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EFFECT OF ATTENUATION CORRECTION ON SURFACE AMPLITUDE DISTRIBUTION OF WIND WAVES

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ABSTRACT

Some selected wave profiles recorded using a ship borne wave recorder are analysed to study the effect of attenuation correction on the disrtribution of the surface amplitudes. A new spectral width parameter is defined to account for wide band and multipeaked spectra. The unattenuated surface profiles when computed from the attenuation corrected variance spectra and the unchanged phase spectra follow the Gaussian distribution even in very wide band cases for which the recorded profiles do not follow the Gaussian law. A narrow band case does not show much changes in the amplitude distribution. The computed surface wave profile shows large changes depending upon the spectral width.

Key-words: Attenuation, wind waves, wave profiles, surface amplitude.

INTRODUCTION

R V Gaveshani and *O R V Sagar Kanya,* the two research ships managed by the National Institute of Oceanography, India, are equipped with ship borne wave recorders (Institute of Oceanographic Sciences, U. K.). Large number of records are collected on a routine basis during the different cruises of these ships. Some of the wave data pertaining to various cruises were processed and published (Gopinathan, Sathe and Rama Raju, 1979; Sathe, Somayajulu and Gapalakrishna, 1979; Fernandes, Gouveia, Sathe and Nagarajan, 1981; Sathe and Gouveia, 1982; Vethamony, Gopalakrishna and Varkey, 1984). But no work is carried out to study the effect of attenuation correction of the variance spectrum on the back-computed surface wave profile. Hence an attempt is made here to study the changes brought about in the surface amplitude profiles computed from the attenuation corrected variance spectrum with no phase spectral change.

DATA AND ANALYSIS

The wave data were recorded using a ship borne wave recorder (Institute of Oceanographic Sciences, U.K.) installed on board the research vessel *Gaveshani*. The sensors are fixed at a depth of 2.1m below the mean water level and the data were recorded for 15 minutes durations at two stations whose depths were 250 and 500m off the east coast of India at about 16.5°N from 24th September to 4th October 1980 (Vethamony, Gopalakrishna and Varkey, 1982). These records were digitised at 1 sec intervals and the resulting time series' were used for the present study.

Eventhough wave records were available for 15 minutes' durations, stabilised portions of the records only were digitised giving always less than 900 digitised values at 1 sec intervals. The data series' thus obtained were analysed for their variance and phase spectra using published programs using FFT (IEE, 1979). These programs would work only with specific number (N) of samples equal to 2^m In the present case only 512 (2^9) values could be used due to this limitation. Eventhough N could be adjusted to 1024 (2^{10}) by adding zeros, this method was not adopted since it requires variance adjustments after the computations and since N = 512 was found suitable for the present study. The spectral densities (after removing noise) were corrected for the attenuation effect due to the submersion of the sensors by 2.1m using a correction formula I.O.S., 1980).

The attenuation corrected variance spectra and the phase spectra were smoothed by a running average method with 11 points resulting in about 22 degrees of freedom.

The attenuation corrected and smoothed variance spectrum within the valid sensor frequency range (0.05 Hz to 0.33 Hz) was used along with unsmoothed raw phase spectrum to back-compute by inverse transform, using published programs (IEEE, 1979), the surface wave profiles (two samples are shown in Fig. 1). Spectral densities outside the valid frequency range were assigned an insignificant base value (0.00001) for obtaining the full frequency range from 0 to 0.5 (Nyquist level for 1 sec sampling interval).

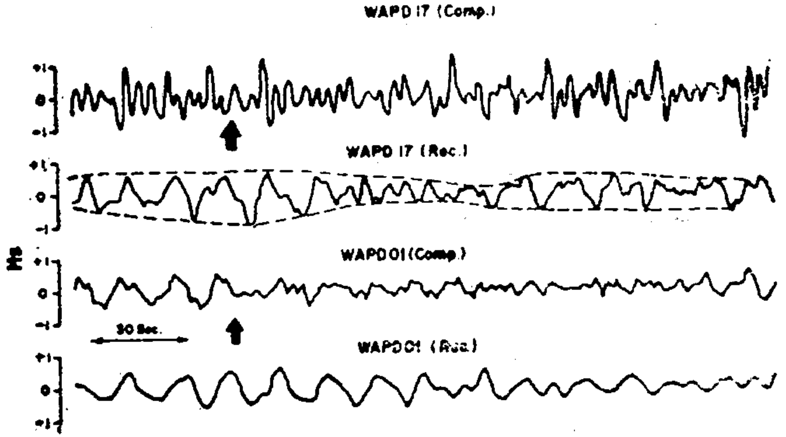

Fig. 1. Recorded (Rec) and computed (Comp) surface wave profiles for a narrow band swell (WAPD01) and a wide band multipeaked sea state (WAPD17).

