CHAPTER 117

ESTIMATION OF WAVE GROUPS PARAMETER FROM WAVE CLIMATE STATISTICS

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Abstract

Field measurement of sea surface elevation for analysis of wave groups have been carried out at the 4 wave observation points around Japan about for 6 months. As the result of analysis of coefficient variation of wave group parameter, that a record length of wave data needs more than 60 minutes for the reliable statistics of wave groups. Using the wave record of the enough length for wave groups analysis, the empirical relationship between wave group statistics and wave climate statistics is estimated.

Introduction

We have well known that wave groups cause hydraulic problems near the surf-zone, for example harbor tranquillity due to long period oscillations taken by wave groups, abrupt beach erosion due to the infragravity waves generated by breaking of wave groups, a sliding of breakwaters by continuous high waves, and fluctuations of over-topping volume on sea-walls. In spite that the grouping waves are the origin force of hydraulic problems, the research on the statistics of the wave groups which incident to beaches and harbor has not been carried out sufficiently yet. For indicating the degree of wave grouping, a lot of parameters have been proposed. For example, Goda(1970) proposed the peakedness parameter of spectral distribution, *Qp*, Funke-Mansard(1979) proposed the groupiness factor, *GF*, Kimura(1980) shows theoretically relationship between

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the run length, j, and the correlation coefficient with succeeding waves, γ_{HH}, and Battjes(1984) proposed the correlation coefficient of wave envelop curve, κ. It is no problem to use whichever parameter for the statistics of wave groups, because they have an adequate correlation each other. The statistical variability of the parameters with record length of the data is rather more important for the analysis.

This study is to discuss on the statistical variability of a wave group parameter for reliable information of wave groups and to propose the empirical formula to estimate the wave groups parameter from wave climate statistics in case of no information on the wave groups.

Field Observation

There are many wave observation stations to observe waves and to get wave climate statistics around Japan. Figure 1 shows the location of wave gages connected to the nationwide ocean wave information network(Nowphas)

