# CHAPTER 15

## Application of Fetch Area Method in Monsoon Wave Hindcasting

Nai-Kuang Liang[1], Shih-Tsan Tang[2] and Ben-Juen Lee[3]

ABSTRACT

The Fetch Area Method ( FAM ) derived from Elementary Wave Model is used to analyze the winter monsoon wave of Taichung Harbour. The empirical wind-wave energy transfer coefficient $\xi$ determined by FAM for this area is $7.25 \times 10^{-4}$. A relationship between $g\,T_{1/3}/2\pi\bar{U}$ and $g\,t'_d/\bar{U}$ is also found, where $\bar{U}$ is the average wind speed and $t'_d$ the duration. A comparision of the wave hindcasting of FAM has shown that the latter is better than the former, and the former is valid only as the wind velocity increases, once the wind decreases the SMB Method is no more valid.

INTRODUCTION

The Fetch Area Method based on Elementary Wave Model ( Liang 1973a, 1973b ) is applicable to the wave forecasting or hindcasting, in which the influence of the whole wind field is considered.

The limited water field and the continental shelf of Taiwan Straits make us believe that the wave generated in this area should be different from that of the open sea like Pacific Ocean ( Fig. 1 ). There are some coastal stations in Taiwan where both wind and wave data are available. Among them, we are most satisfied with the completeness and perfectness of the data in the vicinity of Taichung Harbour. The hindcast work of this paper has been made on the basis of the data on the point observation of Taichung Harbour and the weather maps analyzed by Central Weather Bureau. In this paper we analyzed the wave and wind data according to the Elementary Wave Model to determine the empirical coefficient $\xi$ and the relationship of $T_{1/3}$, the average wind speed of influencing area $\bar{U}$ and the duration $t'_d$ adapted for Taichung Harbour. Using this coefficient and the relationship, one can hindcast or forecast the monsoon waves of this area.

1. Associate professor, Institute of Oceanography, National Taiwan University, Taipei, Taiwan, Rep. of China.
2. Former research assistant, Institute of Oceanography, National Taiwan University, Taipei, Taiwan, Rep. of China.
3. Meteorologist, Central Weather Bureau, Taipei, Taiwan, Rep. of China.

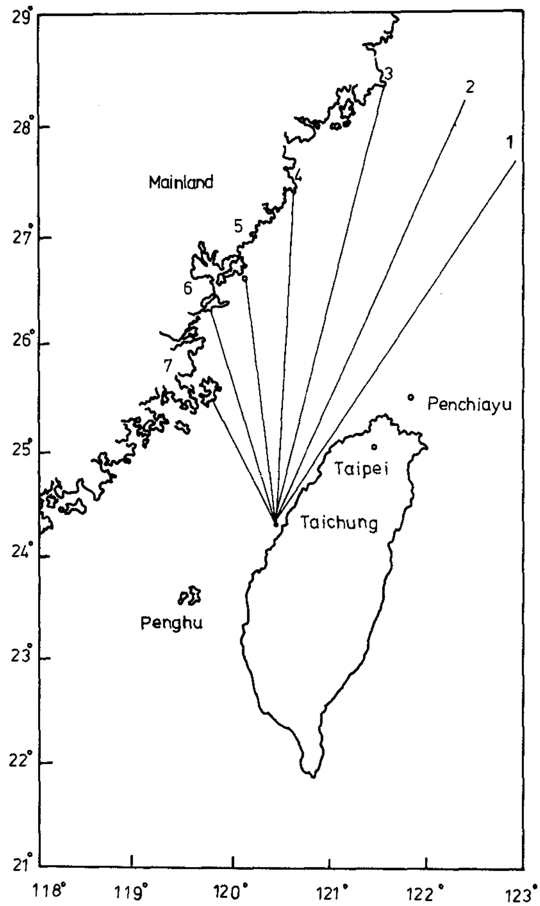


Fig.1 Taiwan Straits

## BASIC THEORY

According to the Elementary Wave Model ( Liang 1973b, 1975 ) and some modifications, the wave energy at the observation point 0 ( Fig. 2 ) is as follows:

$$E = \frac{2}{\pi G} \int_r \int_\theta \xi ( r,\theta ) U^2 ( r,\theta ) \cos^2[ \beta( r,\theta )] \exp ( - \frac{0.08}{U^2} r ) drd\theta \qquad (1)$$

where G is the equivalent group velocity and difined as

$$G = \frac{g}{2} \frac{\int_0^\infty \Phi(\sigma)\sigma^{-1} d\sigma}{\int_0^\infty \Phi(\sigma)\, d\sigma} \qquad (2)$$