The computed surface amplitudes were grouped into classes of 0.15 about the mean water level. Gaussian probability law was fitted to the grouped data and the χ^2 values were computed. These computations were carried out for five selected wave records whose variance spectra showed a wide range of spectral widths and the results are shown in Fig. 2. Normal fits to the five observed wave profiles are shown in Fig. 3.

RESULTS AND DISCUSSION

A casual look at Table I shows that the conventional spectral width parameter ϵ $(=1-m_2\ 2/m_0m_4)^{0.5}$ does not represent the true spectral width both in multipeaked cases (WAPD16 and WAPD17) and in narrow band cases (WAPD 01) with a very low level background sea. Even when normalised spectral densities are used (Oohi, 1982), ϵ is strictly applicable for narrow band swell systems only. Hence another spectral width parameter (r) which is independent of the frequency is defined as below to represent the true multipeaked wide band nature of the spectra (Varkey, 1986). This is found to be very reliable (see Table I and Fig. 5 also) and is discussed later in relation to other parameters.

$$r = (r_P + r_1 (E_1 / E_P) + r_2 (E_2 / E_P) + \dots \dots) / (f_u - f_l)$$

where,

r_P = half energy band width of the highest spectral peak

r_1, r_2 = half energy band widths oof other spectral peaks

E_P = highest spectral peak value, $E_1, E_2 \dots$ = other spectral peak values, and f_u, f_l = highest and lowest frequencies in the valid spectral range (0.33 and 0.05).

Figure 1 shows two recorded and computed wave profiles (WAPD01 and WAPD17); one a narrow band swell spectrum and the other a wide band multipeaked spectrum. The computed profiles show large changes. It is seen that the modulated observed profile (WAPD17) is changed to a demodulated one. Here, it should be mentioned that even the computed profile does not include waves with periods less than 3 sec. Below 3 sec. it is found that application of the attenuation correction results in very unrealistic estimates of specrail densities (Varkey and Gopinathan 1984).

Figure 2 shows Normal fits to the computed wave profiles obtained from the attenuation corrected variance spectra. In Fig. 2 from 'a' to 'e' the spectral width parameter (r) increases regularly. Comparing Figs. 2 and 3, it could be seen that the two wide band sea states (WAPD16 and WAPD17) whose

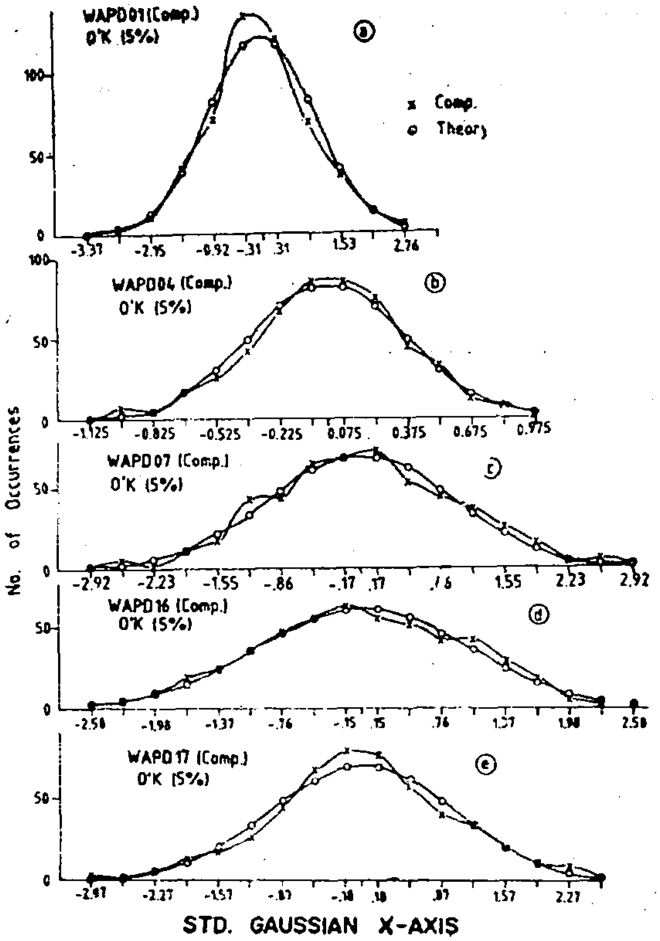

Fig. 2. Normal fits to computed surface wave profiles of some selected records.

