Mahasagar-Bulletin of the National Institute of Oceanography, 19 (2), 1986, 79-85

INFLUENCE OF RECORD LENGTH AND SAMPLING INTERVAL ON OCEAN WAVE SPECTRAL ESTIMATES

M. BABA, C. M. HARISH AND N. P. KURIAN
Regional Centre, Centre for Earth Science Studies, Cochin-682 018.

ABSTRACT

The influence of length of the record, sampling interval etc. on the ocean gravity wave spectral estimates is examined. A record of 512 sec. or more duration gives reasonably stable spectra. The sampling interval has to be as short as possible to get the best results. When sampling interval and lag value influence the spectral peakedness parameter, Qp, the significant wave height estimates are influenced by the record length only. The period corresponding to the highest peak of the spectrum is controlled by spectral resolution.

Key-words : Wave spectra, spectral parameters, spectral computations.

INTRODUCTION

Spectral analysis of ocean wave records gives information on the distribution of wave energy at different frequencies. Also the spectral estimates are utilized for obtaining different standard wave parameters of height, period, etc. (Goda, 1970; Thompson, 1980). However, the stability, resolution and accuracy of the spectrum depends on many parameters, such as record length, sampling interval, number of lags, etc., (Tuckey, 1949; Harris, 1972; Shadrin, 1972; Carvalho, Ramos & Moraes, 1970; Fernandez, Gouveia, Sathe & Nagarajan, 1981; Vethamony, Gopalkrishna & Varkey, 1984 and Harsh & Baba, 1985). An attempt is made here to investigate the influence of few of these parameters on the spectral estimates and to select the optimum sampling interval, record length, etc.

MATERIAL AND METHODS

Wave records are being collected from Alleppey, Kerala, at a depth of 5.5 m using a pressure-type recorder (the transducer of which is kept at a depth of 3 m from the Mean Water Level) as a part of the 'CESS Wave Project' (Baba, Kurian, Thomas, Kumar, Hameed & Harish, 1983). One of the records thus collected was subjected to detailed analysis. The 20 min record was digitized at 0.5 sec interval and the spectra was computed using a standard auto-covariance programme. The pressure recorder gave maximum frequency response below 0.3 Hz (Fig. 1). In order to find the effect of sampling interval, (Δt) record length, (L) and the number of data points, (N) on the spectral estimates they varied between $\triangle t$ = 0.5 — 2.0 sec, L = 256 — 1024 sec and N = 512 — 2048 respectively. In addition to the above the number of lags, (M) which is usually taken as < N/10 varied from 40 to 70. The Nyquist frequency ($1/2 \triangle t$) varied between 0.25 and 1.0, which is sufficiently high compared to the frequency response of the recorder. With the above parameters the spectral resolution varied in the range of 0.005 to 0.02 Hz (Table I). The raw spectral densities are smoothned using a Hanning window. As recommended by Tuckey (1949) and as reported by many workers (Houmb and Overvik, 1976, etc.) the statistical errors in the spectral estimates are assumed to be Chi-square distributed with γ degrees of freedom (= 2N/M), which varied in the present case between 20 and 82 for different estimates (Table I). As shown in this Table, the normalized standard error of the spectral density estimates ($E = \sqrt{2/\gamma}$) varied between 16 and 31%. The pressure attenuation which is negligible in the present case do not have any significant role as it is a comparative study of different spectral estimates from the same record. The wave parameters like the period corresponding to the main peak of the spectrum, T_P the significant wave height, H_S the spectral peakedness parameter, Q_P were obtained from the spectral estimates using standard methods (Goda, 1970; Narasimhan & Deo, 1979) and these results are also presented in Table I.

Table I: Influence of sampling interval, record length etc. on the spectrally obtained parameters.

Sampling interval	Record length	No. of points	No. of lags	Spectral resolution	Degrees of freedom	Normalized standard error in %	Significant wave height	Peak period	Peakedness parameter
$\triangle t$ (sec)	L (sec)	N	M	$\triangle f$ (sec)	γ	E	H_S (m)	T_P (sec)	Q_P
					(a)				
0.5	256	512	50	0.0200	20	31	0.80	12.5	1.10
0.5	512	1024	50	0.0200	41	22	0.72	12.5	1.04
0.5	1024	2048	50	0.0200	82	16	0.69	12.5	1.08
					(b)				
0.5	1024	2048	50	.0200	82	16	0.69	12.5	1.08
1.0	1024	1024	50	0.0100	41	22	0.69	14.3	1.26
2.0	1024	512	50	0.0050	20	31	0.69	14.3	1.48
					(c)				
0.5	256	512	50	0.0200	20	31	0.80	12.5	1.10
1.0	512	512	50	0.0100	20	31	0.72	14.3	1.25
2.0	1024	512	50	0.0050	20	31	0.69	14.3	1.48
					(d)				
1.0	1024	1024	40	0.0125	51	20	0.69	13.3	1.20
1.0	1024	1024	50	0.0100	41	22	0.69	14.3	1.26
1.0	1024	1024	60	0.0083	34	24	0.69	15.0	1.27
1.0	1024	1024	70	0.0071	29	26	0.69	14.0	1.30