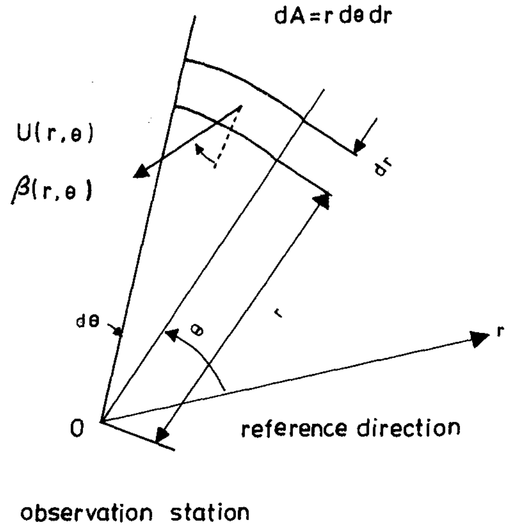


Fig.2 The coordinate system of the wind field.

in which $\Phi(\sigma)$ is the wave spcetrum. $\xi$ is a parameter which characterizes the energy transfer from wind to wave. U ( m/s ) is the wind velocity at 10m above sea level. $\cos^2\beta$ is the angular spreading function which is verified by an experiment ( Liang 1973a,b ). $\exp\left(-\frac{0.08}{U^2} r\right)$ is an e-exponential decay term, which is determined by the 100% developed seas after C. L. Bretschneider, i. e.,

$$\frac{gr}{U^2} = 600{,}000. \tag{3}$$

or

$$r = \frac{600{,}000}{g} U^2 = \frac{600}{g} U^2 \text{ (km)} \tag{4}$$

It is then supposed that the elementary wave energy at the end of the fetch of this 100% developed seas is decayed to 1/100 of the original amount, as it propagates to the observation point 0,

$$e^{-\alpha r} = \frac{1}{100} \tag{5}$$

$$\alpha r = 4.605 \tag{6}$$

From eq.(4) $\alpha \approx \frac{0.08}{U^2}$ (7)

For simplicity, we take

$G_{1/3} = \frac{gT_{1/3}}{4\pi}$ , $E_{1/3} = H^2_{1/3}$ Instead of G and E and assume $\xi$ is a constant, then we have

$$H_{1/3}^2 = \frac{2}{\pi G_{1/3}} \xi \int_r \int_\theta U^2 ( r,\theta ) \cos^2\left[\beta ( r,\theta )\right] \exp\left( \frac{-0.08}{U^2} r \right) dr d\theta \tag{8}$$

or,

$$\xi = \frac{H^2_{1/3}}{2/ (\pi G_{1/3} ) \int_r \int_\theta U^2( r,\theta ) \cos^2\left[\beta ( r,\theta )\right] \exp\left( \frac{-0.08}{U^2} r \right) dr d\theta} \tag{9}$$

## ESTIMATION OF WIND FIELD AND DETERMINATION OF INFLUENCING WIND FIELD

The preliminary data for wave forecasting or hindcasting is the information of wind field over sea areas. Unfortunately, there are few wind data available in these areas and it is believed that there are still some difficulties to determine the wind field over the ocean ( Bunting, 1970 ). Hence, we have made some objective judgement of the wind field over these sea areas. Estimates of wind field over sea areas are made on the basis of the isobaric pattern of synoptic weather charts and the wind data of nearby meteorological stations. The sea areas can be roughly divided into two regions, i.e., the region to the north of Pengchiayu and the region in the Taiwan Straits. Since the region to the north of Pengchiayu belongs to an open sea where the isobaric pattern is less influenced than that in the Taiwan Straits, the wind field in this area is estimated from the calculated wind speed and the wind data of the nearby stations.

The calculated wind speed is obtained from the geostrophic balance equation

$$Ug = \frac{1}{\rho a f} \frac{\Delta p}{\Delta n} \tag{10}$$

and some corrections with geostrophic surface-wind relationship given by

$$U = aUg + b \tag{11}$$

where a = 0.54 and b = 2.5 ( Hasse and Wagner, 1970 )

In the region of Taiwan Straits the isobaric lines are greatly curved and the presure gradient is too great to be determined precisely from the weather chart. However the wind was observed offshore of Taichung Harbour at 2 hour interval. Hence, the observed wind data at this area will be used to represent the wind field over the Straits.