recorded amplitudes do not fit into Normal law, after attenuation correction, provide surface amplitude profiles which agree well with the Normal distribution. Eventhough, this effect is not so conspicuous for narrow band spectra the computed profiles do show small χ^2 values. Fig. 4 shows the dependence of the χ^2 values on the effective spectral width parameter (r). The χ^2 values show an increasing trend (AB) with r for the recorded profiles. This is so because as r increases and as the number of peaks increase more of the high frequency range is covered by the spectrum and the attenuation correction affects the spectral area more and more (see Fig. 5 also) since the correction factor increases exponentially towards high frequency. The computed profiles show a decreasing trend (CD) due to the large effects of attenuation correction on the computed profilles (see Fig. 1 also) bettering the χ^2 levels even compared to the narrow band cases. The two lines AB and CD join over the narrow band range of r showing the null effect of attenuation correction for narrow band cases. Line EF (Fig. 4) shows the percentage reduction χ^2 values for the different spectra.

The line steeply rises as r increases since the percentage change of χ^2 is directly related to the relative energy content over the high frequency range.

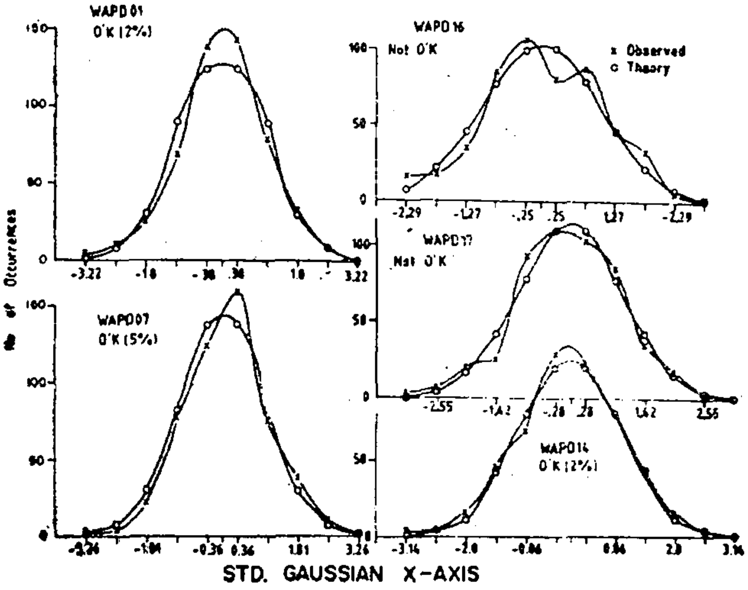

Fig. 3. Normal fits to recorded surface wave profiles of some selected records.

Table I presents various parameters derived from the spectra and the Normal fits. Comparing ϵ and r and the different spectra in Fig. 5 it is clearly seen that the effective spectral width parameter (r) represents truly the real nature of the spectra r also idealy varies from 0 to 1. For narrow band swells (eg. WAPD01) r would be very small (eg. 0.089) and for multipeaked sea states

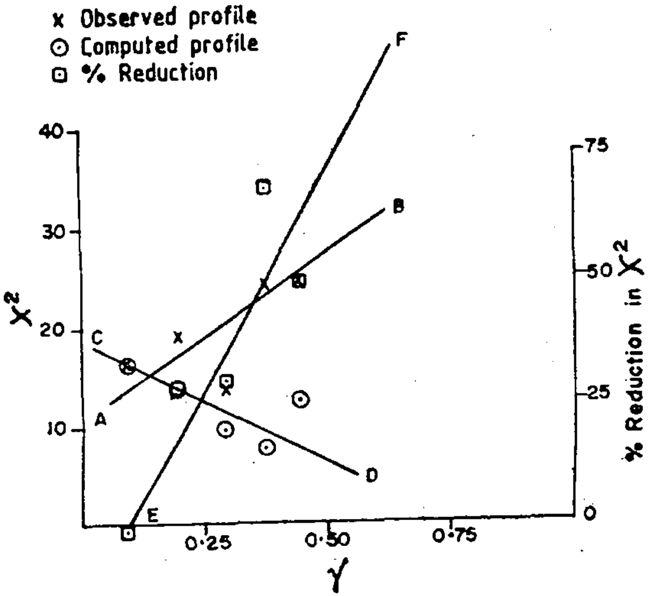

Fig. 4. A plot of effective spectral width (r) versus χ^2 and its percentage reduction.

Table I - Different parameters derived from the various spectra and the normal fits.

