ROYAL OBSERVATORY, HONG KONG

Technical Note No. 79

PREDICTION OF THE STRENGTH OF OVERNIGHT EASTERLY WINDS IN HONG KONG IN WINTER

by

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Published March 1989

Prepared by

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551.509.322(512.317)

SUMMARY

Existing methods available to Royal Observatory forecasters for predicting easterly wind strength during easterly occasions in the cool season were verified using data in 1987-88. They were found to be not accurate enough for daily operational use. New regression equations were derived using data from 1980-87 for the maximum wind overnight at Waglan, using synoptic pressure values and wind speed at Waglan as parameters. Prediction errors of around 2 m/s were found for the equations. The equations were verified using data in 1987-88, and similar errors were found. The set of equations were also found to be only weakly dependent on the pressure pattern. An additional equation was also established for using Δ Ps values estimated from prognostic charts to give longer terms prediction of easterly wind strength.

The equations could be adopted for daily operational use in the Central Forecasting Office, their usage will assist forecasters in forecasting wind force during easterly occasions or when easterlies are expected to arrive overnight.

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TABLES

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1. INTRODUCTION

During the cool season in Hong Kong (October to April), the winter monsoon manifests itself as intermittent bursts of cold air in the form of a northerly surge or an easterly surge. The former occurs when the push from the north is strong enough to allow the cold air to penetrate through the Nanling ranges (Figure 1) and arrive at Hong Kong as northerlies. An easterly surge usually occurs when

i) The continental anticyclone responsible for the northerly surge moves eastwards, and the orientation of the isobars turn to favor winds from the east (Figure 2); and

ii) With a rapid eastward moving anticyclone, the southward penetration of cold air falls short of the Nanling ranges, and the cold air will take an alternative route, moving down the Taiwan Strait and arriving at Hong Kong as easterlies (Figure 3. See also Chin 1969). This study deals with easterly surges.

Lam (1976) and Chu (1978) found that cold surges will affect Hong Kong 2 days after a 500 hPa trough passed over Lake Baikal. Morrice (1973) developed some forecasting aids for predicting easterly wind strength during the arrival and continuation of easterlies in the cool season, but over the years his results has not been verified. In addition, he imposed a rather strict selection criterion in his investigation, namely, a "normal" pattern of east-west oriented isobars, whereas in a lot of occasions some sort of ridging can be found along the southeast China coast (Figure 3). Thus the applicability of his forecasting aids could be limited. The objectives of this work were to verify Morrice's results under more relaxed selection criteria and to establish better forecasting aids if necessary.

2. DIURNAL VARIATION OF WINDS DURING EASTERLY OCCASIONS

Definitions of an easterly occasion is again the same as that in Morrice(1973), namely, four consecutive observations at Waglan with wind directions within the range 060 and 120 and hourly mean wind speeds over 10 m/s. It has often been alleged that during easterly occasions, winds overnight are stronger than those during the day. The following is an attempt to demonstrate this point.

From the period considered, easterly occasions which satisfy the following additional criteria were selected to demonstrate the diurnal variation:

a) Winds at 15 and 21 UTC differs by less than 3 m/s and both are over 8 m/s.

b) Maximum winds in two consecutive nights both over 10 m/s.

c) 8 consecutive observations at Waglan reported easterly winds.

Conditions a and b were taken to ensure that there was no significant change in the background field during the 24 hour period, and condition c was taken so that meaningful statistics could be compiled.

In all, a total of 91 easterly occasions satisfying these three additional conditions were found. The winds at each synoptic hour were averaged over these 91 occasions, and the result is shown in Table 1.

The results suggest that winds at 21 UTC are on the average 20% stronger than those at 09 UTC. Thus a wind speed of 11 m/s overnight roughly corresponds to a wind speed of about 9 m/s in the afternoon. Therefore an easterly occasion is defined to continue if the wind speed overnight is over 10 m/s and the wind speed during the day is over 8 m/s.

3. EXAMINATION OF EXISTING FORECASTING METHODS

a) Geostrophic winds

A first estimation of the windspeed is by using the gradient wind formula. However, the curvature of the isobars is difficult to measure and there is a lot of subjectivity in its determination. Hence a simpler approach is taken and the geostrophic wind is used instead.

The geostrophic wind is given by the following formula:

$$V_g = \frac{1}{\rho f} \frac{\delta p}{\delta n} \qquad \ldots \quad (1)$$

The pressure difference between Shantou and Dongsha (see Figure 6) was taken to represent the pressure gradient. To verify this method, surface data for all (61) easterly occasions in the period October 1987 to April 1988 are taken and the geostrophic wind calculated. (In this paper, verification of all the methods will be taken for this same period for easy comparison of results.) The calculated windspeed is then compared with the maximum wind observed overnight at Waglan. The resulting geostrophic winds were on the average much larger than the observed winds, probably due to frictional and orographic effects.

To obtain more reasonable comparisons, the correlation coefficient between the geostrophic winds and the observed winds was calculated, and the result shown in Table 2. The results will be discussed in Section 3d below.

b) Morrice's results

Based on the data in the period October to March 1966-1972, Morrice(1973) obtained two relations between strength of easterly winds overnight and synoptic data during daytime. The first relationship relates 2 hPa isobar spacing measured at 0600 UTC between 20° N and 25° N at 117° E, and the maximum and average hourly mean wind measured at Waglan during the following 1200 UTC to 2100 UTC. (Waglan is an offshore island just to the southeast of Hong Kong. It has been selected as a reference station for wind observations for Hong Kong (Chen 1975). Because of the exposure of its anemometer, a measured wind of 14.5 m/s is considered equivalent to 11.5 m/s at the sea surface.) The second (and tighter) relationship relates the isobar spacing and mixing height measured at Shantou (Figure 6) to the average hourly mean wind at Waglan. Since full ascents at Shantou have not been received since 1974, the second relationship cannot be verified. It also means that the method cannot be applied operationally.

An attempt was made to verify the first relation (isobar spacing versus wind strength) again using observations in October 1987 to April 1988. The result is shown in Figure 4 together with Morrice's regression line. The correlation coefficient between the predicted winds and the actual observed maximum winds is again given in Table 2. A root mean square error of 3.8 m/s was found, much higher than the one found by Morrice (2 m/s) and a bit too large to be accepted as useful guidance in an operational environment.

c) Δ Ps

The value of the pressure difference between Shanghai and Hong Kong (Δ Ps) has been used by Royal Observatory forecaster as a qualitative indicator of the strength of easterlies for years. No quantitative rule has been established but it has been noted that the higher the value of Δ Ps, the more likely is the occurrence of strong winds (Table 3). Using data from October 1980 to April 1987, a regression equation was obtained relating the value of Δ Ps at 06 UTC to the maximum wind overnight at Waglan. The regression equation is as follows:

$$V_{max} = 7.78 + 0.614 \times \Delta Ps(06) \qquad .... (2)$$

This equation is then applied to data in the period October 1987 to April 1988. The result is shown in Figure 5 and Table 2. A root mean square error of 2.6 m/s was found for the predictions. This error is much lower than that given by Morrice's method discussed in Section 3b above.

d) Discussion

The above paragraphs showed that by using the value of the geostrophic wind and Δ Ps, quite reasonable estimations of the windspeed can be made. However, they are but two of many possible indicators of the pressure gradient over southeast China. There may well exist other similar parameters which exhibit better correlations with the wind than the value of Δ Ps or the geostrophic wind. Also, the rate of change of the pressure gradient has not been taken into account. The inclusion of other parameters and their time rate of change may give even better estimations of the windspeed. In the following section such an investigation is carried out.

4. QUANTITATIVE FORECASTING ON STRENGTH OF EASTERLIES

a) Continuation

As discussed in Section 3, during an easterly occasion, winds overnight are on the average stronger than that during the day. One problem the forecaster faces is to forecast the maximum wind overnight using the latest available synoptic data. Investigations were made to try to relate synoptic data available up to the synoptic hours 00, 06 and 12 UTC with the maximum hourly mean wind observed at Waglan during the following night (12 to 21 UTC). In Section 3, it has been shown that winds of 8 m/s during the day were roughly equivalent to winds of 10 m/s overnight. For easy application to operational environment, all occasions with 2 observations during the day (00 to 09 UTC) having easterly winds of over 8 m/s were considered. In all, there are 340 cases in the 7 cool seasons, but in 20 of those cases, the winds turned northerly and no easterly winds were observed during the night. All these cases correspond with the arrival of a northerly surge in the evening, and they were not considered in this investigation. Thus, a total of 320 cases were considered.

As discussed in Section 3d the parameters considered were parameters similar to Δ Ps and the geostrophic winds and their time variations. The actual wind observations at Waglan were also considered as a persistence element. A list of the parameters used can be found in Table 4. A map showing the stations considered is given in Figure 6. The list of parameters were definitely not exhaustive, but all bear some physical relationship (either kinematical or dynamical) with the maximum wind overnight.

Multivariate regressions were run between the parameters and the maximum winds. A two-step regression was used since the number of parameters considered (about 100) was not insignificant compared to the total number of cases (about 300). The parameters were first separated into groups, and a regression was done for each group of parameters. Then the parameters showing the best correlation were grouped together for a second regression to be done.

In the 320 cases, there were only 30 cases in which winds of above 14 m/s (strong winds equivalence) overnight were reported, while easterly winds of 5 m/s to 14 m/s (equivalent to moderate to fresh winds) were reported in the remaining 290 cases. Initially, all cases were assigned equal weight in the regression. However, it was found that the regression fitted the moderate to fresh winds cases much better than the strong winds cases simply because of the small number of cases with strong winds. Each strong winds case was then assigned a weight of 4 so that each range of wind speed contained roughly the same number of cases. The regression was then performed again. The same set of predictors were again chosen, but the coefficients were slightly different. The strong winds cases were then fitted better, while the fit for the moderate to fresh winds cases deteriorated slightly. Since in an operational environment we were more interested in forecasting strong winds, the second approach was taken. Note that even with this approach, the cases with moderate to fresh winds were still fitted slightly better than the cases with strong winds.

Three regression equations were established, one for each of the synoptic hour 00, 06 and 12 UTC. All of the equations showed rather tight correlation with the maximum wind overnight (correlation coefficient all greater than 0.7, see Figures 7(a-c), and they could be easily incorporated into a simple computer program to aid the forecaster. The equations and some of the properties of their predictions are discussed in Appendix A.

The 06 and 12 UTC relations showed that pressure differences between Hong Kong and the stations 58666 and 58853 (see Figure 6) were better indicators than the pressure difference between Hong Kong and Shanghai (Δ Ps) which has been used by forecasters as a qualitative indicator of easterly wind strength.

The results also have physical meaning. The winds blowing at Waglan obviously bear some correlation with the winds overnight (the persistence factor), and more so as the time lag is decreased, as shown by the fact that the coefficient of the WIND parameter in the prediction equations increases from 00 to 12 UTC. Δp of a station to our northeast represents the pressure gradient, which should bear some relationship to the absolute magnitude of the wind, and its time rate of change should indicate whether the wind is increasing or decreasing. So the appearance of these parameters in the regression equations are not at all surprising.

(b) Arrival

The equations discussed in section a above all involved the strength of easterlies at Waglan during the day, hence they cannot be applied to cases when easterlies are expected to arrive during the night. In view of this, a further set of three equations was developed which depended only on surface pressure values, leaving out the strength of wind at Waglan during the day. Since this set of equations only depended on surface pressure values and their rate of change, they should be indicative of the wind strength overnight no matter whether easterlies were being experienced at time of calculation. These equations are listed in Appendix B. Results of their predictions were shown in Figures 7(d-f).

The fit of these equations were not as good as those in Appendix A. However, when this set of equations were applied to cases when easterlies arrived overnight, the standard error were similar to those calculated for continuation cases when the equations themselves were derived (please see Appendix B). Hence this set of equations can be applied when easterlies are expected to arrive overnight.

5. DEPENDENCE ON SURFACE PATTERN

Morrice separated easterly cases into two categories depending on the surface pressure pattern, namely normal and ridging patterns. His ridging pattern covers the cases with a narrow ridge along the southeast coast of China. Morrice noted that his forecasting aids only apply for the normal cases. Closer examination of the surface pattern revealed that the surface pattern could best be divided into three categories: normal, slight ridging, and narrow ridges. The first two categories together made up Morrice's normal pattern. A question then arose: does the applicability of the regression equations derived above depend on the surface pressure pattern?