The 6-hr weather map is always changing, we should assume that the wind is steady during the six hour interval. Since the winter monsoon blows steadily from the north or northeast, it's appropriate to say that the wave in the generating area is quasi-fully-developed. It is then assumed that the elementary wave energy propagates at the speed of the fully-arisen equivalent group velocity determined by the local wind, i.e, 0.5 U after Neumann. The authors use a series of surface synoptic charts to determine the influencing wind field. For example, if we try to hindcast the wave at 1400Z, Feb. 26, 1974, the weather chart at 1500Z should be checked at first. The weather charts are available at 0300Z, 0900Z, 1500Z and 2100Z. Since the weather system is assumed unchanged during the 6-hr interval, the wind field is stationary from 1200Z to 1800Z. The wind speed of Taichung Harbour at 1500Z Feb. 26, 1974 is $U_1$ = 17.4 m/s, the first influencing sector has a redius ( Fig.3 )

$$\begin{aligned} r_1 &= 0.5 \times 17.4 \times \Delta t_1 \\ &= 0.5 \times 17.4 \times 2^1 \times 3600 \ (m) \\ &= 0.6 \ (\text{lat.}) \end{aligned}$$

Then we check the former chart ( Fig.4 ) of 0900Z on which the wind speed near $r_1$ is $U_2$ = 11 m/s, Hence,