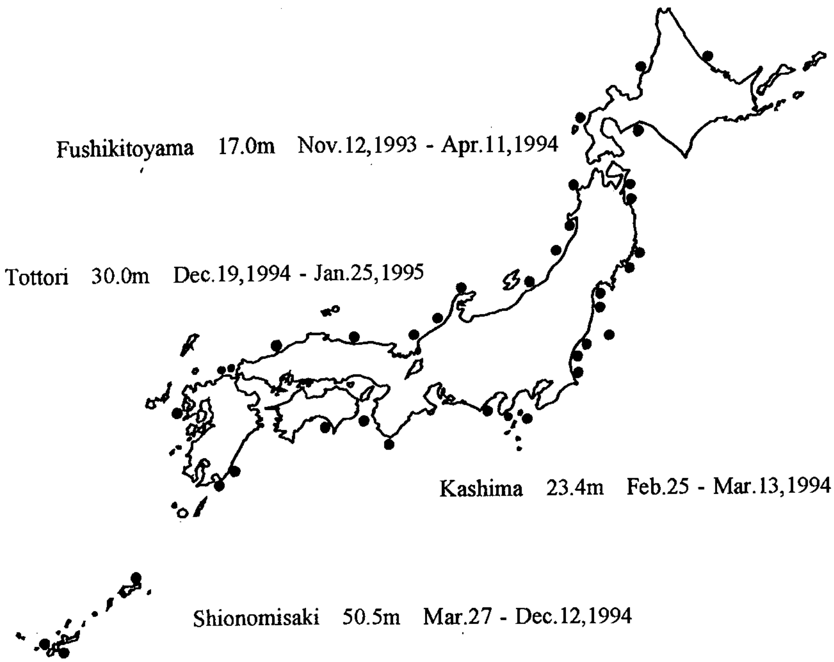

Figure 1 Location, water depth of wave gages, and observation terms

and some of the independent wave gages. This network consist of the wave gages near the big harbors. The data of this network is generally collected about 100 waves every 2 hours and sent to the Port and Harbour Research Institute. The representative value of the wave such as mean wave height and period and the significant wave height and period are computed. The data of un-networked wave gages is similarly processed at each station. This record length is enough for analysis of the representative value of the individual waves distribution, but for analysis of wave groups, it is too short to get the reliable results. Therefor, the special recordings of continuous 119 minutes every 2 hours for about 6 months of sea surface elevation are done at the 4 wave stations(Toyama, Kashima, Tottori and Shionomisaki) which are selected with a basis of the different sea condition. The locations, the establishment water depths and the observation periods of the stations are shown in the figure 1. The sea surface data divided every 2 hours is A/D transformed with a sampling interval 2 Hz and stored in MO disk. After whole data recorded, the data which has some noise was removed and the data was deducted in the tide level change. Table 1 shows the value of skewness and kurtosis of sea surface elevation each observation

Table 1 Skewness and kurtosis of surface elevation

	Skewness	Kurtosis
Fushikitoyama	0.068 ± 0.054	3.0 ± 0.079
Kashima	0.086 ± 0.041	3.0 ± 0.069
Shionomisaki	0.059 ± 0.036	3.0 ± 0.086
Tottori	0.086 ± 0.036	3.0 ± 0.081

points and their standard deviation. At the each points, the skewness almost equals to zero and the kurtosis equals to 3. These value indicate that the distribution of surface elevation is not affected of wave breaking and wave shoring.

Parameter to Identify Wave Groups

There are several parameter of wave groups. The groupiness factor *GF* is calculated in the value of coefficient variation of smoothed instantaneous wave energy history(SIWEH). The run length j is calculated in how many time the wave height which is higher than the standard height such as $H_{1/3}$ or H_{mean} happens continuously after defining the lines of individual wave heights. The γ_{HH} is by the correlation coefficient of consecutive wave heights. The spectral peakedness *Qp* is the moment of spectral distribution. The envelope correlation κ is the correlation coefficient of wave