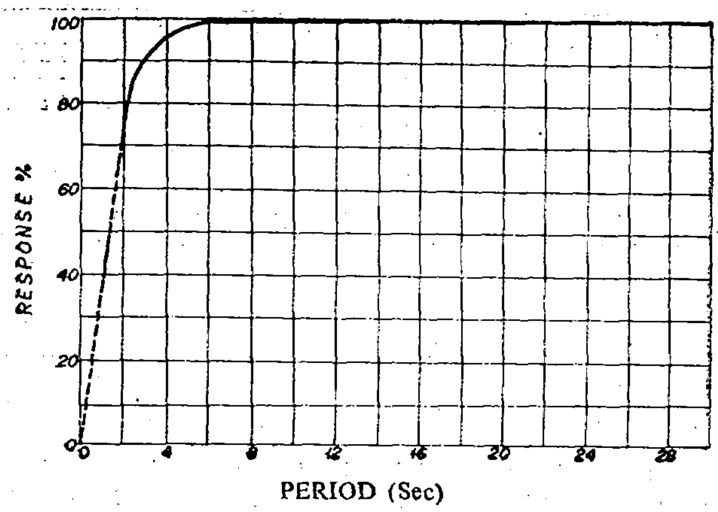

Fig. 1. Frequency response of the pressure sensor.

RESULTS AND DISCUSSION

Length of record

The computed spectra for the different length of wave records are presented in Fig. 2. It is found that with a decrease in the duration of the records the energy estimates show an increase and the deviation is highest for the shortest length, i.e. 256 sec. The latter clearly lies beyond the accuracy limits of the spectrum of the longest record. The increase in the length beyond 512 sec. gives very little deviation. Similarly among the spectrally obtained parameters (Table Ia) only $H_{\bar{s}}$ showed some variation that too within 8%. The difference in H_s obtained for the longest records is quite insignificant. This leads to assume that the best estimates are obtained for L $\leq$ 512 sec. This is in conformity with the observation of Harris (1972) and Shadrin (1972). Krilov, Strekalov & Tzipluhin (1976) suggests that increase in statistical stability is attained by way of increasing the length of the record. But Harris (1972) showed that smoothness and stability of the spectrum do not change much beyond L = 1024 sec.

The duration of record, of course, must depend on the period of the phenomenon of interest (Harris, 1972). For example, records longer than 1024 sec. would be used for the study of surf beat or harbour surges, since the period of importance in these phenomena are much longer than the characteristic periods of the waves generated directly by winds. Selection of the longest possible record increases the precision of the analysis (Harris, 1974). Krilov, Strekalov & Tzipluhin (1976) also suggests long records with high resolution for accurate analysis of cases involving neighbouring major peaks.

Sampling interval

For a constant length of record the sampling interval, Δt brings in considerable changes in the spectral estimates (Fig. 3). In addition to the significant

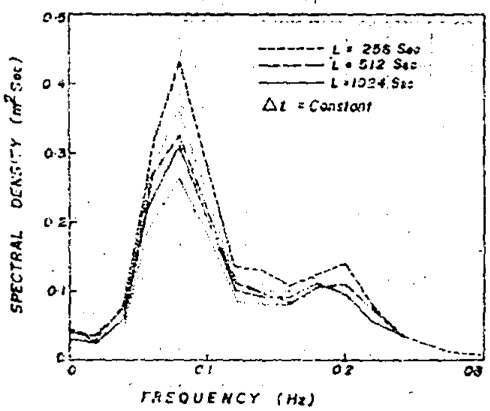

Fig. 2

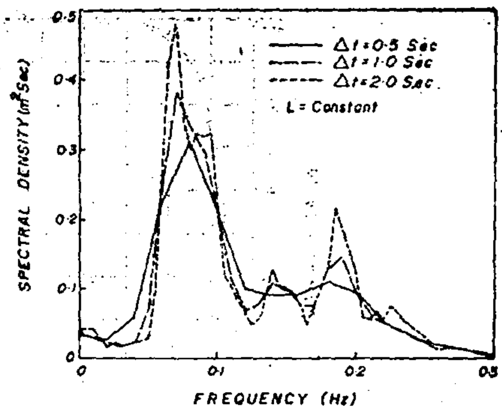

Fig. 3

Fig. 2. Wave spectra for different record lengths, L (corresponds to Table Ia). Dotted lines indicate the confidence limits of spectral estimates for L = 1024 sec.