Easterly cases in the period 1980-87 were classified into the aforementioned three categories. The regression equations were then applied separately to each of the three categories, and the standard error for each category was computed. The results were shown in Table 5. The results showed that the prediction errors of the equations depended only weakly on the surface pattern, with the smallest errors obtained for the slight ridging cases, and the errors about ten per cent higher for the other two cases. This indicated that the equations can be applied to all three categories of surface pattern.

6. VERIFICATION

The equations were developed using data during the period 1980-87. Synoptic data from October 1987 to April 1988 were used to verify the equations. The results were shown in Table 6 and Figures 8(a-f). The results showed that the predictions in 1987-88 exhibited roughly the same standard error as when the equations were derived using 1980-87 data. This verified that the equations could be employed as prediction equations. In addition, when the prediction errors and correlation coefficients of the predictions given by this set of equations were compared to those discussed in Section 3, it is seen that predictions here are superior to those methods discussed in Section 3.

7. EXAMINATION OF CASES WITH LARGE PREDICTION ERRORS

The above sections showed that the standard errors of the prediction equations were in the region of 2 m/s. This means that there were some cases where the errors were higher than this value. All cases with prediction errors over 3 m/s in 1987-88 were examined and situations under which these cases arose were summarized below.

In all, out of the total 61 easterly cases, there were 16 cases (or 26%) where the prediction error of one or more of the prediction equations were over 3 m/s. They can be separated into the following categories:

a) 7 cases with large prediction errors at 00 UTC but the errors were acceptable for the 06 and 12 UTC predictions.

b) 6 cases predicted winds stronger than actual. During those occasions, winds turned northerlies during the night or early the next day, and surface charts showed a ridge spreading down from our west.

c) 2 cases predicted very strong winds on arrival. The actual winds, although weaker than those predicted, did exceed 14.5 m/s at Waglan.

d) 1 case when 12 UTC prediction was too high for the overnight period (12 to 21 UTC), but the winds did increase during the following morning to within the acceptable range.

The large errors in categories a, c and d could be considered as acceptable. The main problem lies in the cases in category b. It appears that a ridge extending from our west, with the isobar turning from east-west orientated to eastnortheast-westsouthwest orientated, the strength of the winds are lower than expected from considering the pressure gradients and pressure changes. Thus, if northerlies are expected to affect Hong Kong soon, the predictions of the equations should be taken with more caution.

8. LONGER TERM PREDICTION USING NUMERICAL GRID DATA

Predictions of the numerical models of the European Centre for Medium Range Weather Forecasts (ECMWF) and the United Kingdom Meteorological Office (EGRR) have been distributed globally. Experiences have shown that they have become more and more reliable even over the tropical region. Thus one might envisage using their grid point data as predictors in regression equations to obtain longer term prediction of the strength of easterly winds.

Since the models are frequently updated, a Model Output Statistics type approach is not advisable. Instead, a Perfect Prognosis approach is taken here. The prediction equations are first developed by using actual synoptic data, but in the predictions, values taken from the predictions by the numerical models are substituted in.

Since the value of ΔPs can be estimated easily from the plotted numerical charts, it is the most handy parameter to be used. An equation was derived using synoptic data from October 1980 to April 1987 relating ΔPs values at 12 UTC to the maximum winds at Waglan:

$$Vmax = -0.140\ \Delta Ps(D-1) + 0.657\ \Delta Ps(D0) - 0.179\ \Delta Ps(D+1) + 9.36 \quad \ldots\ldots(3)$$

This equation was applied to prognostic charts received from both ECMWF and EGRR in the period October 1987 to April 1988. Predictions were calculated up to 3 days ahead. The results are shown in Figures 9(a-f) and Table 7. The prediction errors are higher than those discussed in Section 6 but appreciably smaller than those by using Morrice's method.

Correlations for these predictions are a lot lower than those obtained in the previous section due to the following reasons:

a) The equation itself was not as good as the ones discussed above since only 12 UTC data were used.

b) The predicted values of ΔPs added in some additional errors.

To illustrate these points, actual values of ΔPs were substituted into equation 3 and the predictions calculated. A root mean square error of 2.6 m/s and a correlation coefficient of 0.52 were found.

Table 7 shows that the predictions obtained by using the two numerical models have comparable errors. A further effort was made to decide upon which model products to use in equation 3. Forecast ΔPs values estimated from the 2 sets of prognostic charts and their forecast changes in 24 hours during the whole period October 1987 to April 1988 were compared to the actual values and the result is shown in Table 8. The results clearly show that the ΔPs values estimated from ECMWF forecasts were definitely superior to those estimated from the EGRR forecasts and should be used in Equation 3.

We can look at the predictions using the prognostic charts in a more favourable light. In Section 7 it has been shown that some of the cases with large prediction errors were due to winds turning to northerlies during the night. These cases were associated with a ridge extending southwards to the west of Hong Kong and should be apparent to forecasters synoptically. These cases were taken out from the sample and prediction errors and correlation coefficients were calculated (Table 9). The results showed that the predictions using ECMWF charts for days 1 and 2 were comparable to those of Equations A1 and B1 and correlations were about 0.6, indicating that they do have some forecasting values.

Here we only used surface forecasts of one special parameter to demonstrate the possibility of using the numerical products for longer term prediction of wind strength. Further efforts could be made to make use of upper air forecasts and maybe forecasts of other grid point values and better predictors than Equation 3 might be obtained.

9. CONCLUSION

The forecasting aids being used by forecasters were found to exhibit unacceptably large prediction errors. A set of regression equations had been developed with prediction errors of about 2 m/s and their applicability verified using 1987-88 data. The predictions from this set of equations can be used as guidance to forecasters operationally.

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APPENDIX A EQUATIONS FOR PERSISTENT EASTERLIES

Three different regression equations have been developed involving Waglan wind as a parameter which are applicable at 00, 06 and 12 UTC respectively.

a) 00 UTC

$$PRED = 0.351\,\Delta P_s(00) - 0.379\,\Delta P_{666}(-06) + 0.703\,\Delta P_{666}(00) - 0.704\,\Delta P_{853}(-18) + 0.544\,\Delta P_{849}(00) + 0.247\,WIND(00) + 4.71 \quad \text{.........} \quad (A1)$$

Standard error = 2.4 m/s
Mean error = 2 m/s
Correlation = 0.7

b) 06 UTC

$$PRED = -0.347\,\Delta P_{666}(-12) + 1.009\,\Delta P_{666}(06) + 0.534\,WIND(06) + 2.85 \quad \text{.........} \quad (A2)$$

Standard error = 2.1 m/s
Mean error = 1.5 m/s
Correlation = 0.8

c) 12 UTC

$$PRED = -0.371\,\Delta P_{853}(-18) + 0.677\,\Delta P_{853}(12) + 0.730\,WIND(12) + 3.25 \quad \text{......} \quad (A3)$$

Standard error = 1.5 m/s
Mean error = 1 m/s
Correlation = 0.9

where PRED = predicted maximum hourly mean wind overnight at Waglan in m/s

$\Delta P_x(TT)$ = pressure difference between station x and Hong Kong at time TT UTC (TT negative for data from the day before)

WIND(TT) = hourly mean wind at Waglan observed at TT

and, for the stations x,

s : Shanghai(58367)
666 : Dachen Dao(58666)
849 : Mazu(58849)
853 : Taishan(58853)

APPENDIX B EQUATIONS FOR ONSET OF EASTERLIES

Equations not involving Waglan wind as a parameter:

a) 00 UTC

$$PRED = 0.365\,\Delta P_s(00) - 0.281\,\Delta P_{666}(-06) + 0.595\,\Delta P_{666}(00) - 0.604\,\Delta P_{853}(-18) + 0.486\,\Delta P_{849}(00) + 7.29 \quad \ldots\ldots (B1)$$

Standard error = 2.5 m/s
Mean error = 2 m/s
Correlation = 0.7

b) 06 UTC

$$PRED = -0.410\,\Delta P_{666}(-12) + 0.426\,\Delta P_{666}(06) + 0.444\,\Delta P_{853}(03) + 0.720\,\Delta P_{849}(06) + 7.16 \quad \ldots\ldots (B2)$$

Standard error = 2.2 m/s
Mean error = 1.8 m/s
Correlation = 0.7

c) 12 UTC

$$PRED = -0.571\,\Delta P_{853}(-18) + 1.333\,\Delta P_{853}(12) + 0.987\,\Delta P_{944}(06) - 0.946\,\Delta P_{944}(12) + 0.219\,\Delta P' + 7.42 \quad \ldots\ldots (B3)$$

Standard error = 2.2 m/s
Mean error = 1.7 m/s
Correlation = 0.8

The meanings of the symbols were similar to the ones in Appendix A. The locations of the stations could be found in Figure 6.

The above equations were derived using cases when the easterly wind strength at Waglan was over 8 m/s during the day. However, since the prediction equations only involved pressure values as parameters, there was no particular reason why they could not be applied to arrival cases. All cases when easterly arrived overnight in 1980-87 were found, and the prediction equations (B1) - (B3) applied. The standard errors for the predictions are shown below:

Equation	Standard error	
	arrival cases	continuation
00 UTC (B1)	2.3	2.5
06 UTC (B2)	2.2	2.2
12 UTC (B3)	2.5	2.2

The above table shows that the standard errors for the arrival cases for all three equations were similar to the standard errors for the continuation cases. Hence this set of equations can be applied to arrival as well as continuation cases.

TABLE 1. DIURNAL VARIATION OF EASTERLIES

Synoptic hour (UTC)	Mean wind (m/s) during 91 easterly occasions in 1980-1987
00	12.0
03	11.7
06	10.8
09	10.4
12	11.0
15	11.8
18	12.2
21	12.2

TABLE 2. CORRELATION BETWEEN ACTUAL OBSERVED WINDS (1987-88) WITH WINDS CALCULATED BY DIFFERENT METHODS

Method	Correlation Coefficient
Geostrophic Wind	0.50
Morrice	0.27
Δ Ps(06)	0.53

TABLE 3. PERCENTAGE OF CASES WITH STRONG WINDS OVERNIGHT AT WAGLAN WITH VARIOUS Δ PS VALUES AT 06 UTC

Δ Ps	% of cases with strong winds occurring in 1980-87 with such a Δ Ps at 06 UTC (no. of cases in bracket)	
	Continuation	All (including arrival)
$0 \leqslant \Delta Ps < 2$	3 (1/32)	3 (1/32)
$2 \leqslant \Delta Ps < 4$	0 (0/45)	2 (1/49)
$4 \leqslant \Delta Ps < 6$	6 (5/82)	9 (8/94)
$6 \leqslant \Delta Ps < 8$	6 (4/71)	7 (7/100)
$8 \leqslant \Delta Ps < 10$	17 (8/46)	21 (14/67)
$10 \leqslant \Delta Ps < 12$	25 (7/28)	28 (11/39)
$12 \leqslant \Delta Ps < 14$	57 (4/7)	38 (5/13)
$14 \leqslant \Delta Ps$	100 (1/1)	100 (3/3)
Total	10 (30/312)	13 (50/397)

TABLE 4. PARAMETERS CONSIDERED

a) ΔP_s = P(58367) - P(HK)

b) ΔP_{666} = P(58666) - P(HK)

c) ΔP_{853} = P(58853) - P(HK)

d) ΔP_{849} = P(58849) - P(HK)

e) ΔP_{944} = P(58944) - P(HK)

f) P(HK) - P(59658)

g) P(59134) - P(58911)

h) P(59134) - P(HK)

i) P(59134) - P(59358)

j) $\Delta P'$ = g + h + i

k) P(58927) - P(59792)

l) Wind at Waglan

m) P(59316) - P(59792) ~ Geostrophic wind

The parameters are taken at the following times:

00, 06, 12, and 18 UTC of the day before, and
00, 03, 06, and 12 UTC of the day in question.
In so doing, the time rate of change of the parameters have been included implicitly.