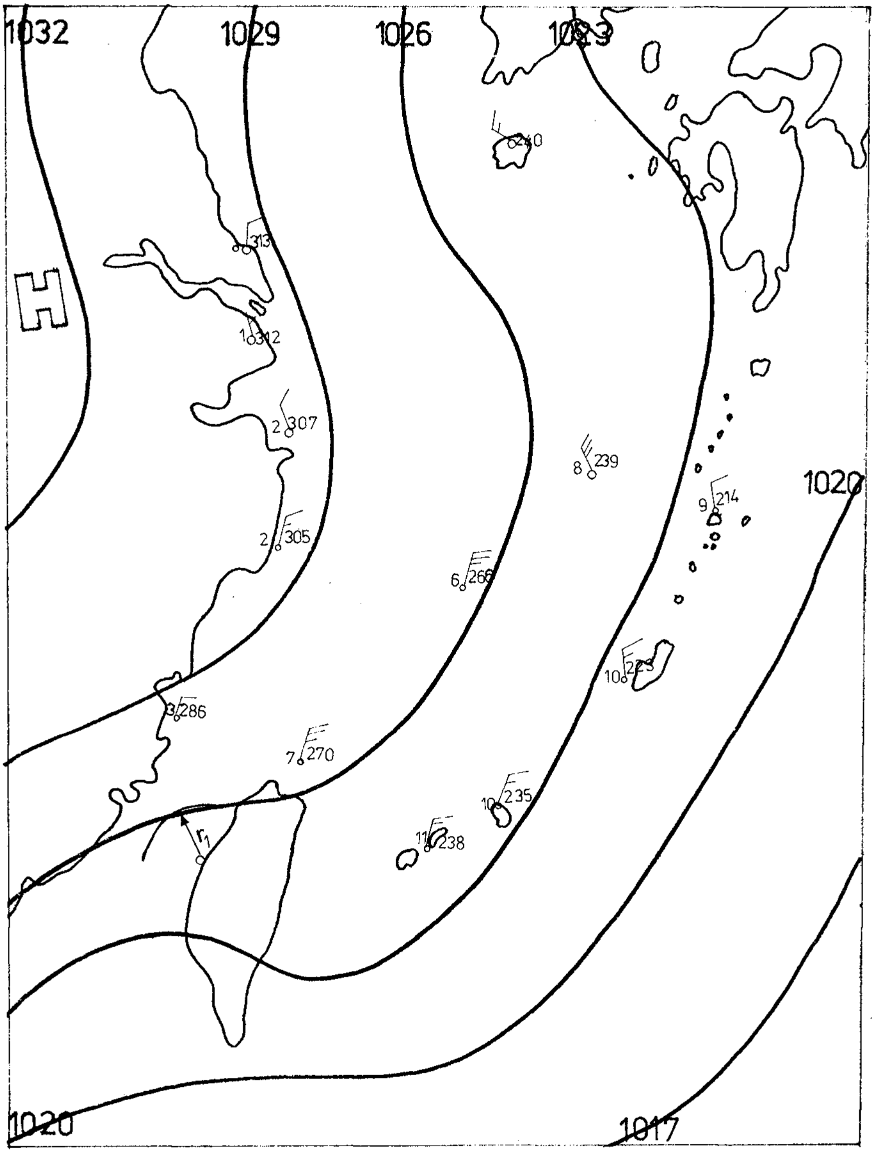


Fig.3 Surface synoptic chart for 1500Z, Feb. 26, 1974

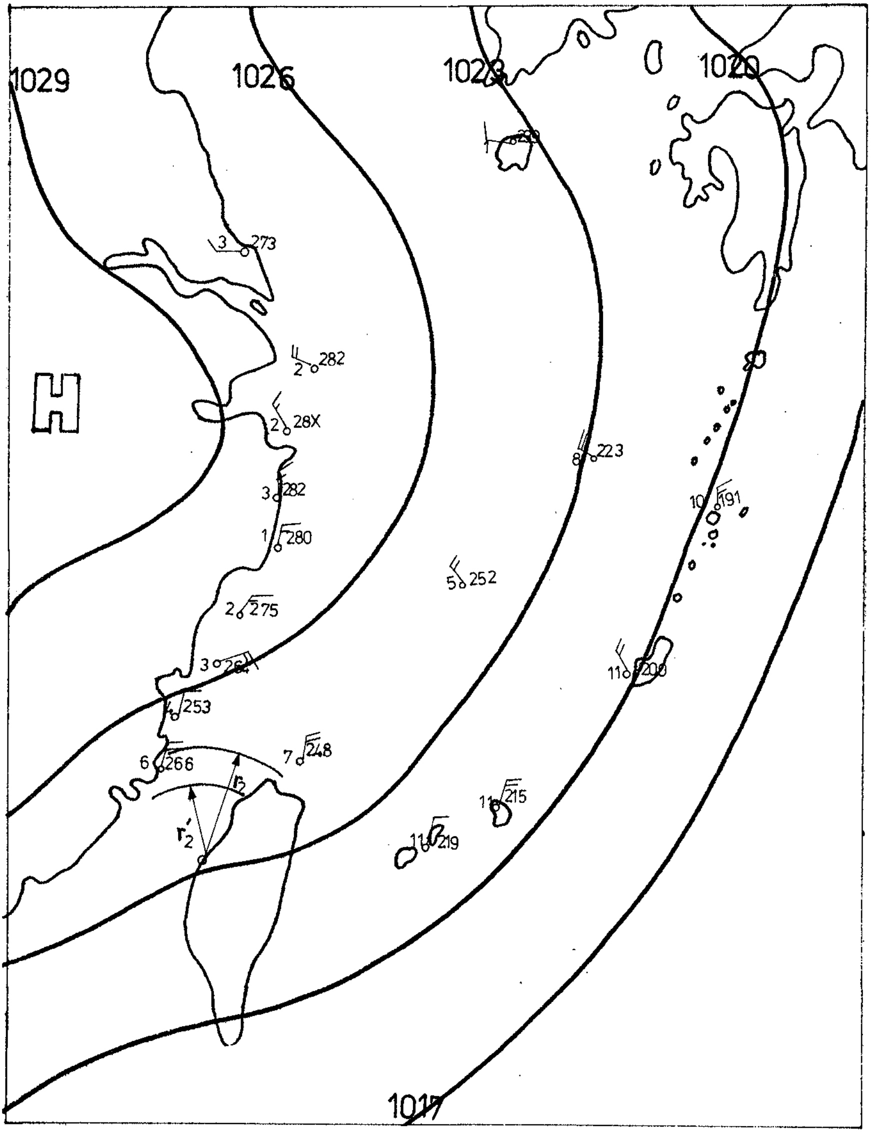


Fig.4 Surface synoptic chart for 0900Z, Feb. 26, 1974

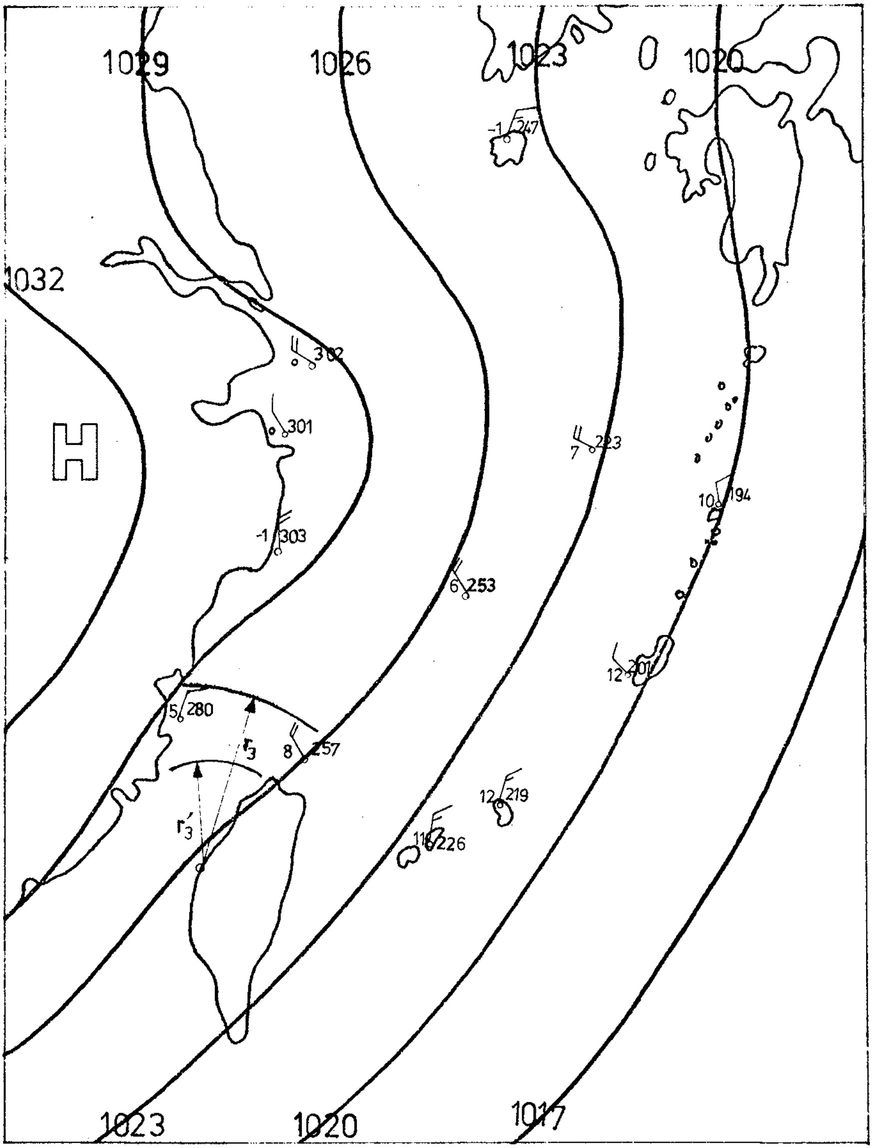


Fig.5 Surface synoptic chart for 0300Z Feb. 26, 1974

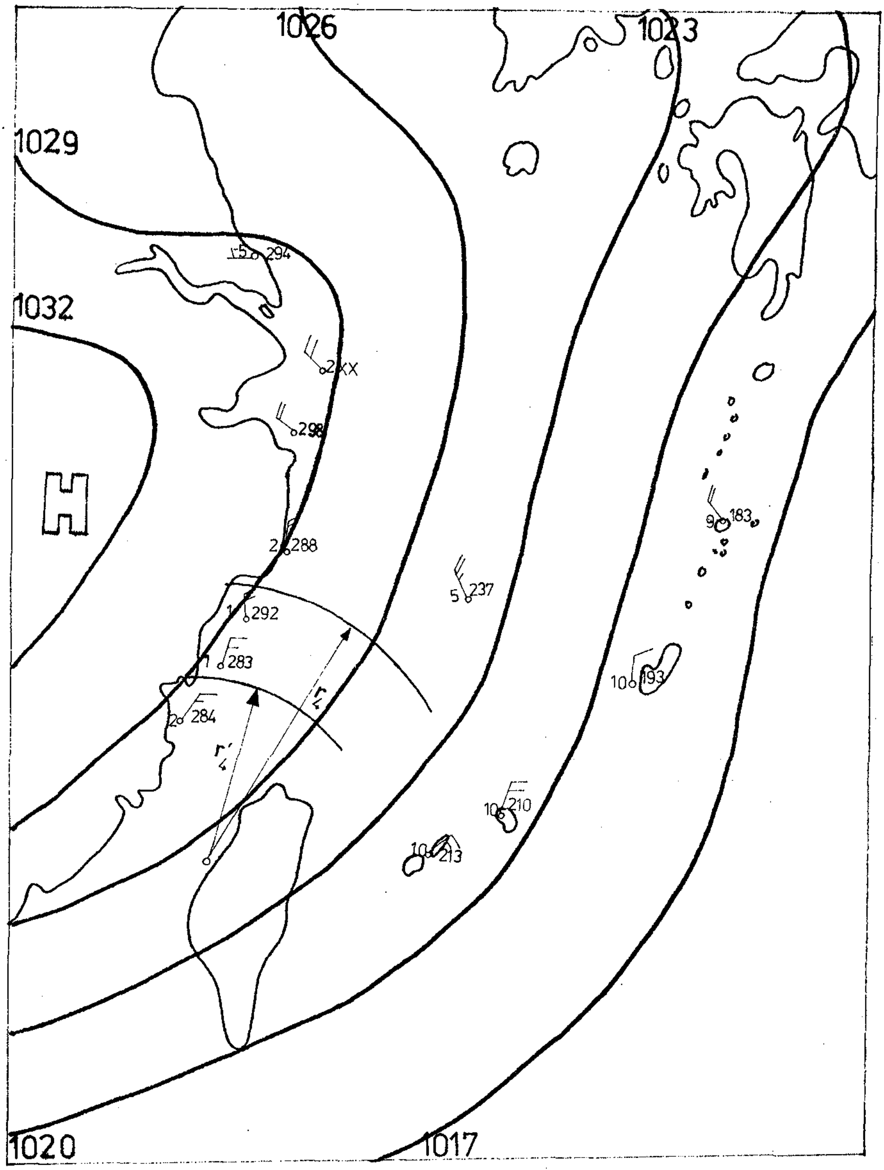


Fig.6 Surface synoptic chart for 2100Z Feb. 25, 1974

$$r_2 = 0.5 \times 11 \times ( \Delta t_1 + \Delta t )$$
$$= 0.5 \times 11 \times ( 2 + 6 ) \times 3600 \text{ (m)}$$
$$= 1.4 \text{ ( lat. )}$$

$$r'_2 = 0.5 \times 11 \times \Delta t_1$$
$$= 0.5 \times 11 \times 2 \times 3600 \text{ (m)}$$
$$= 0.4 \text{ ( lat. )}$$

Since the wind data to the north of Pengchiayu is not valid for Taiwan Straits of which the radius is about 1.0 lat., we should take $r'_2$ = 1.0 lat.

In Fig. 5, the weather chart of 0300Z shows the wind speed near $r_2$ is $U_2$ = 10 m/s. Then

$$r_3 = 0.5 \times 10 \times ( \Delta t_1 + 2\Delta t )$$
$$= 0.5 \times 10 \times ( 2 + 2 \times 6 ) \times 3600 \text{ (m)}$$