Fig. 3. Wave spectra for different sampling intervals, $\triangle t$, with constant record length, L (corresponds to Table Ib).

increase in the energy density at the peaks of the spectrum around 0.08 and 0.2 Hz with an increase in $\triangle$ t, the shape of the spectrum itself undergoes significant changes with the appearance and growth of more secondary peaks. The very fact that these extra secondary peaks at higher frequencies appear with an increase in the sampling interval, gives evidence that they do not represent any physical process associated with the waves. This is explained to be due to the inadequacy of sufficient sampling interval to characterise the high frequency end (Shadrin, 1972).

By keeping the number of data points constant (N) at 512, the spectra showed much variability with an increasing $\triangle$ t (Fig. 4). Here the changes are observed mainly in the shape, but the energy at the main peak remained unaltered. The growth of secondary peaks observed with increasing $\triangle$ t may be given the same reasoning as in the case of Fig. 3.

Comparing Table I a, b & c, it may be seen that the sampling interval, $\triangle$ t do not have any influence on H_S Similar observations have been reported by Goda (1974). However, the record length shows similar (as with a constant $\triangle$ t mentioned earlier) influence on H_S with a varying $\triangle$ t when the record length is varied in the same range. At the same time variation in the number of data points do not change the H_S values. Harris (1972) did not find any change in the H_S value with an increase in record length in the case of records longer than that in the present study. The shift (16%) in the peak period of the spectrum when the sampling interval $\triangle$ t increases from 0.5 sec. is the same for the cases of both constant number of data points, N or constant length of record. Same is the case with the peakedness parameter, Q_P which showed a systematic increase with $\triangle t$ as is predicted by Goda (1974). This parameter is very sensitive to $\triangle$ t and hence special care may have to be given during its interpretation.

The sampling interval should be kept as short as possible in order to secure accurate analysis of wave periods (Goda, 1974). The upper limit for $\triangle$ t will be determined as a compromise between the accuracy and efficiency of data analysis, but the results of the simulation analysis of Goda (1974) suggests that $\Delta t = 0.05\, Tp$ will be a practical choice.

Number of lags

The number of lags, M should be less than N/10 in spectral computations. However, it is also to be decided from the following two mutually conflicting criteria of confidence and resolution (Tukey, 1949; Cavalho, Ramos & Moraes, 1970). In order to obtain high statistical confidence in the spectral estimates the degrees of freedom, should be large, which means the number of lags should be small ($\gamma = 2N/M$) At the same time an increased spectral resolution is attained by increasing the number of lags. Thus the proper selection of lag number is crucial for obtaining accurate and more realistic spectral estimates keeping in view the use of results.

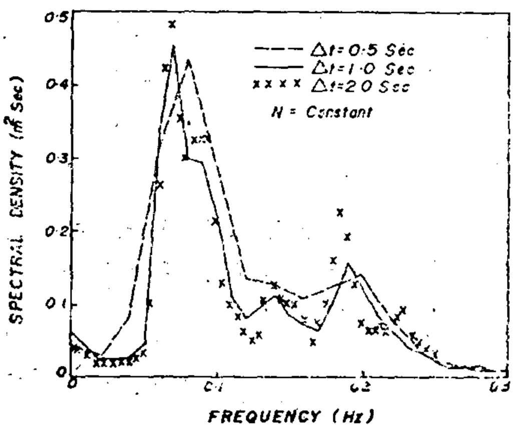

Fig. 4

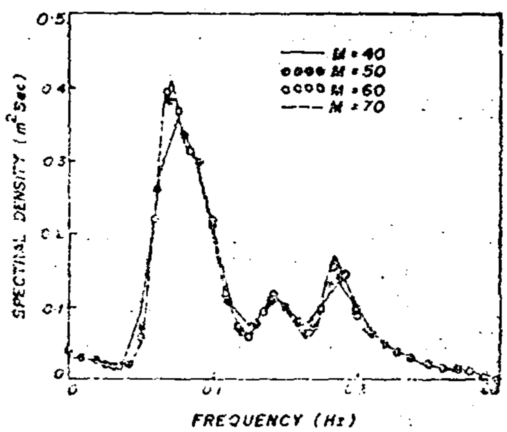

Fig. 5

Fig. 4. Wave spectra for different sampling intervals, Δ t, with constant number of points, N (Corresponds to Table Ic).

Fig. 5. Wave spectra for different number of lags, M (corresponds to Table Id).