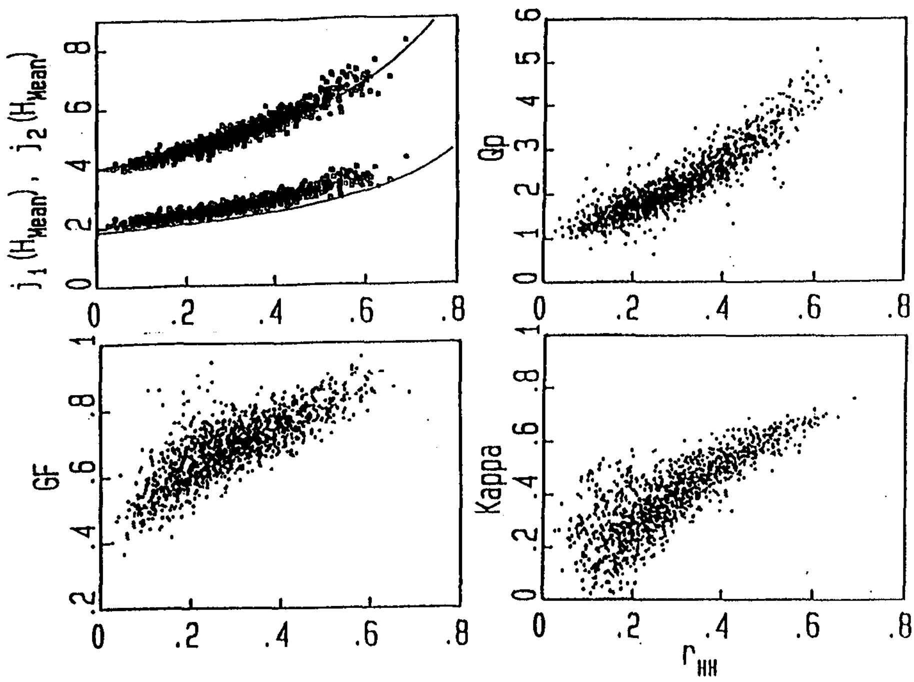

Figure 2 Relationship between γ_{HH} and others

envelop curve. The each correlation of these parameters are adequate. Among these parameters, the parameter γ_{HH} are used following analysis. Because it is easy to calculate in a series of analysing wave climate statistics based on the individual wave analysis and it is possible to change from the γ_{HH} into the others using the relationships which was gotten from field observation. Figure 2 show the relationship between γ_{HH} and other parameters. In the upper left graph, solid lines are theoretically given by Kimura. The relation in each graphs can be approximated with the simple functions. Suzuki and Kawai et al.(1994) also showed the relationships among them by numerical simulations.

Statistics Variability of Wave Groups Parameter γ_{HH}

In order to estimate statistical variability of the parameter γ_{HH} which is related to the record length, the value of coefficient variation,C.V., of the standardized parameter $\gamma_{HH}(t)/\gamma_{HH}(119)$ is used, where $\gamma_{HH}(t)$ is calculated with the record length of variable t minutes and $\gamma_{HH}(119)$ is the value with 119 minutes of data length. Figure 3 shows the change of statistical variability γ_{HH} with the record length t minutes. The solid line is the mean value of the 372 various conditions of wave groups. As the record length becomes

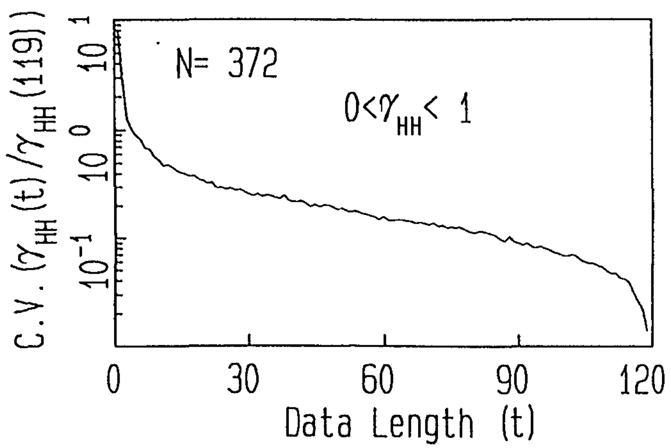

Figure 3 Change of statistical variability of γ_{HH} with the record length

long, the variability of γ_{HH} becomes small rapidly until 30 minutes and decrease of it tend to stable longer than 30 minutes. The value of γ_{HH} is reliable with a record length of 60 minutes although there is some variability in the value of γ_{HH}. As considering the sea condition change of itself, for example, the change due to the movement of the low atmosphere pressure, it is necessary for wave groups analysis to observe among from 60 minutes to 120 minutes. In this paper, the record length of 119 minutes is used for further analysis. Figure 4 show the relative frequency of the parameter γ_{HH} at the 4 observation points. In each figure, The symbol *N* shows total number of records. There is a difference in the occurring frequency of the large value of γ_{HH}, because the total number is not equal.