$$= 2.3 \text{ ( lat. )}$$

$$r'_3 = 0.5 \times 10 \times ( \Delta t_1 + \Delta t )$$
$$= 0.5 \times 10 \times ( 2 + 6 ) \times 3600 \text{ (m)}$$
$$= 1.3 \text{ ( lat. )}$$

In the weather chart of 2100Z, Feb. 25, 1974 ( Fig. 6 ) the wind speed near $r_3$ is $U_4$ = 11 m/s, therefore

$$r_4 = 0.5 \times 11 \times ( \Delta t_1 + 3\Delta t )$$
$$= 0.5 \times 11 \times ( 2 + 3 \times 6 ) \times 3600 \text{ (m)}$$
$$= 3.7 \text{ ( lat. )}$$

$$r'_4 = 0.5 \times 11 \times ( \Delta t_1 + 2\Delta t )$$
$$= 0.5 \times 11 \times ( 2 + 2 \times 6 ) \times 3600 \text{ (m)}$$
$$= 2.5 \text{ ( lat. )}$$

## EVALUATION OF $\xi$ and $T_{1/3}$ - $\overline{U}$ - $t'_d$ - RELATIONSHIP.

The detail to calculate eq. (9) is illustrated in Fig. 1. It consists of 7 radials from the wave station at intervals of $10^\circ$ and extending these radials until they interesect the shoreline.