TABLE 5. DEPENDENCE ON SURFACE PATTERN

Equation	Standard Error (m/s)			
	Normal	Slight Ridge	Narrow Ridge	All Cases
A1	2.6	2.3	2.4	2.4
A2	2.3	1.8	2.3	2.1
A3	1.5	1.4	1.2	1.5
B1	2.6	2.2	2.6	2.5
B2	2.2	2.1	2.3	2.2
B3	2.2	2.0	2.2	2.2
Ave.	2.2	2.0	2.2	2.1
Morrice	3.6	3.1	2.9	3.4

TABLE 6. ERRORS OF PREDICTIONS BY THE REGRESSION EQUATIONS (CORRELATION COEFFICIENTS IN BRACKETS)

Equation	Standard Error (m/s)	
	Verification 1987 - 88	Derivation 1980 - 87
A1	2.4 (0.6)	2.4 (0.7)
A2	1.9 (0.8)	2.1 (0.8)
A3	1.5 (0.9)	1.5 (0.9)
B1	2.5 (0.6)	2.5 (0.7)
B2	2.0 (0.7)	2.2 (0.7)
B3	2.7 (0.7)	2.2 (0.8)

TABLE 7. ERRORS OF PREDICTIONS BY USING PROGNOSTIC CHARTS (CORRELATION COEFFICIENTS IN BRACKETS)

	ECMWF	EGRR
Day 1	2.9 (0.5)	3.0 (0.4)
Day 2	3.0 (0.4)	3.3 (0.3)
Day 3	3.0 (0.3)	3.0 (0.3)

TABLE 8. ERRORS IN PREDICTION OF Δ PS USING PROGNOSTIC CHARTS (CORRELATION COEFFICIENTS IN BRACKETS) OCTOBER 1987 to APRIL 1988

	ECMWF	EGRR
+24 hr	1.9 (0.9)	2.2 (0.9)
+48 hr	2.2 (0.9)	3.2 (0.8)
+72 hr	2.5 (0.8)	3.6 (0.7)
+96 hr	2.8 (0.8)	4.0 (0.6)
24 - 00 hr	2.0 (0.9)	2.6 (0.8)
48 - 24 hr	2.6 (0.8)	3.4 (0.6)
72 - 48 hr	2.9 (0.7)	3.4 (0.6)
96 - 72 hr	3.1 (0.6)	3.9 (0.4)

TABLE 9. ERRORS OF PREDICTIONS WITH NORTHERLIES CASES TAKEN OUT (CORRELATION COEFFICIENTS IN BRACKETS)

	Standard errors (Corr. coeff.)
A1	2.2 (0.58)
A2	1.6 (0.80)
A3	1.0 (0.91)
B1	2.4 (0.57)
B2	1.8 (0.73)
B3	2.4 (0.65)
ECMWF D1	2.1 (0.63)
ECMWF D2	2.2 (0.61)
ECMWF D3	2.4 (0.42)
EGRR D1	2.3 (0.51)
EGRR D2	2.7 (0.41)
EGRR D3	2.4 (0.37)

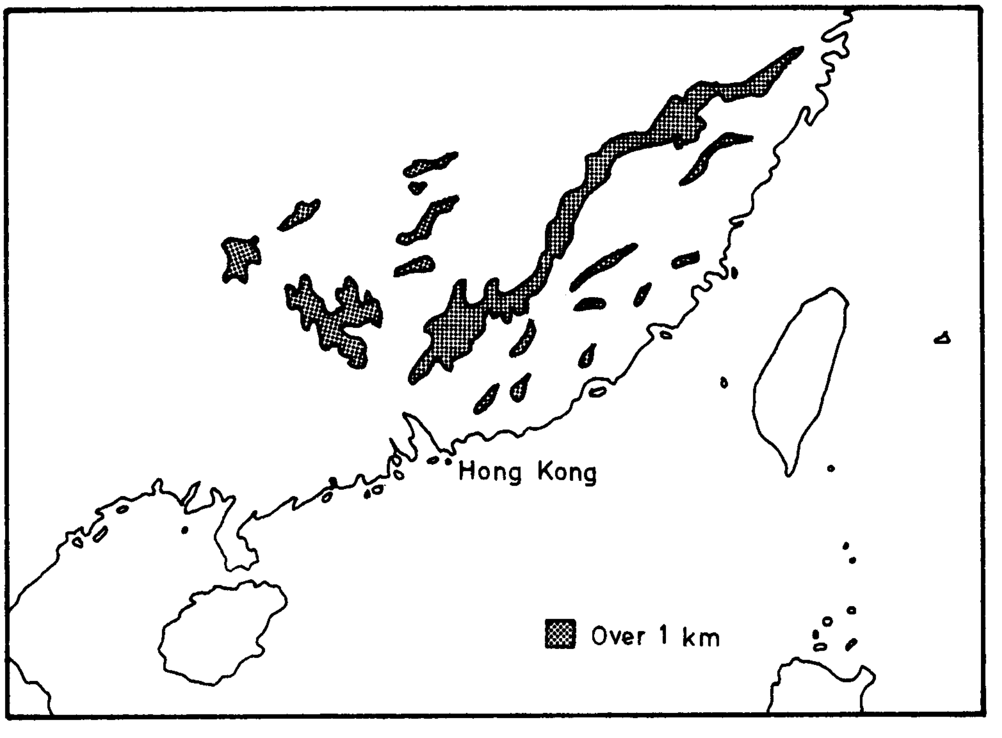

Fig. 1 Nanling Ranges.

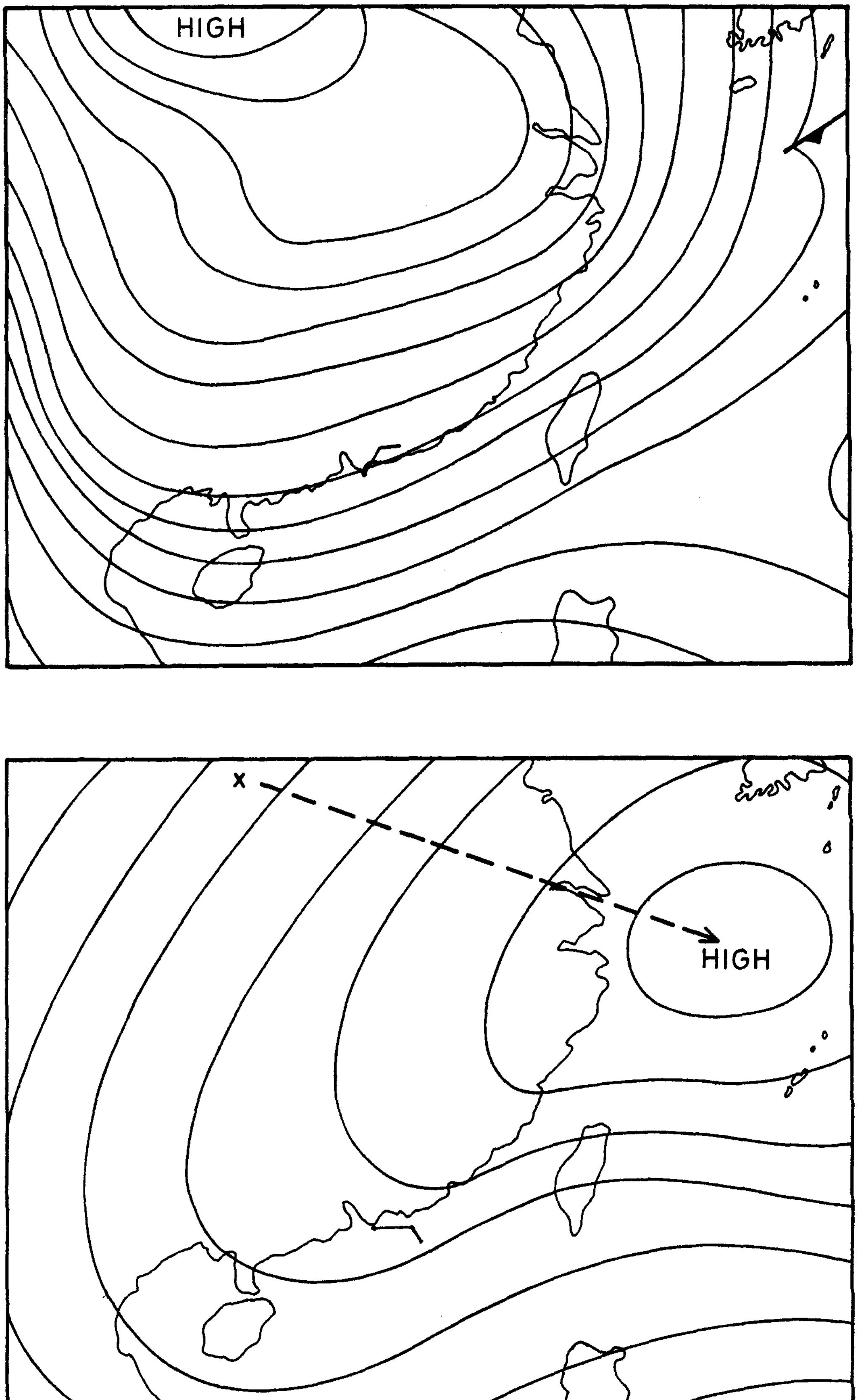

Fig. 2 Northerlies turning easterlies.

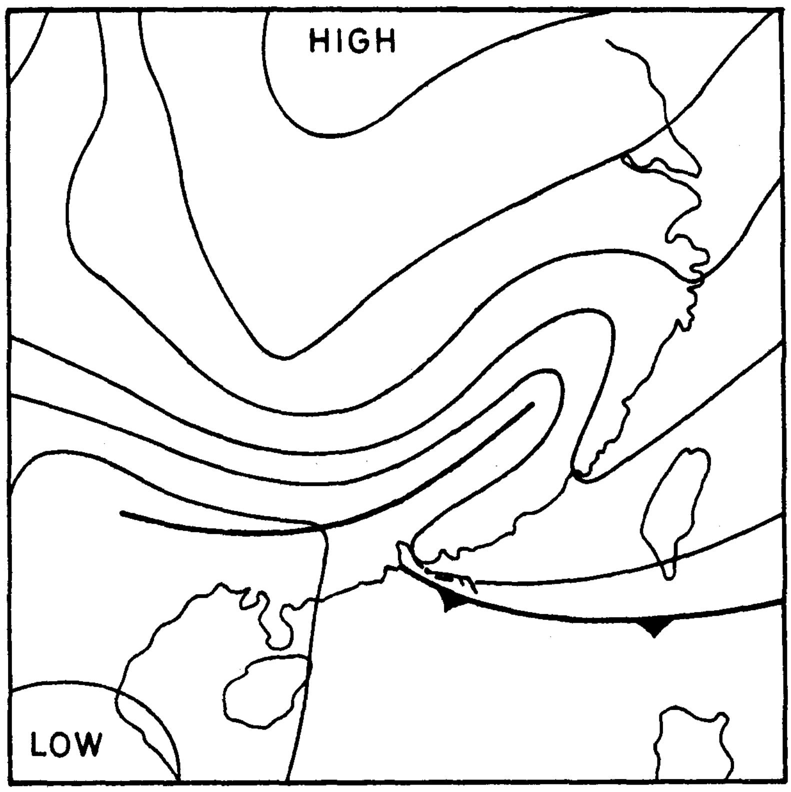

Fig. 3 Easterlies with narrow ridge.