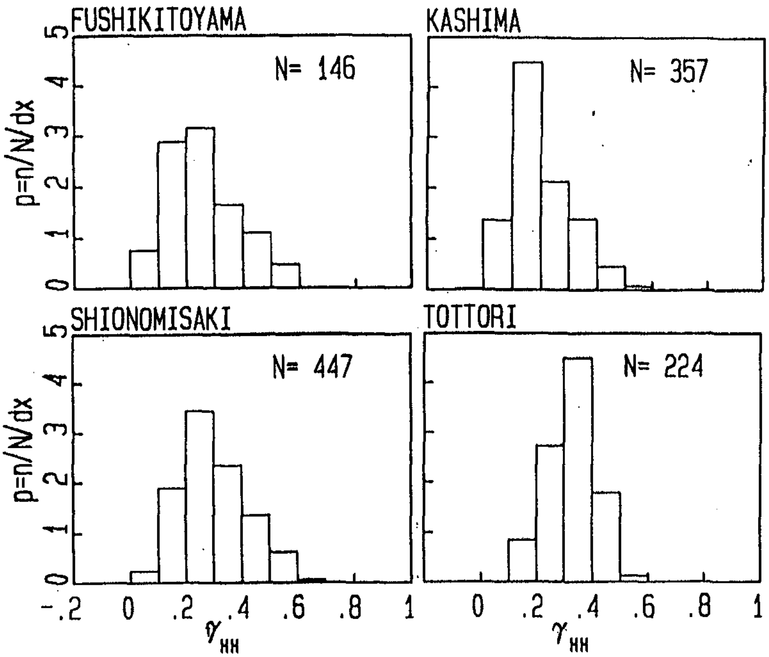

Figure 4 Relative frequency of γ_{HH}

Relationship between Wave Group Statistics and Wave Climate Statistics

It is necessary to record as a lot of waves as possible from now, to study on wave groups structure, and to process statistics of the wave group characteristics. As for getting a statistical value of it, however, the long terms are needed by getting a reliable value because strong wave groups happens rarely. Then, for information of wave groups, it is necessary to show the degrees of the wave group using the characteristics of wave climate such as ($H_{1/3}$, $T_{1/3}$) and (H_{mean}, T_{mean}) which is obtained enough at many ports. As for the study on the statistics of the wave characteristics, a principal objective is placed in the height of the waves. For example, above-mentioned $T_{1/3}$ is average period with higher 1/3 rank wave height and also the peak period T_p obtained by spectral analysis is the period with highest spectral density. In case of analysis of the wave group, the analysis to have paid attention to the period must be done. Figure 5a and 5b

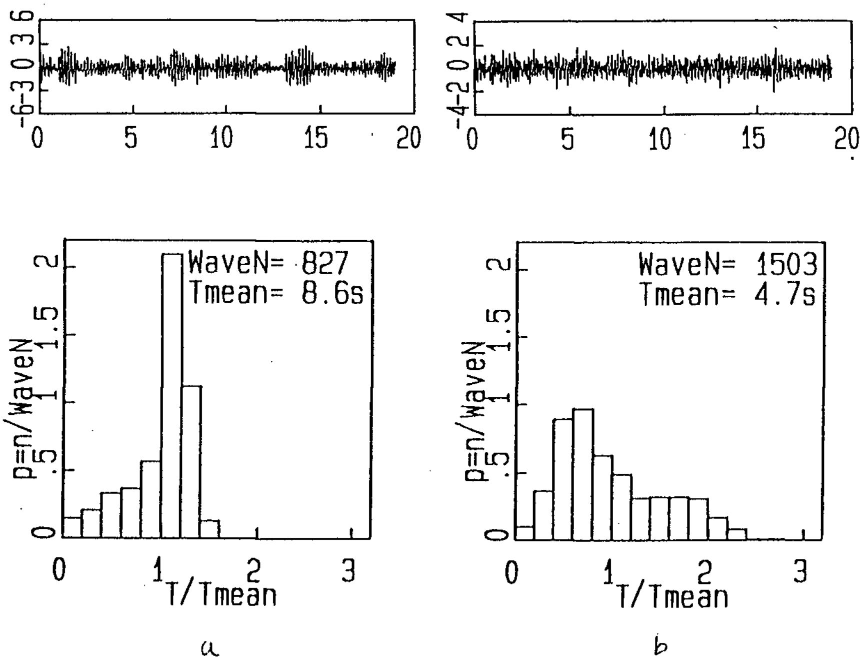

Figure 5 Time series of surface elevation and its period distributions

are the time series of surface elevation and the its non-dimensional periods distribution obtained different wave groups condition. When the wave grouping appears strongly in the time series(5a), the non-dimensional distribution of periods has a peak towards long period side. The other hand, when the wave grouping does not appear clearly(5b), the distribution has a peak towards short period side. This fact indicates that the skewness of periods distribution is related with the wave group parameter γ_{HH} . The skewness can be easily measured with the quartile skewness, *QS*, with the definition of the following:

$$QS=\frac{(T_{75}-T_{50})-(T_{50}-T_{25})}{T_{75}-T_{25}} \qquad \cdots(1)$$

where the quartile value of periods, T_{xx}, is selected in ascending order of wave period until the subscript $_{xx}$ percentage of the total number of waves is reached. When the peak leans to the large percentage with the condition of the distribution has a one peak, the value of the index *QS* is negative. When the peak leans to small side, the *QS* is positive. Figure 6 shows the