Record	ε	ν	χ^2			Variance (m^2)			Skewness		Kurtosis		Appro. Vari. (m^2) for	
			Rec.	Comp.	%Red	Rec.	Comp.	% Inc	Rec.	Comp.	Rec.	Comp.	Highest Peak	Oth. Pea
WAPD01	0.87	0.089	16.3	16.6	-01.8	0.0445	0.0600	34.8	−0.141	+0.012	3.161	3.313	0.0178*	0.0082
WAPD14	0.76	0.191	19.2	13.8	28.1	0.0686	0.1318	92.1	−0.189	−0.128	2.997	3.106	0.0380*	0.0185
WAPD07	0.49	0.293	13.9	9.9	28.8	0.0428	0.1910	364.3	+0.052	0.106	2.869	2.864	0.0638+	0.0148
WAPD16	0.65	0.372	24.3	7.8	67.9	0.0876	0.2430	177.4	−0.040	+0.095	2.658	2.959	0.0205*	0.0918
WAPD17	0.65	0.444	24.6	12.6	48.8	0.0697	0.1840	164.0	−0.272	−0.089	3.368	3.344	0.0182*	0.0752

Spectral maximum in the (+) high frequency and (*) low frequency region.

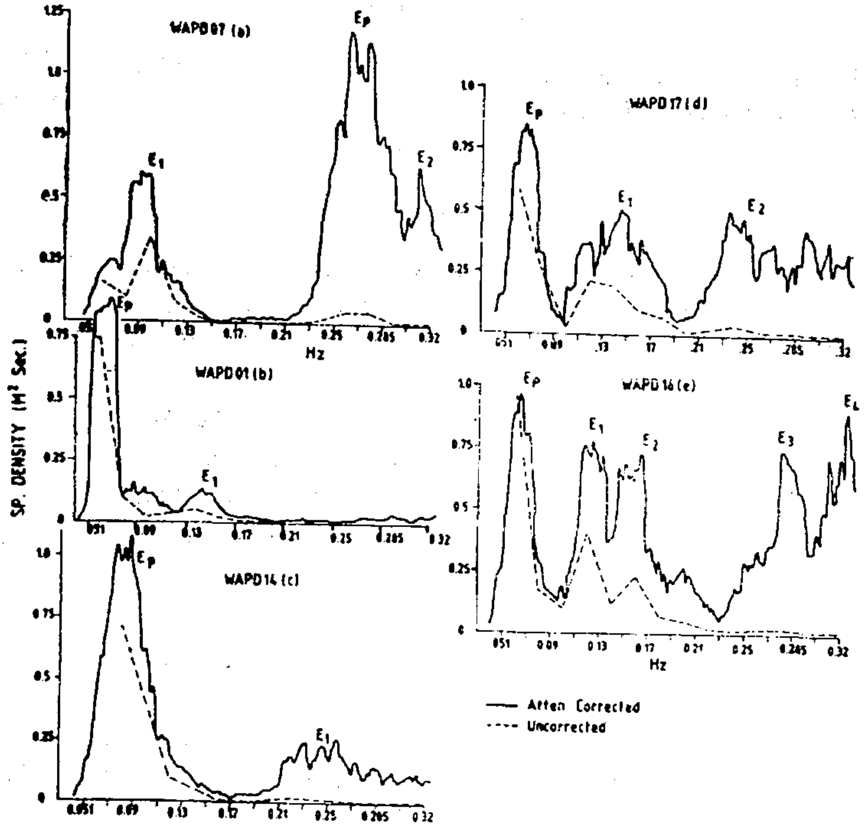

Fig. 5. Attenuation corrected and smoothed (running average of 11 points) variance spectra for the selected set of records; dashed profiles are of uncorrected spectra (segment average of 11 points).

(eg. WAPD17) *r* is found to be large (eg. 0.444). *r* is also independent of the frequency ranges over which the spectral peaks occur. In naturaly occuring normal sea states *r* could be expected to vary from 0.01 to $\sim$ 0.5. A close look at the variations in the 2-nd 3-rd and 4-th central moments (variance, skewness and kurtosis) reveals some interesting features. The first moment (mean) is always adjusted to zero. The two swell dominated records (WAPD01) and WAPD14) improved their 3-rd moments (horizontal asymmetry between crest and trough) but the 4-th moments (vertical asymmetry of crest and trough) showed increased variations from Normal probability law. In the case of the two multipeaked spectra (WAPD16 and WAPD17), the variances showed almost same amount of increase ($\sim$170%). For WAPD16 skewness becomes bad but the kurtosis becomes better. For WAPD17 the skewness improves with the kurtosis remaining almost the same. With almost the same type of spectra for both WAPD16 and WAPD17, the reason for the different trends in skewness and kurtosis is not clear. For WAPD07 which showed 346% increase in variance with attenuation correction, there is no change in kurtosis but the skewness increased by 0.06 (insignificant). The reasons for the differences observed between WAPD07, WAPD16 and WAPD17 are not clear.

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