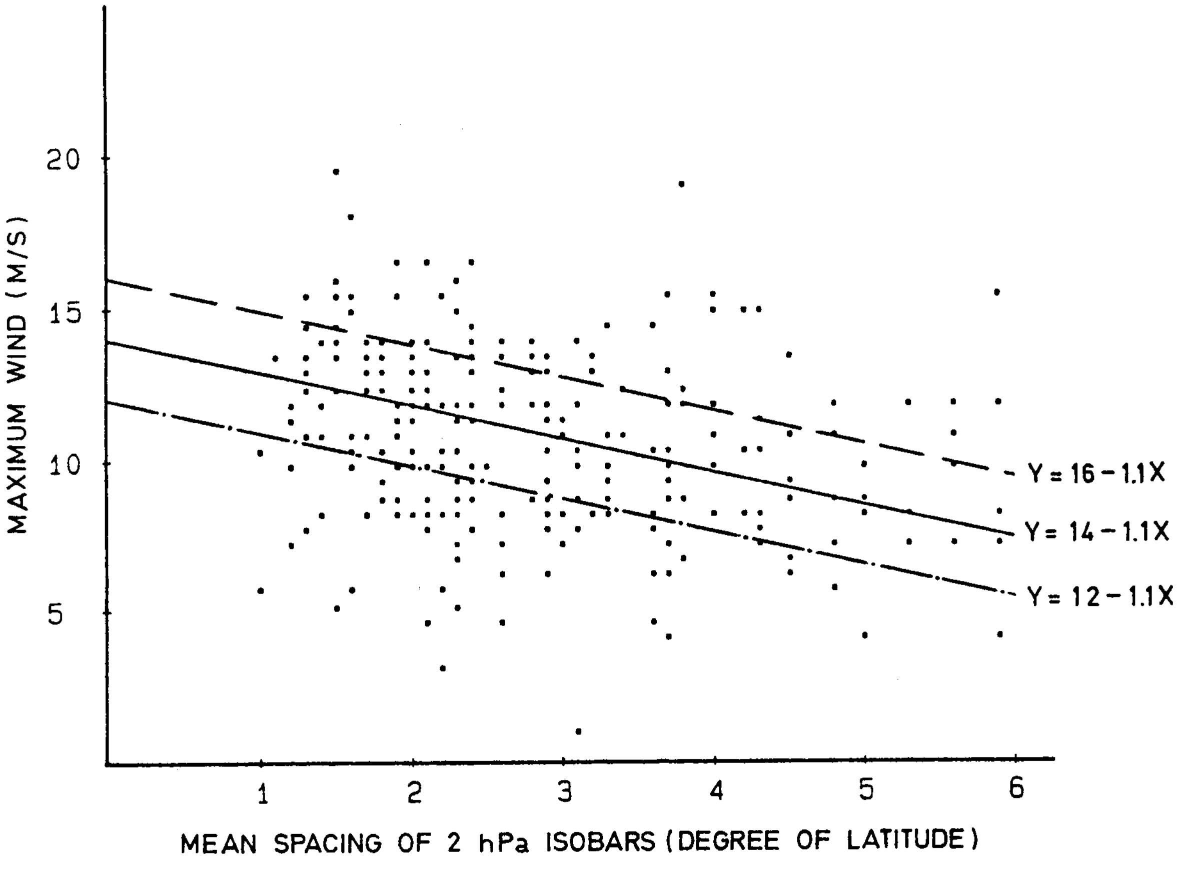

Fig. 4 Verification of Morrice's method.

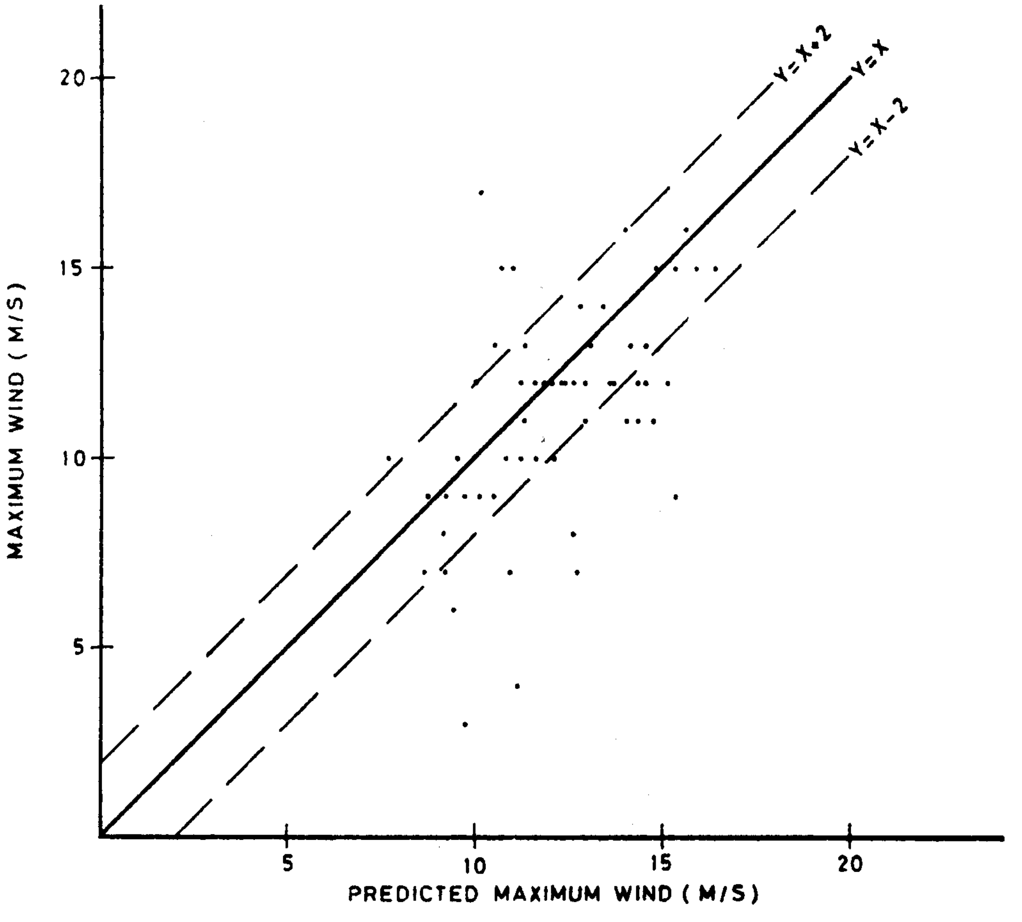

Fig. 5 Verification of Equation 2.

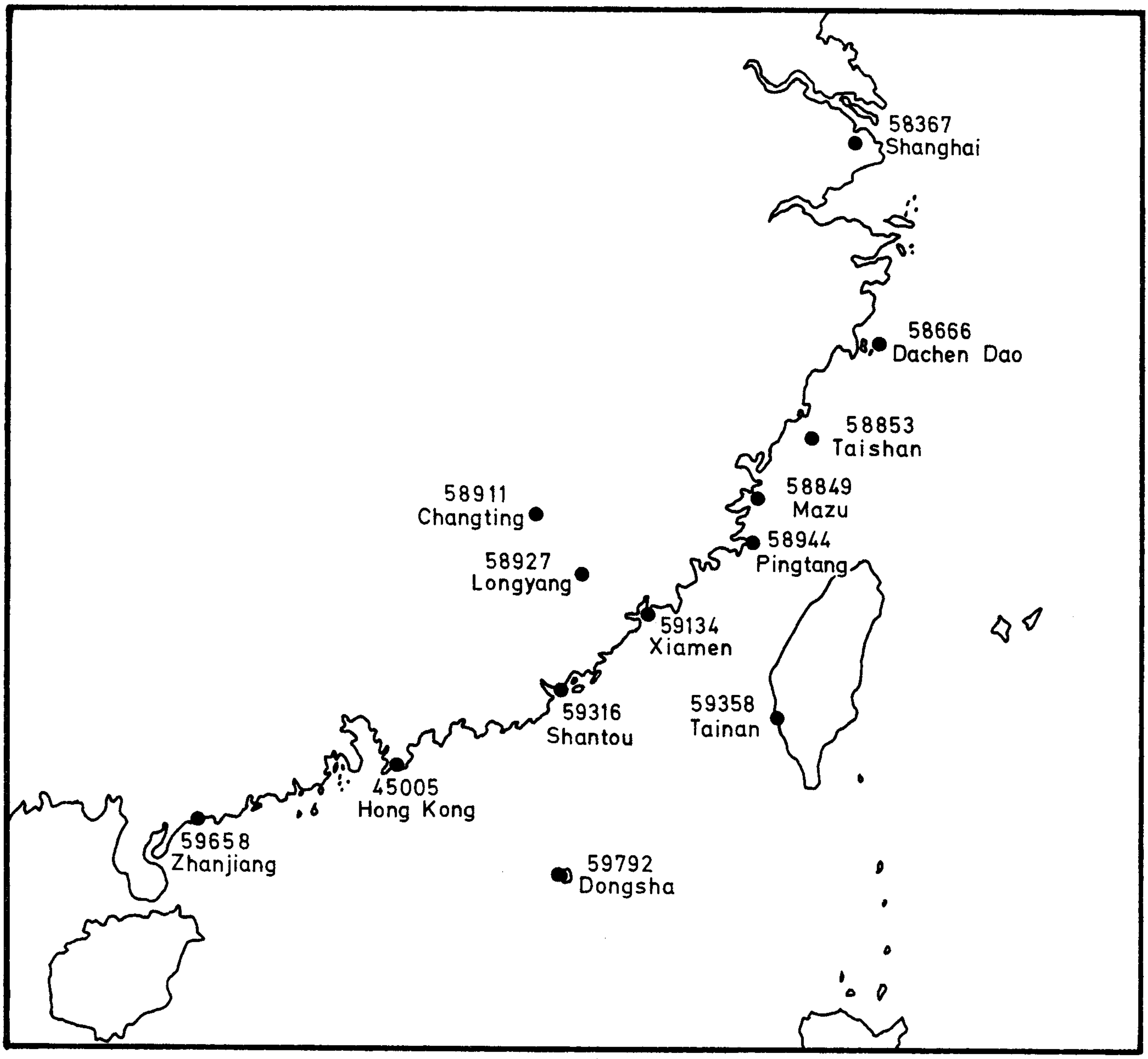

Fig. 6 Stations considered.

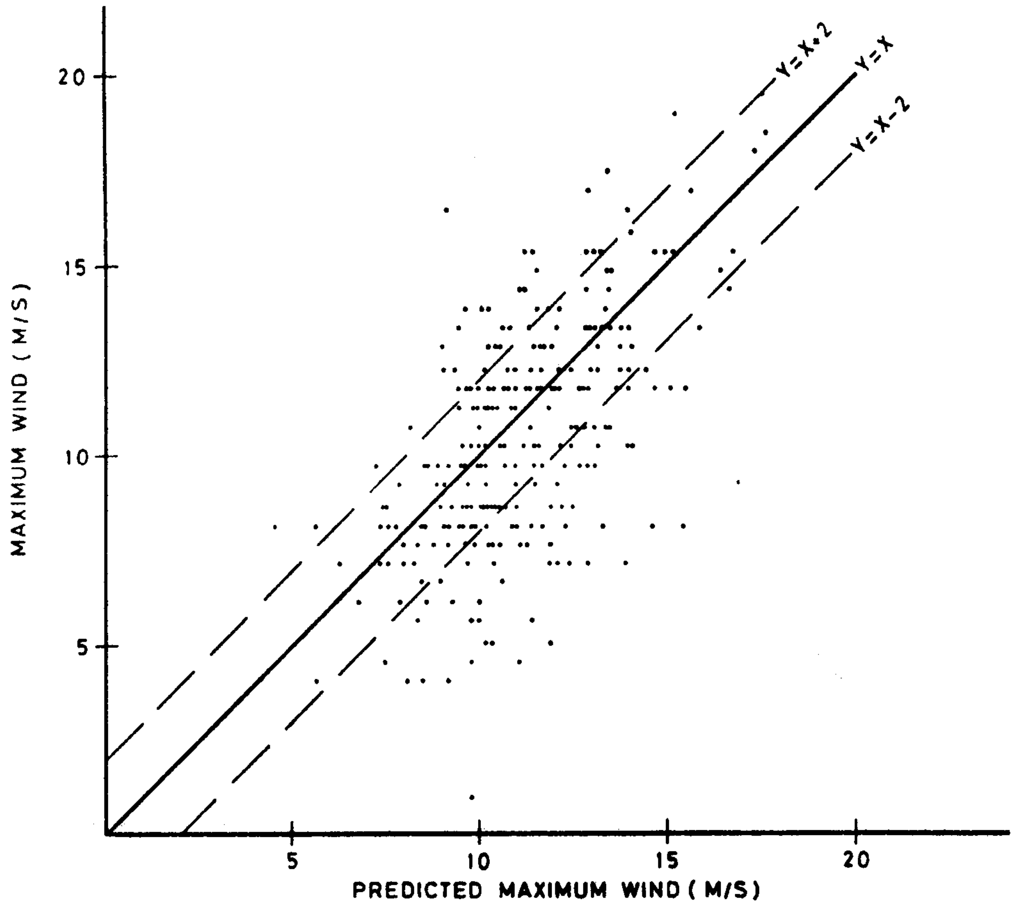

Fig. 7a Actual versus fitted values for Equation A1.