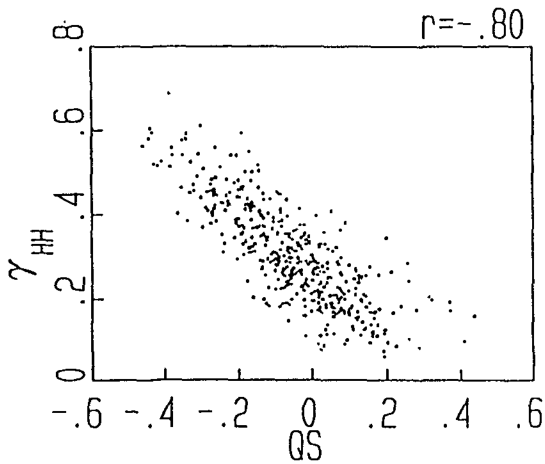

Figure 6 Relationship between γ_{HH} and *QS*

relationship between QS and γ_{HH}. Their coefficient of correlation is 80%. We find that the wave groups influence strongly in the distribution of periods. In our field wave climate observation, however, a standard procedure is not to define representative wave period such a T_{xx}, depend on the distribution of wave periods. Therefor, I use the combination parameter wave height ratio and the period ratio, which is calculate the characteristics of wave such a (H_{max}, T_{max}), $(H_{1/3}, T_{1/3})$, and (H_{mean}, T_{mean}) depend on the wave height, instead of the distribution representative period T_{xx}. For estimating the value of γ_{HH} from the value of wave heights and periods, the combination parameter $\chi^n\tau^m$, which composed of wave periods ratio $\tau = T_{1/3}/T_{mean}$ and wave height ratio $\chi = H_{1/3}/H_{mean}$ is used as the parameter QS. The powers of this parameter are defined on condition that the parameter has high correlation with γ_{HH}. Figure 7 shows the correlation coefficient between γ_{HH} and $\chi^n\tau^m$ with value of n and m. The combination parameter $\chi^n\tau^m$ has

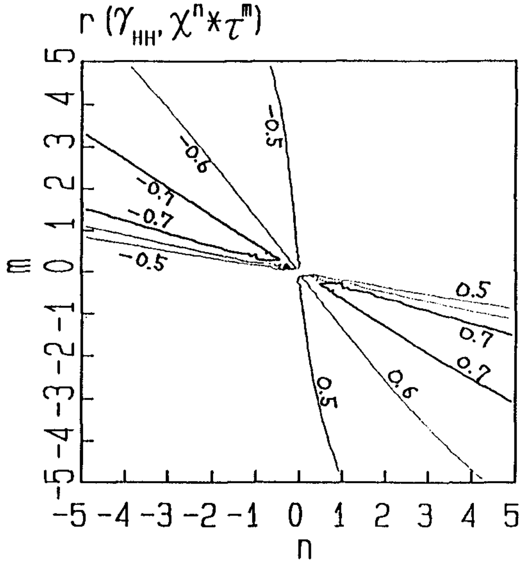

Figure 7 Correlation coefficient between γ_{HH} and $\chi^n\tau^m$

high correlation with the ratio of n and m on 5 to -2. This ratio of n and m is same at this 4 observation points. The value of n=2.5 and m=-1 are chose because the combination parameter has positive correlation coefficient and the relationship between γ_{HH} and this parameter is almost linear. The γ_{HH} is approximated with a first order function of $\chi^{2.5}\tau^{-1}$ as follows:

$$\gamma_{HH} = a\chi^{2.5}\tau^{-1} + b \qquad \cdots(2)$$

and determined the constant a and b using the least squares method. Table 2 shows the pair of coefficients a and b at each observation points. These pair of coefficients are approximately same value at the 4 observation points in spite of different sea condition

