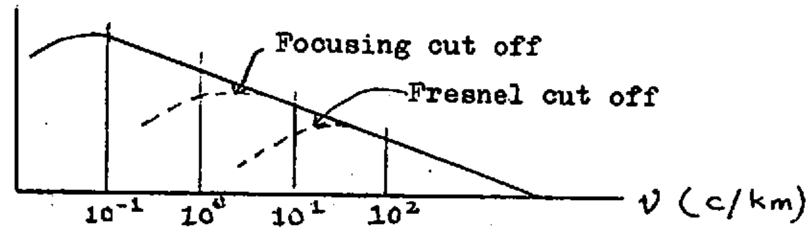

Fig. 4. Region of internal wave spectrum responsible for intensity fluctuations.

Equivalent scale size $r_o \approx 100$ m, $\phi_o^2 = \beta z = 10$ rad^2. Estimates give $Z \approx 0.12$, $\gamma \approx 80$, $Z_{fo} \approx 0.18$. Curves (Fig. 1) give $\sigma_I^2 = 1.5 \pm 0.25$

(1) $\sigma_I^2 > 1$ and is near a peak (σ_I^2(observed) = 1.6)

(2) Spectrum of intensity fluctuations $\sim \nu^{-2}$, ν^{-1} in range 10 c/km $< \nu < 120$ c/km. Frequency spectrum of the same form and extending above buoyancy frequency.

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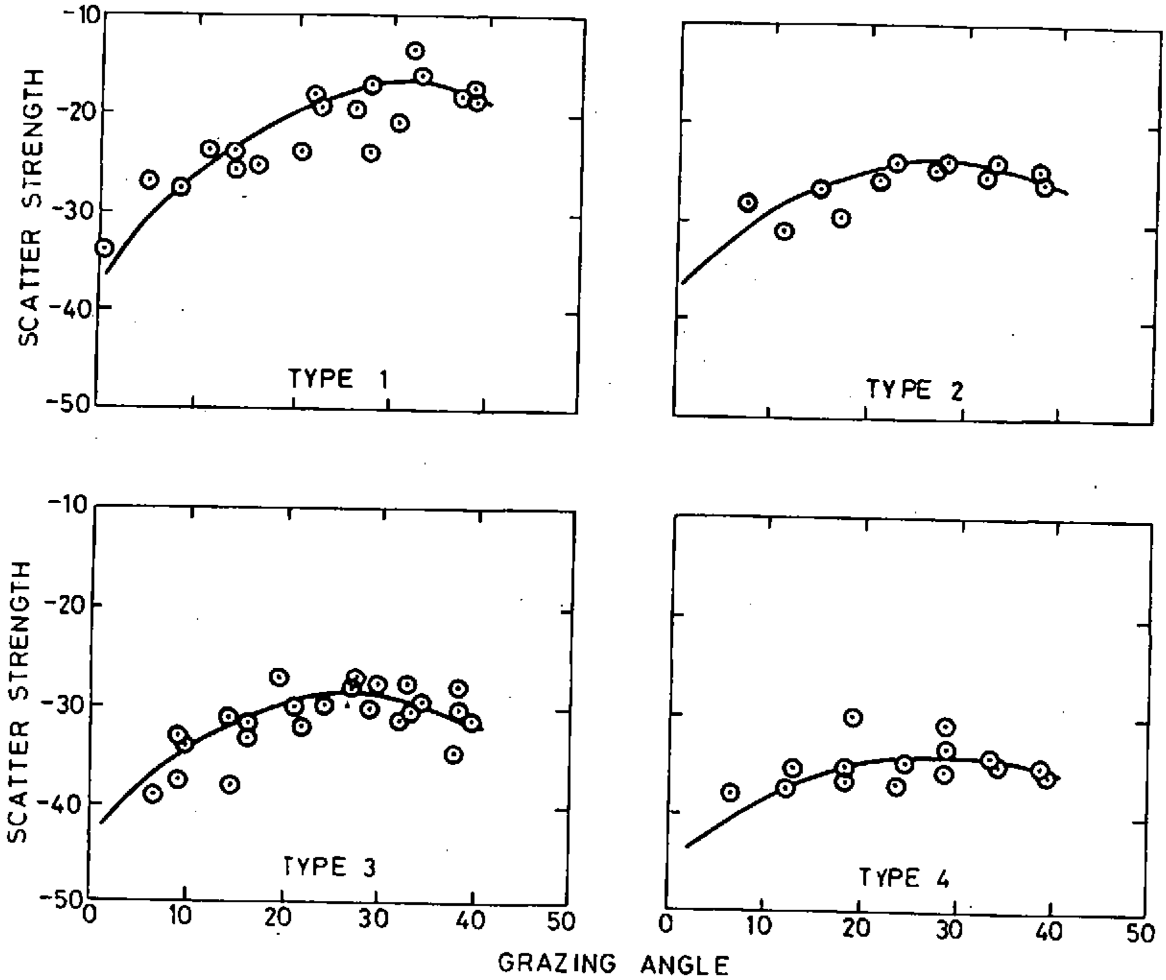

FIG. 1 BACKSCATTERING STRENGTH VERSUS GRAZING ANGLE FOR FOUR DIFFERENT BACKSCATTER TYPES

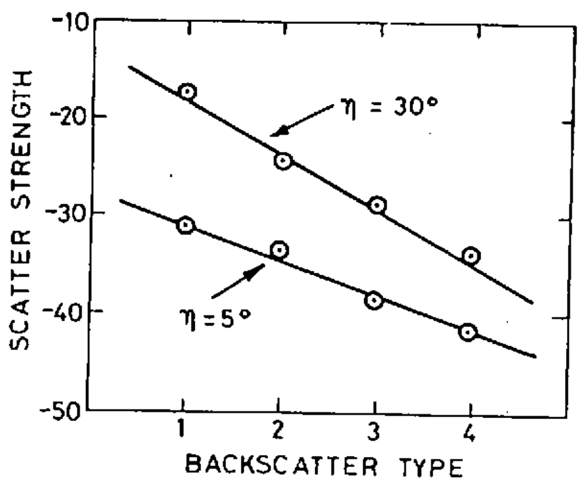

FIG. 2 THE RELATIONSHIP BETWEEN BACKSCATTER TYPE AND TARGET STRENGTH AT 2 GRAZING ANGLES

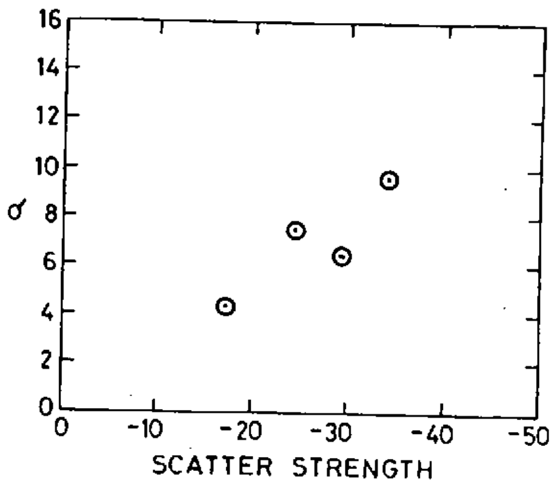

FIG. 3 THE RELATIONSHIP BETWEEN THE RMS BOTTOM SLOPE (σ) AND THE TARGET STRENGTH AT 30° GRAZING ANGLE