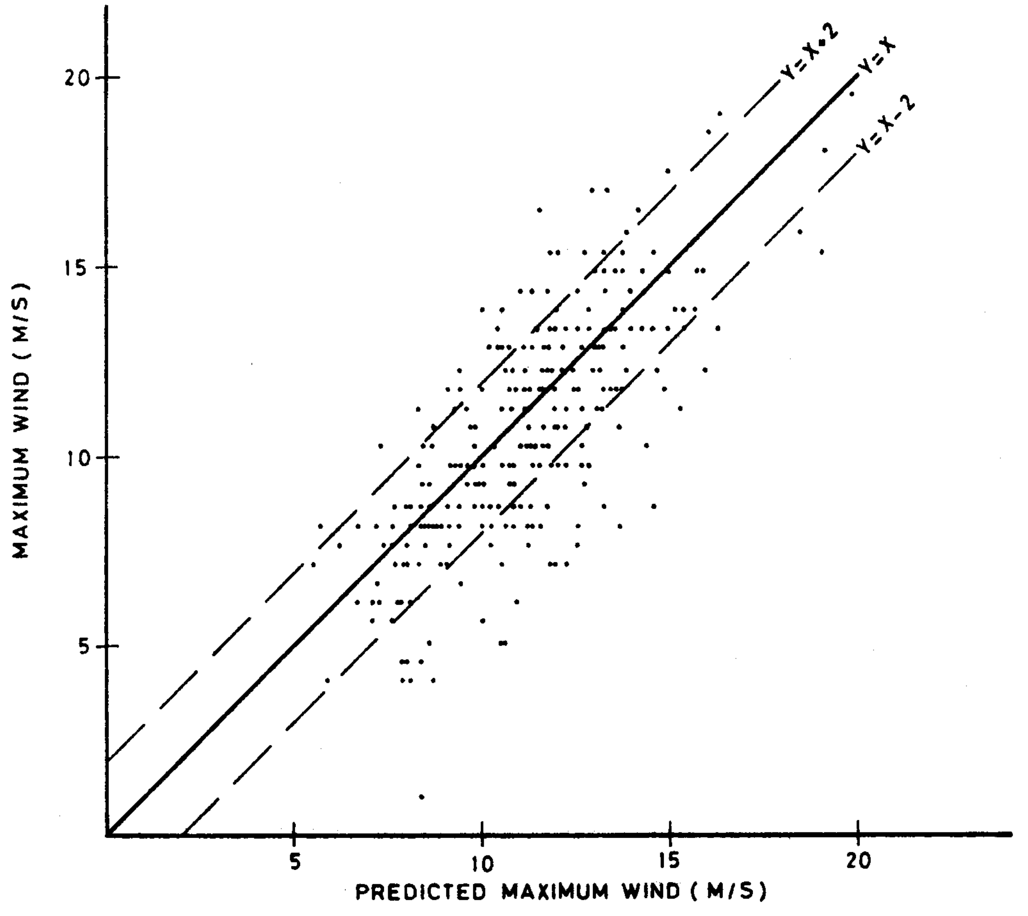

Fig. 7b Actual versus fitted values for Equation A2.

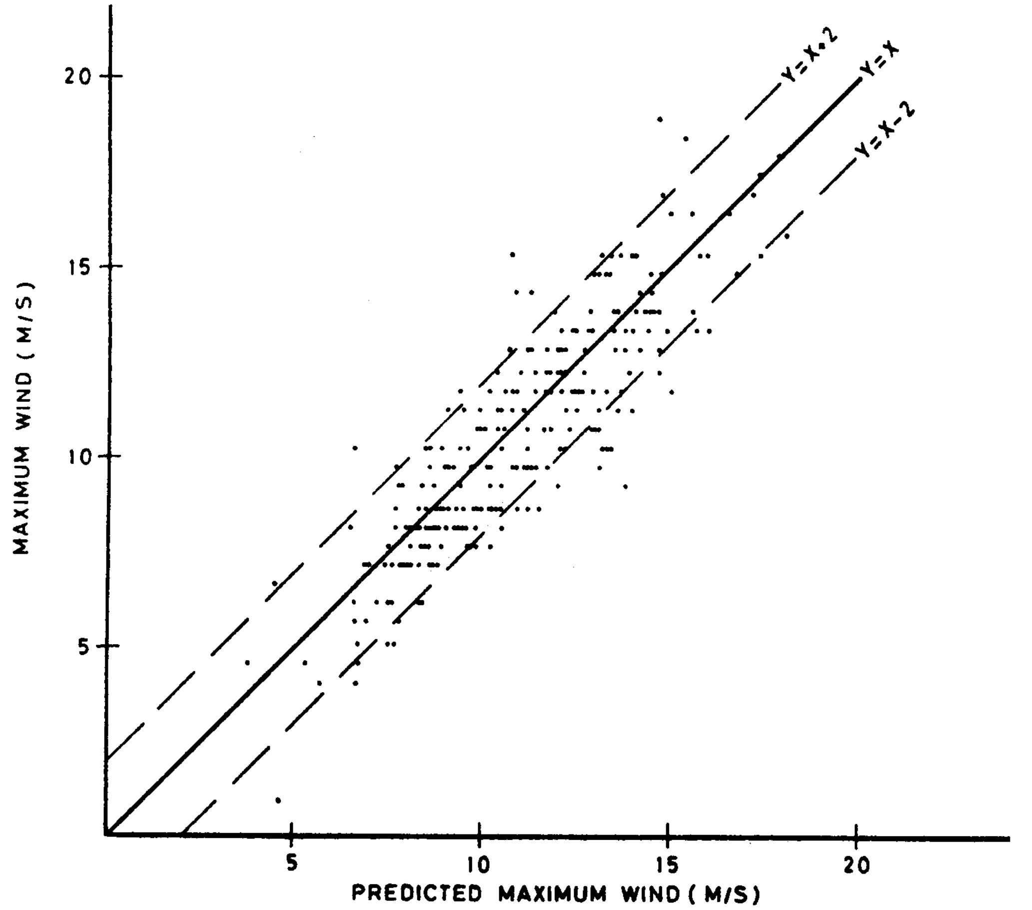

Fig. 7c   Actual versus fitted values for Equation A3.

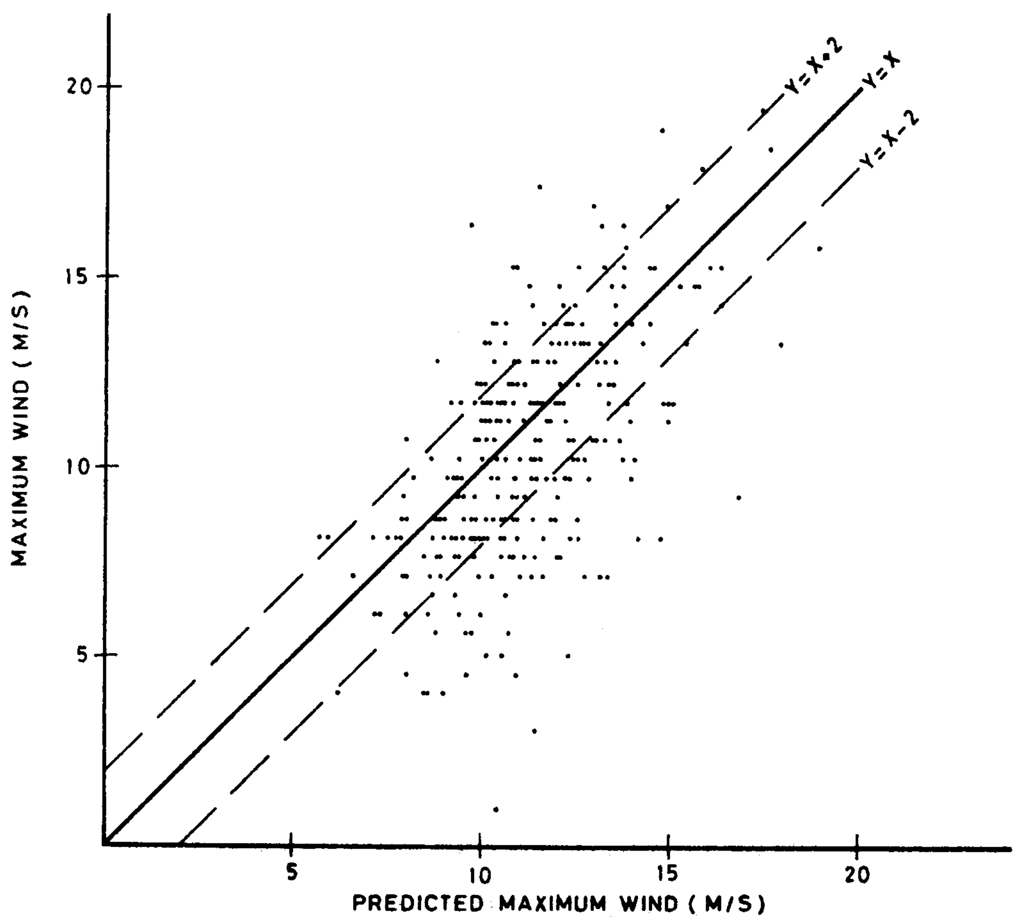

Fig. 7d   Actual versus fitted values for Equation B1.

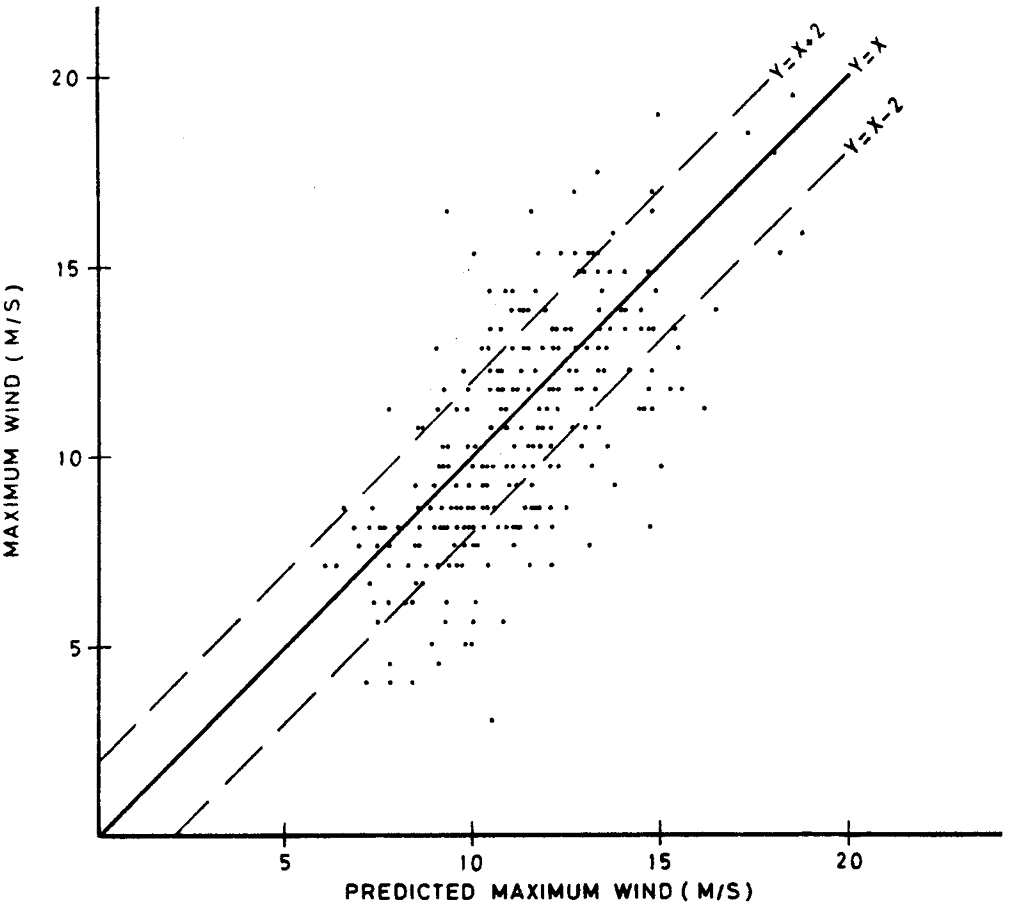

Fig. 7e Actual versus fitted values for Equation B2.