Table 2 Pair of coefficients a and b

	a	b
Fushikitoyama	0.74	-1.69
Kashima	0.69	-1.50
Shionomisaki	0.69	-1.52
Tottori	0.72	-1.57

of wave energy and direction. This result shows that the degree of wave groupiness is independent to the location of wave gages. On all seashore, the grouping waves come. Figure 8 shows a comparison of the observed γ_{HH} with the estimated one at the Shionomisaki observation point. There is a close agreement between them. The empirical formula to estimate the wave groups parameter from wave climate statistics is proposed.

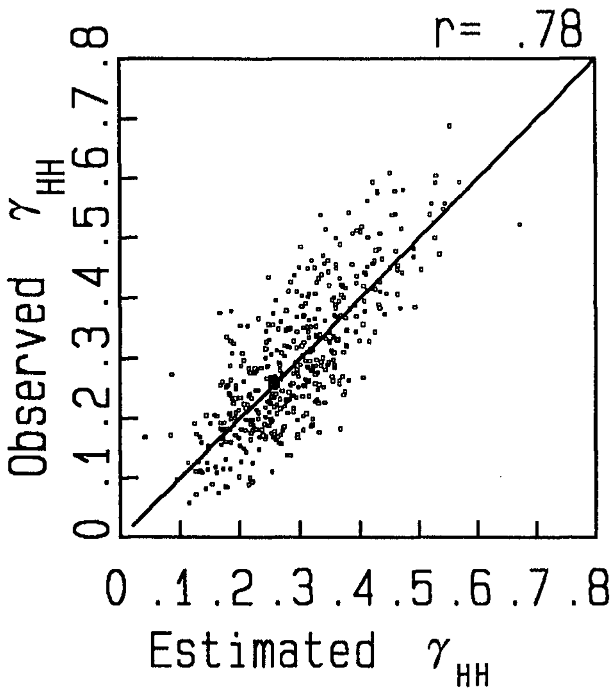

Figure 8 Comparison of observed γ_{HH} and estimated one

Conclusions

To identify wave groups, the correlation coefficient of consecutive wave heights, γ_{HH}, is easy to add in a series of analysing wave climate statistics based on the individual wave analysis. It is possible to change from the γ_{HH} into the other parameter proposed by many researchers using the relationships obtained from field observation.

The value of wave group parameter γ_{HH} is corresponded to the data record length. The reliability of γ_{HH} increases rapidly until 30 minutes of data length and increase of it tend to stable longer than 30 minutes. The value of γ_{HH} is reliable with a record length of 60 minutes although there is some variability in the value of γ_{HH}. Using the enough record length of sea surface elevation data, the relative frequency of the parameter

γ_{HH} based on the 6 months observation at 4 points are shown.

The degree of wave grouping appears on the skewness of distribution of periods strongly. The relationship between quartile skewness of distribution of periods, QS and γ_{HH} has 80% coefficient of correlation. In case that the distribution of wave periods is not calculated, standard wave climate procedure don't define representative wave period such a T_{xx}, the combination parameter, $\chi^{2.5}\tau^{-1}$, composed of wave climate statistics ($H_{1/3}$, $T_{1/3}$) and (H_{mean}, T_{mean}) have an adequate correlation with wave groupiness.

Empirical formula of the wave groupiness to estimate from wave climate (equation 2) is proposed. The coefficients are constant regardless of the observation points.

References

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Professor Robert L. Wiegel and Rebecca D. Edge at San Francisco Seawall, California. Photo courtesy of Billy L. Edge.

PART III

Coastal Structures

Detached breakwaters at Caxambas Pass, Marco Island, Florida. Photo courtesy of Coastal Engineering Consultants, Inc.