With the influencing wind field determined we can calculate the integral along each radial. All the work is finished by a computer program. 233 data during the time from Feb. 7, 1974 till March 15, 1974 are selected to evaluate the $\bar{\xi}$ -value. It seems to have no correlation between $\bar{\xi}$ and wind speed.

The average value of $\bar{\xi}$ of these 233 cases is $7.24990 \times 10^{-4}$, its standard deveation is $2.19916 \times 10^{-4}$.

Two definitions have been made: $\bar{U}$ is the area average wind speed from the observation point to the sea area where the e-exponential decay term $\exp\left( \frac{-0.08}{U^2} r \right) = 0.6$ and the duration $t'_d$ is defined as the time interval between the first and the last weather chart we used to evaluate the average wind speed $\bar{U}$. A relationship of $T_{1/3}$, $\bar{U}$ and $t'_d$ is expressed as a dimensionless phase velocity $gT_{1/3} / 2\pi\bar{U}$ and dimensionless duration $gt'_d/\bar{U}$ on log-log plot ( Fig. 7 ). A linear relationship in log-log plot is suggested:

$$\frac{g\, T_{1/3}}{2\pi\bar{U}} = 0.00488 \left( \frac{gt'_d}{\bar{U}} \right)^{0.4472} \tag{12}$$