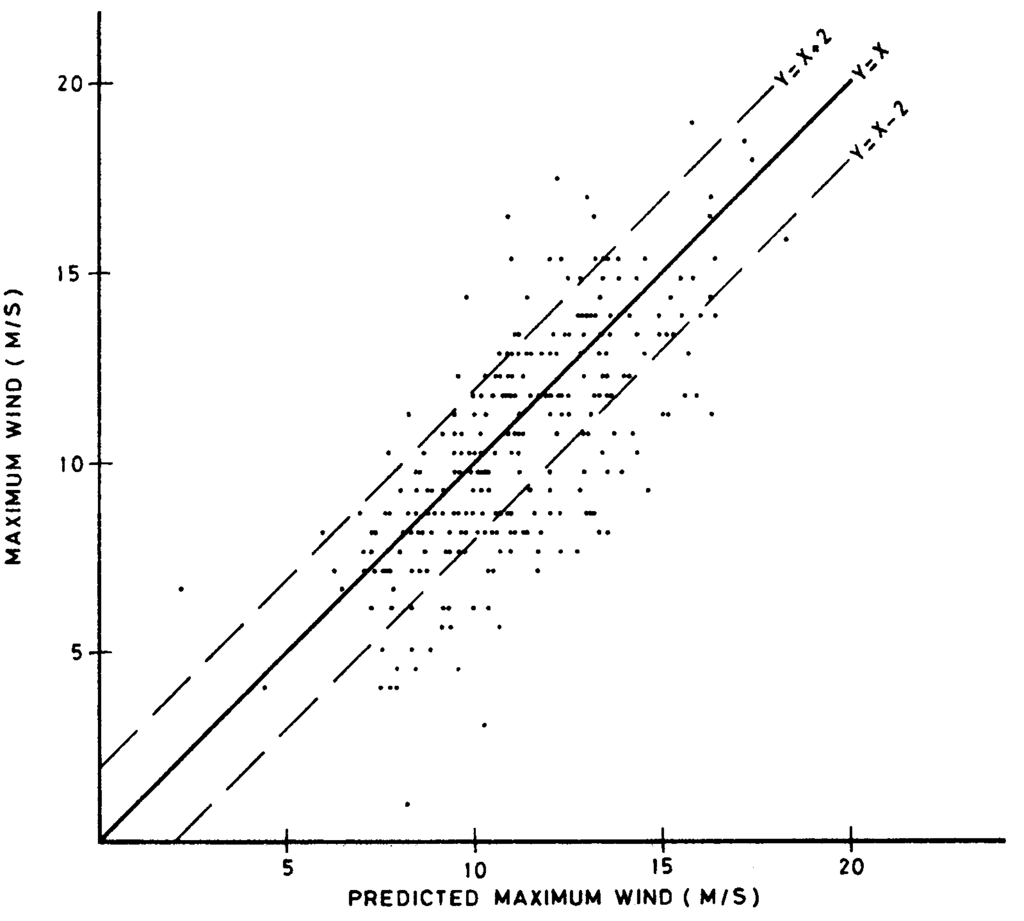

Fig. 7f Actual versus fitted values for Equation B3.

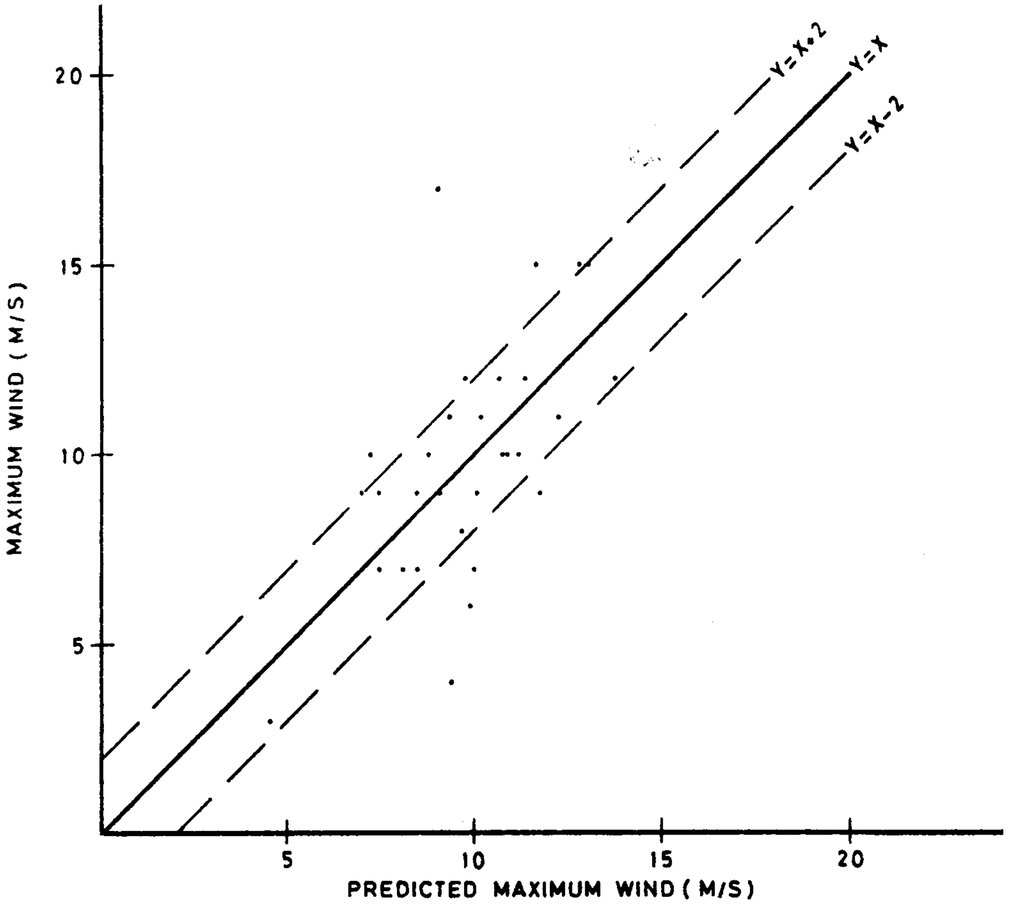

Fig. 8a Verification of Equation A1.

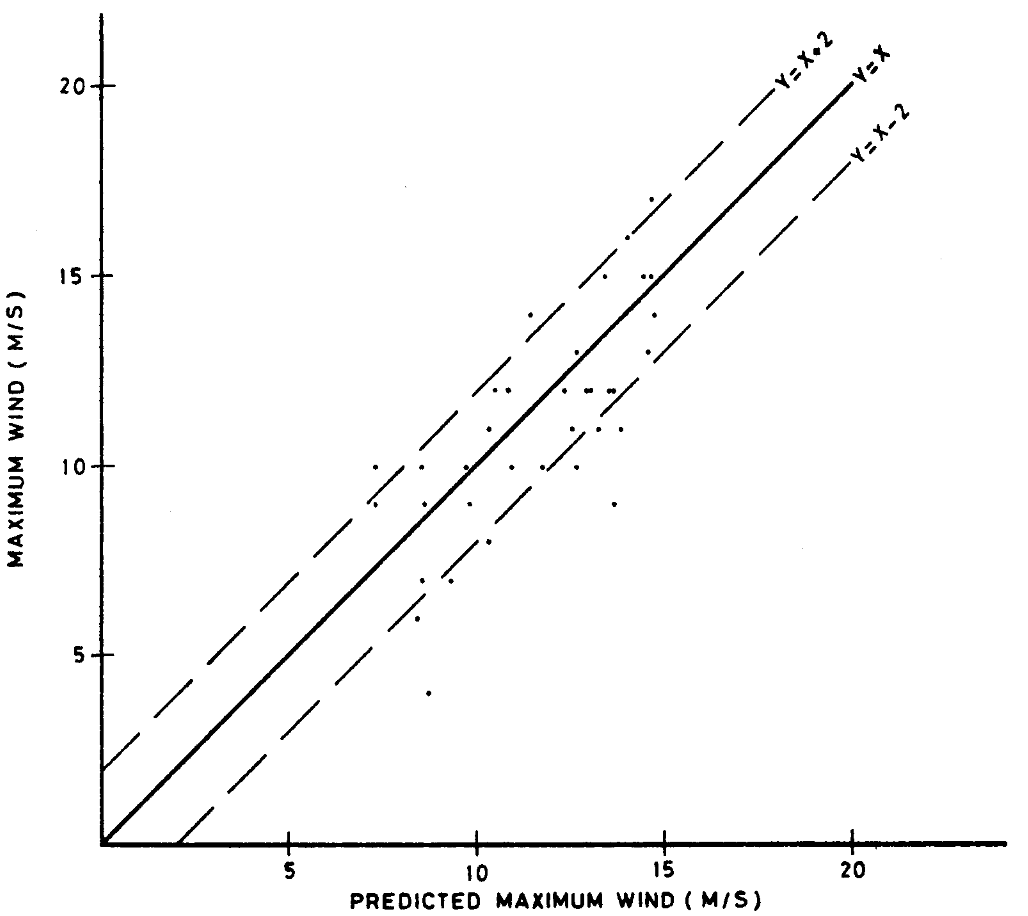

Fig. 8b Verification of Equation A2.

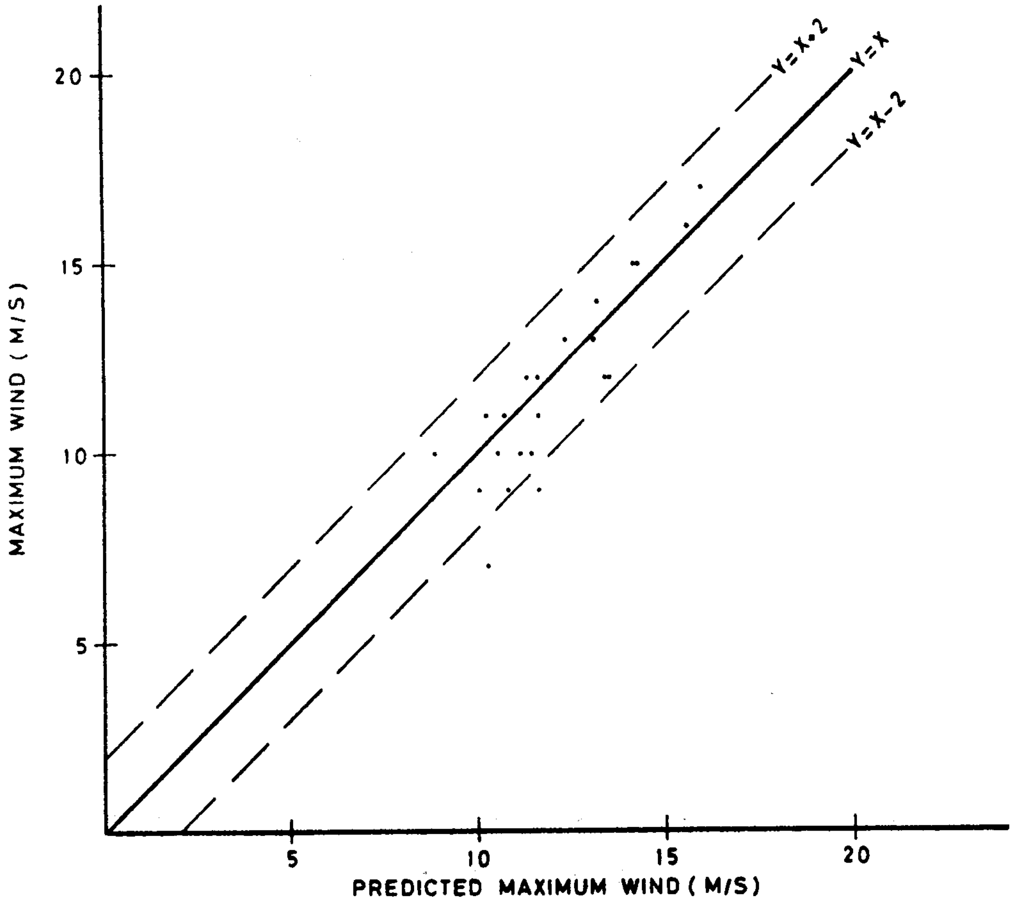

Fig. 8c Verification of Equation A3.