The characteristics of the spectra for a small range of M (the range is selected considering the above) are presented in Fig. 5. Compared to the influence of Δ t L or N the influence of M on the spectral estimates is very small and lies within the standard error estimates. However, a slight growth in the energy density at the peak is observed with an increasing M. Similar growth has been earlier reported by Krilov, Strekalov and Tzipluhin (1976).

These changes in number of lags do not change H_S (Table Id). Some small shifts observed in the peak period, T_p are within the limits of the spectral resolution. This leads to assume that the best T_p value will be the one obtained from a spectrum with maximum resolution. Q_P is found to increase with an increase in M. Eventhough the maximum increase observed is only about 8%, considering the small range of number of lags in the present study, its influence on Q_P is significant as observed earlier by Goda (1983).

Thus within the limits of this study it is found that the record length influences the spectrum below 512 sec. and above this the spectral estimates are practically stable. However, the sampling interval has considerable influence on the spectra and it has to be chosen as a compromise between accuracy and efficiency. The relationship suggested by Goda (1974), i.e. $\Delta t = 0.05\ Tp$ seems to be appropriate for selecting the sampling interval. When sampling interval and maximum lag influence the peakedness parameter, Q_p the significant wave height Hs is influenced only by the record length. The spectral resolution which is controlled by Δt and M seems to be important in determining the value of peak period. T_p. An appropriate selection of spectral resolution, considering the above criteria also with respect to Δ t and L. will give the best T_p values.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Harsh K. Gupta, Director and Dr. Tapas K. Mallik, Head (MSD), CESS for encouragement and permission to publish this paper.

REFERENCES

Baba, M., N. P. Kurian, K. V. Thomas, M. P. Kumar, T.S.S. Hameed and C. M. Harish, 1983. Wave Project (1980). *Technical Report,* Centre for Earth Science Studies, Trivandrum No. 29-83, 28 pp.

Carvalho, M. M., F.S. Ramos and C.C. Moraes, 1970. Spectral computations on pressure wave gauge records. *Proceedings of Twelth International Conference on Coastal Engineering,* ASCE, washington, 65-83.

Esteva, D. and D. L. Harris, 1970. Analysis of pressure wave records and surface wave records. *Proceedings of Twelfth International Conference on Coastal Engineering,* ASCE, Washington, 101-116.

Fernandez, A.A., A.D. Gouveria, P.V. Sathe and R. Nagarajan, 1981. Wave observations in the Mahanadi Basin (Bay of Bengal) during September, 1980. *Mahasagar — Bulletin of the National Institute of Oceanography,* **14** : 239-249.

Goda, Y., 1970. Numerical experiments on wave statistics with spectral simulation. *Report of Port and Harbour Research Institute.* **9** (3) : 3-57.

Goda, Y., 1974. Estimation of wave statistics from spectral information. *Proceedings of the International Conference on Ocean Wave Measurement and Analysis.* ASCE, New Orleans, 320-337.

Goda, Y., 1983. Analysis of wave grouping and spectra of long-travelled swells. *Report of Port and Harbour Research Institute,* **22** : 3-41.

Harish, C. M. and M. Baba, 1985. On spectral and statistical characteristics of shallow water waves. *Ocean Engineering (in press).*

Harris, D. L., 1972. Characteristics of wave records in the coastal zone. In : *Waves on beaches and resulting sediment transport,* Academic Press, 1-51.

Harris, D. L., 1974. Finite spectrum analysis of wave records. *Proceedings of the International Conference on Ocean wave measurement and analysis,* ASCE, New Orleans, 107-124.

Houmb, O. G. and T. Overvik, 1976. Parameterization of wave spectra and long term joint distribution of wave height and period. *Proceedings* of BOSS'76, Trondheim 145-169.

Krilov, U.M., S. S. Strekalov and V. P. Tzipluhin, 1976. *Wind waves and their action on structures.* Gidrometizdat, Leningrad, 256 pp.

Narasimhan, S. and M. C. Deo, 1979. Spectral analysis of Ocean waves — a study. *Proceedings of Conference on Civil Engineering in Oceans,* ASCE. San Fransisco, 877-892.

Shadrin, E.F., 1972. On the estimation of spectral characteristics of shallow water waves. In: *Process of Development and Methods of Investigation of Marine Sea coasts,* Nauka Publications, Moscow, 124-128.

Thompson, E.F., 1980. Interpretation of wave energy spectra. *Coastal Engineering Technical Aid* No.80-5,

Tukey, J. W., 1949. The sampling theory of power spectra estimates. *Proceedings of Symposium on Application of Autocorrelation Analysis to Physical Problems. Office of Naval Research, Washington.*

Vethamony, P., V. V. Gopalkrishna and M. J. Varkey, 1984. Wave spectra and statistics off Godavari during September-October 1980. *Mausam* **35**: 199-204.