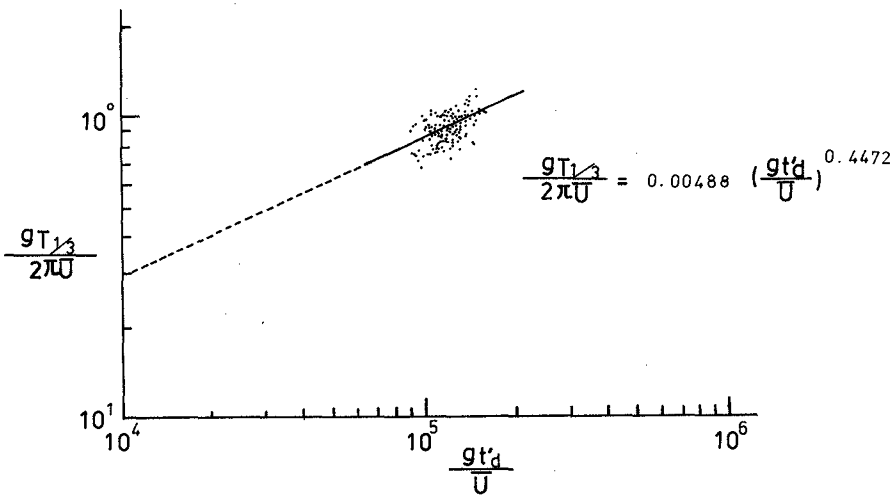


Fig. 7 Dependence of dimensionless phase velocity on dimensionless duration

## COMPARISON OF SMB AND FAM

49 wave data during the time from Oct. 28, 1975 to Nov. 1, 1975 are selected to illustrate the comparison of SMB ( U.S. Army, Corps of Engineering ) and FAM hindcasting. The FAM hindcasting is finished by a computer. We need only give the wind velecties in specified areas at 6-hr interval. The result is shown in Fig. 8. and Fig. 9. It can be seen clearly that SMB has a little better result as the wind velocity increases. Once the wind velocity decreases, SMB is no more valid. In general, FAM has a much better hindcasting. The percentage of $H_{1/3}$ and $T_{1/3}$ within specified percent error by both methods is shown in Table I.

Table I Accuracy of hindcasting

| Percent Error | Percentage of $H_{1/3}$ within Percent error | | Percentage of $T_{1/3}$ within Percent error | |
|---|---|---|---|---|
| | SMB | FAM | SMB | FAM |
| 5 | 8 | 39 | 22 | 16 |
| 10 | 22 | 61 | 33 | 43 |
| 15 | 27 | 71 | 53 | 63 |
| 20 | 35 | 88 | 73 | 84 |
| 25 | 47 | 92 | 82 | 88 |
| 30 | 51 | 94 | 90 | 96 |
| 35 | 57 | 98 | 96 | 100 |
| 40 | 63 | 100 | 100 | 100 |

## CONCLUSION

1. SMB is a good method to predict or hindcast waves when the wind is increasing. Once the wind decreases, SMB is no more valid, at least for limited water field such as Taiwan Straits.

2. In general, FAM is much better than SMB, because the former has considered the influence of the whole wind field.

3. FAM can be used for routine work, such as Fishery Weather Forecasting of the Central Weather Bureau, Taiwan, Rep. of China, if one can precisely predict the wind in the Taiwan Straits.

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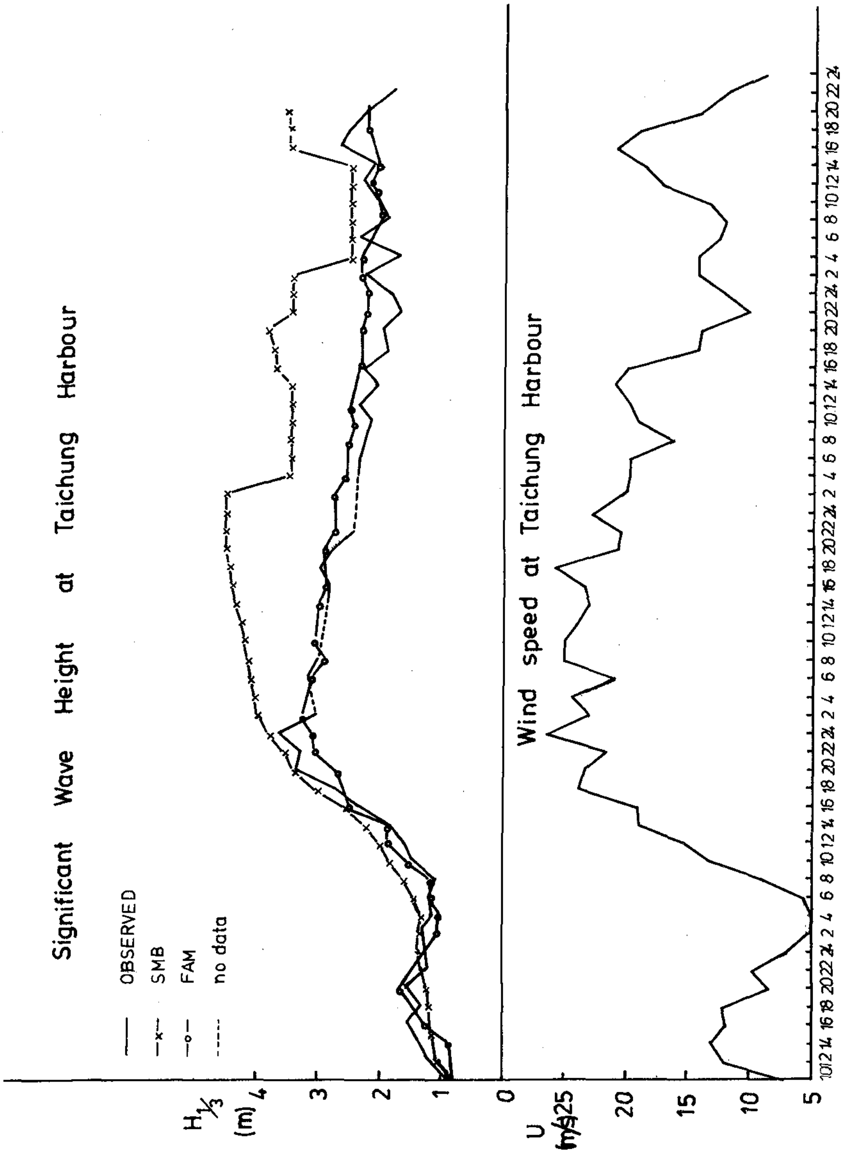