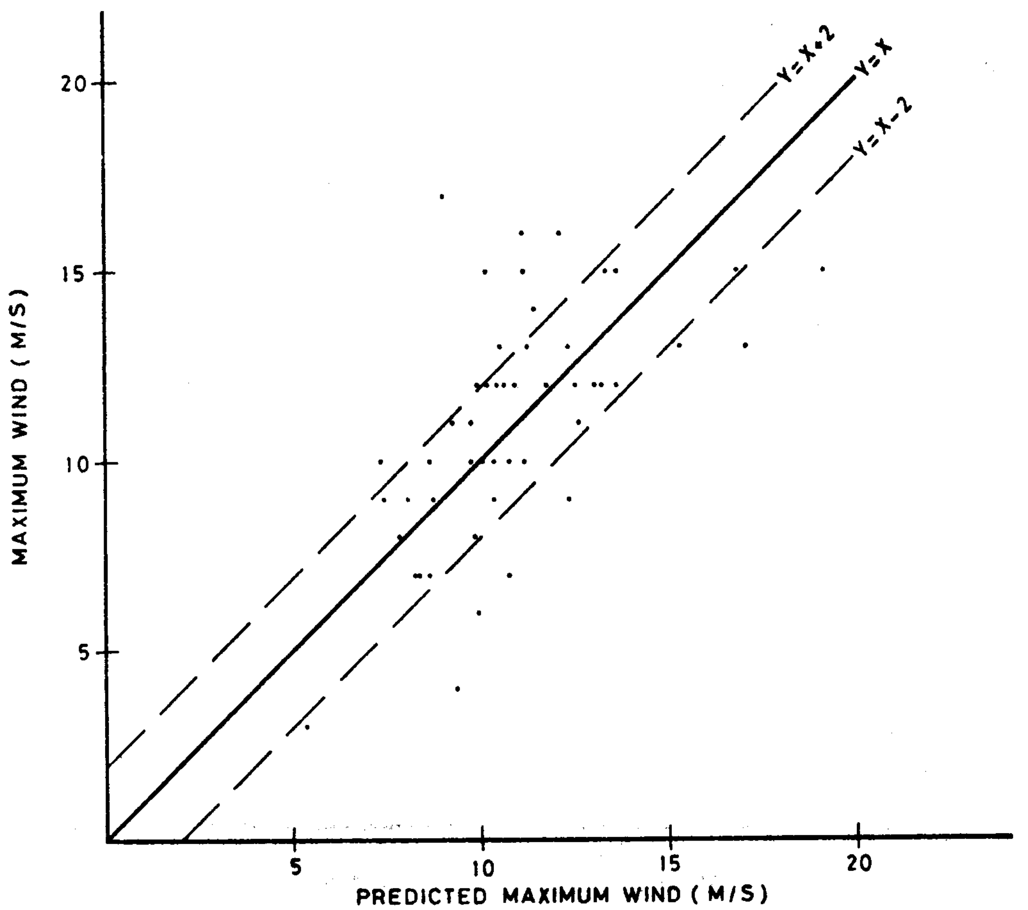

Fig. 8d Verification of Equation Bl.

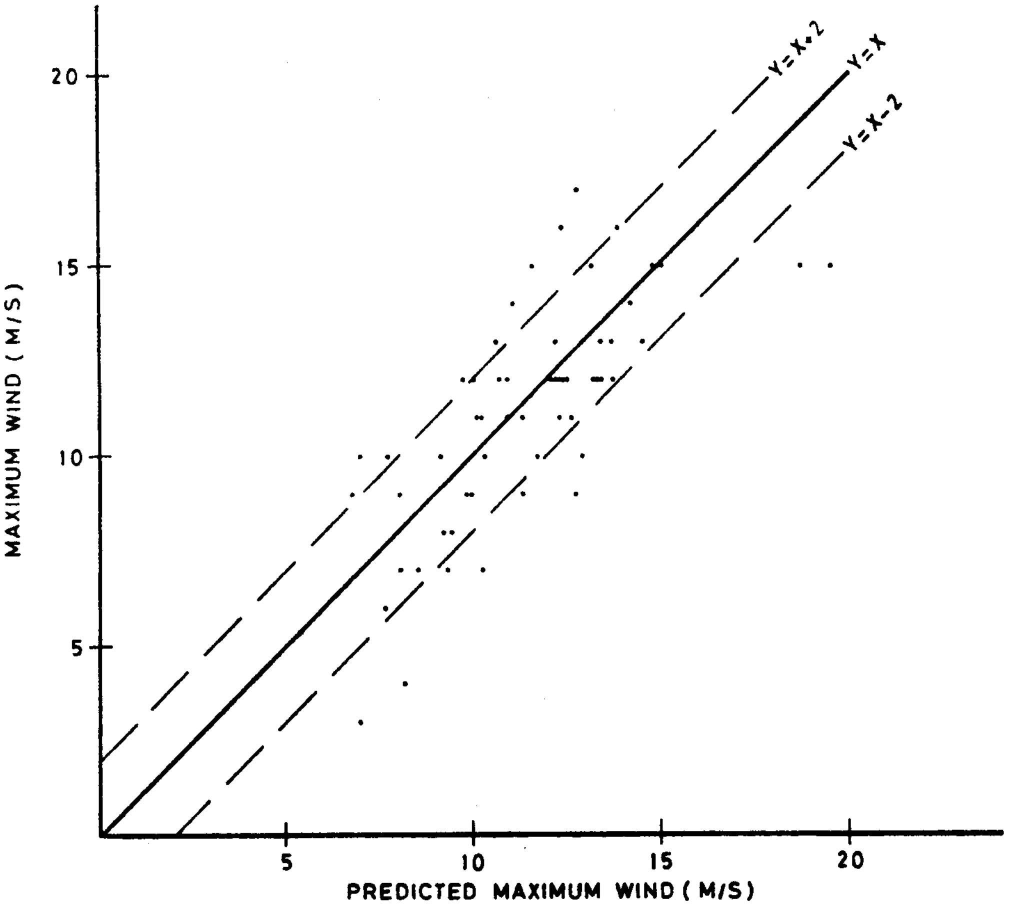

Fig. 8e Verification of Equation B2.

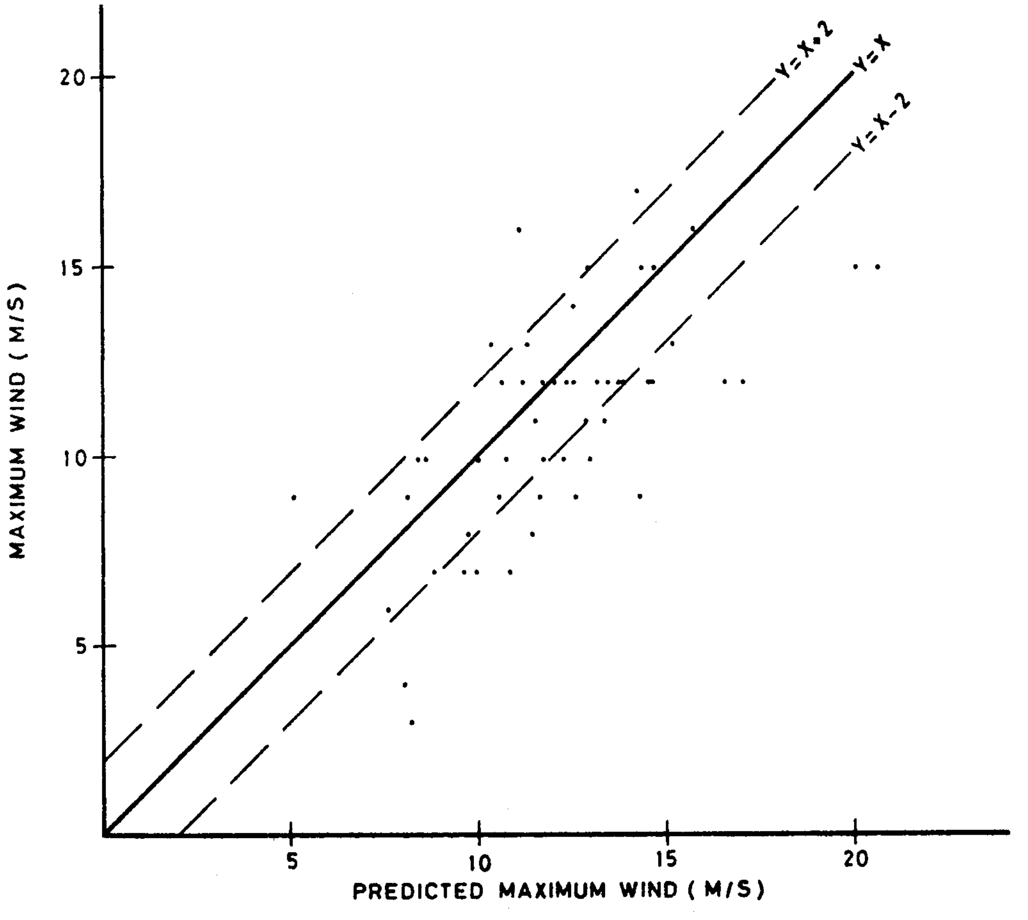

Fig. 8f Verification of Equation B3.

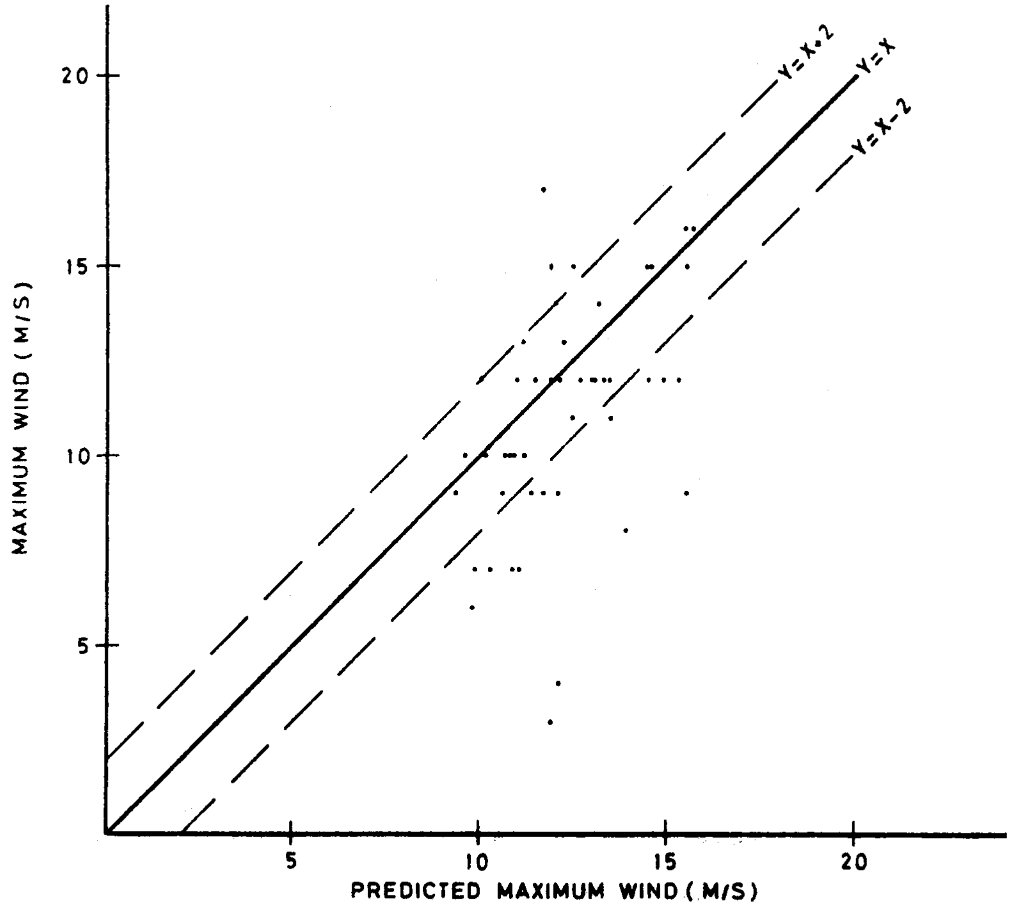

Fig. 9a Verification of Equation 3 using ECMWF prognostic charts for day 1 forecasts.