Fig.8 Comparison of significant wave heights

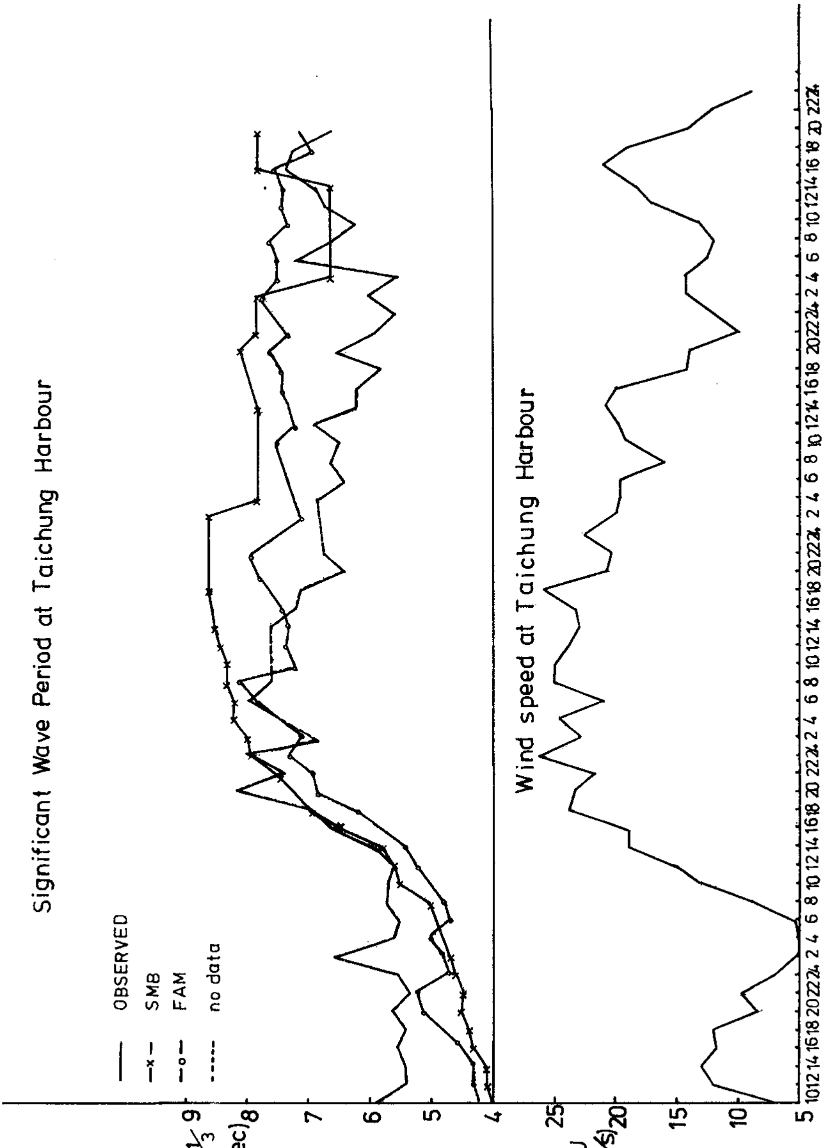


Fig.9 Comparison of significant wave periods

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