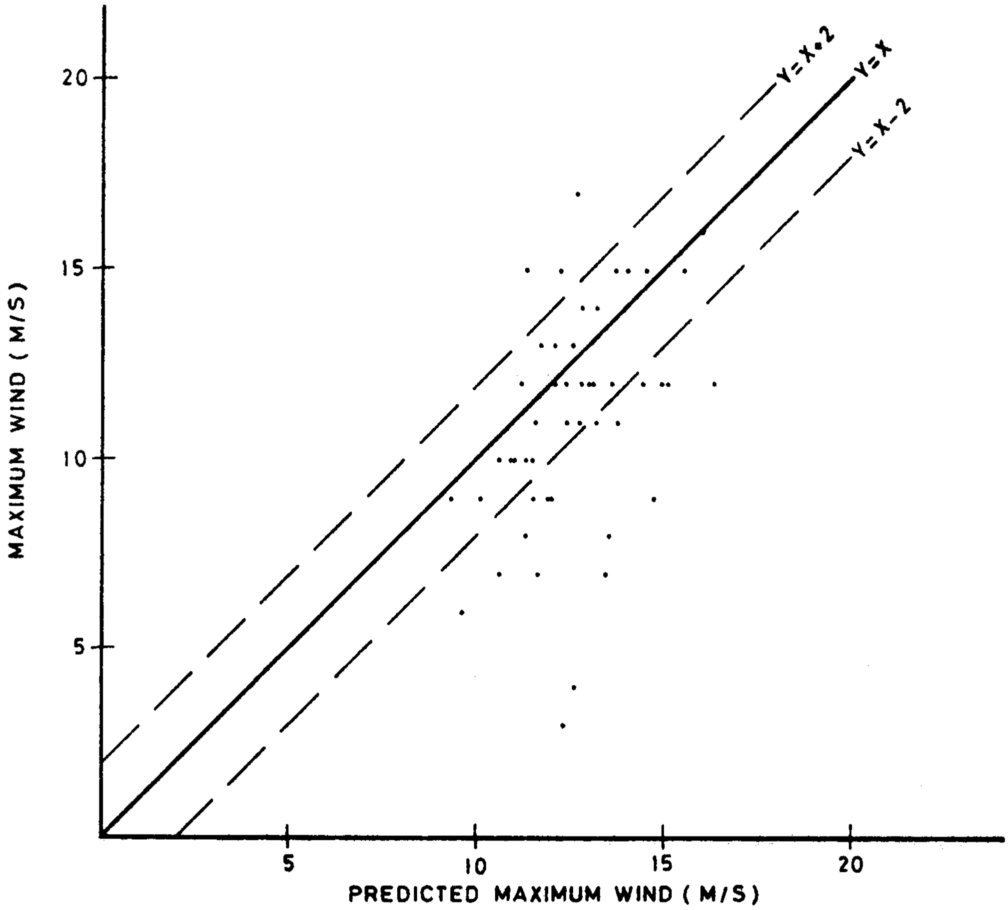

Fig. 9b Same as 9a but for day 2 forecasts.

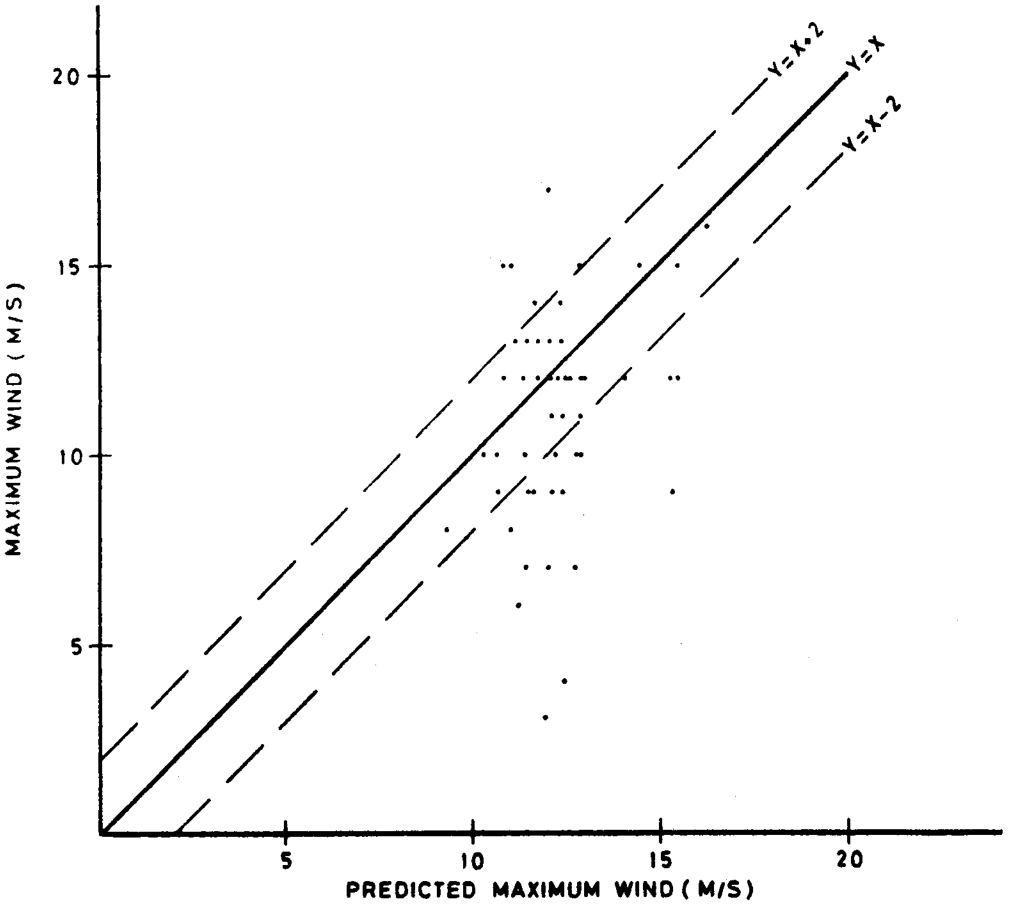

Fig. 9c Same as 9a but for day 3 forecasts.

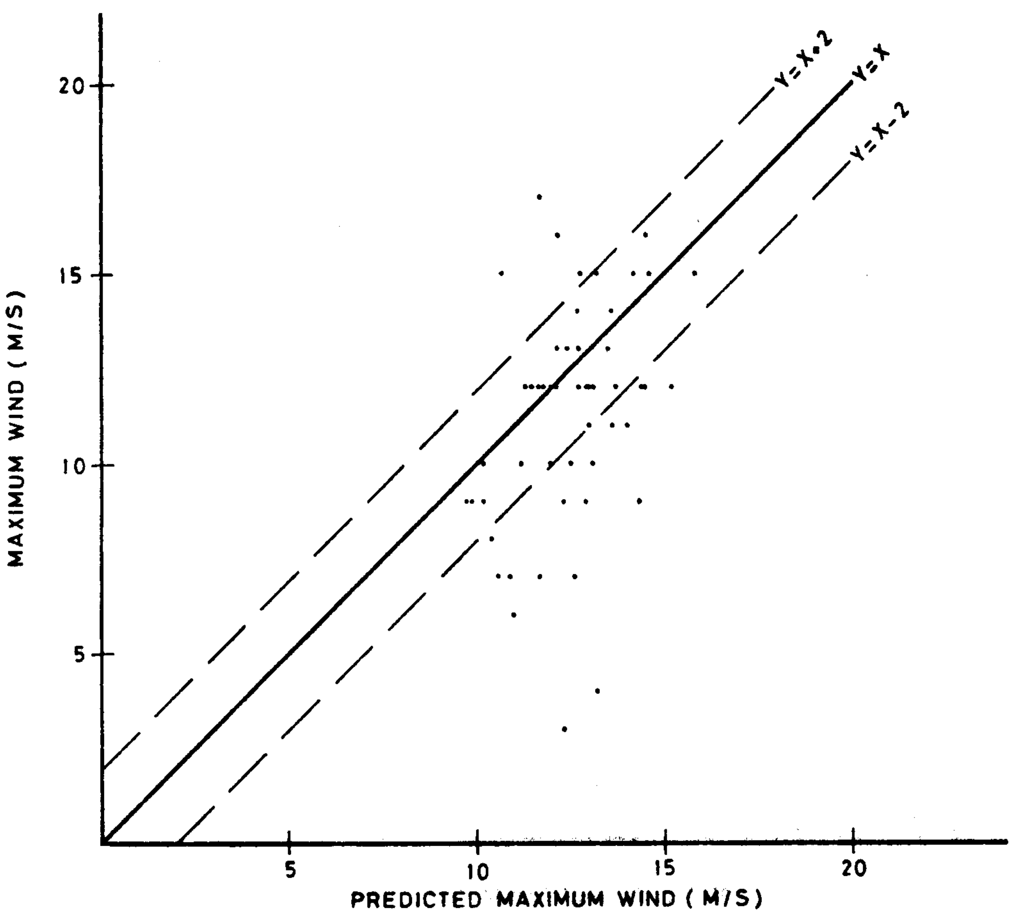

Fig. 9d Same as 9a but using EGRR prognostic charts.

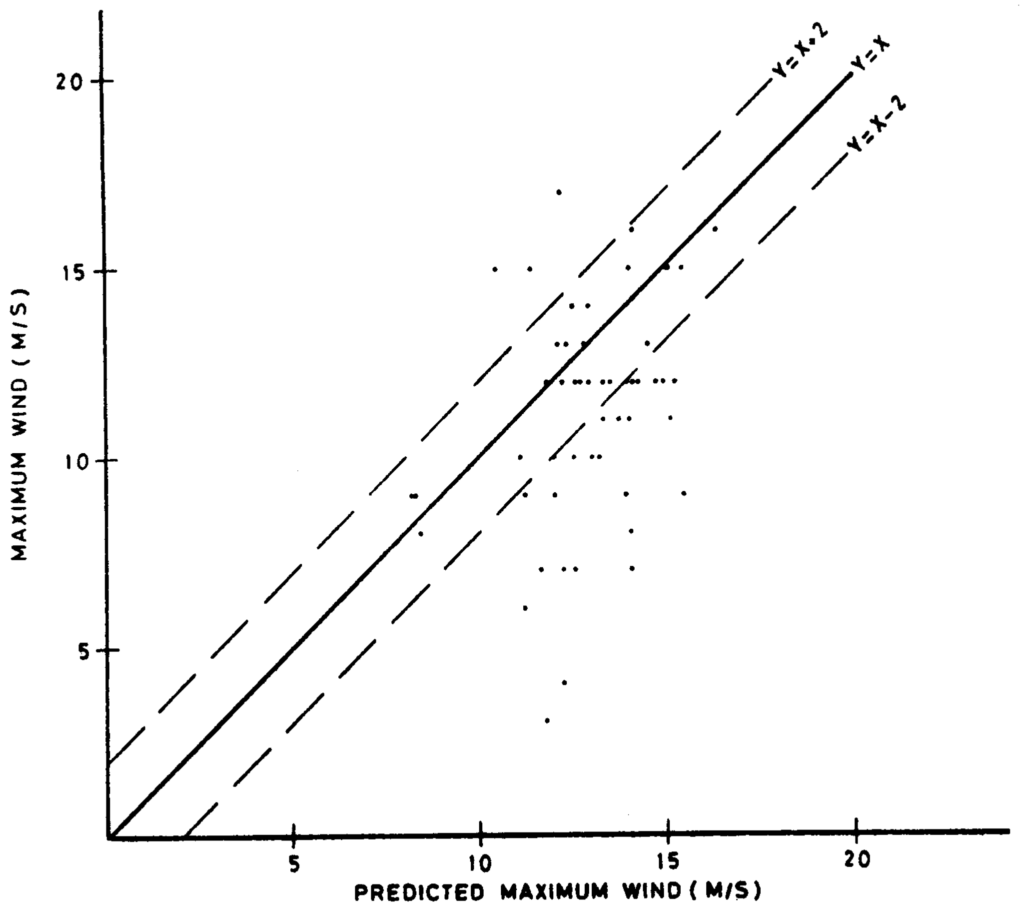

Fig. 9e Same as 9b but using EGRR prognostic charts.

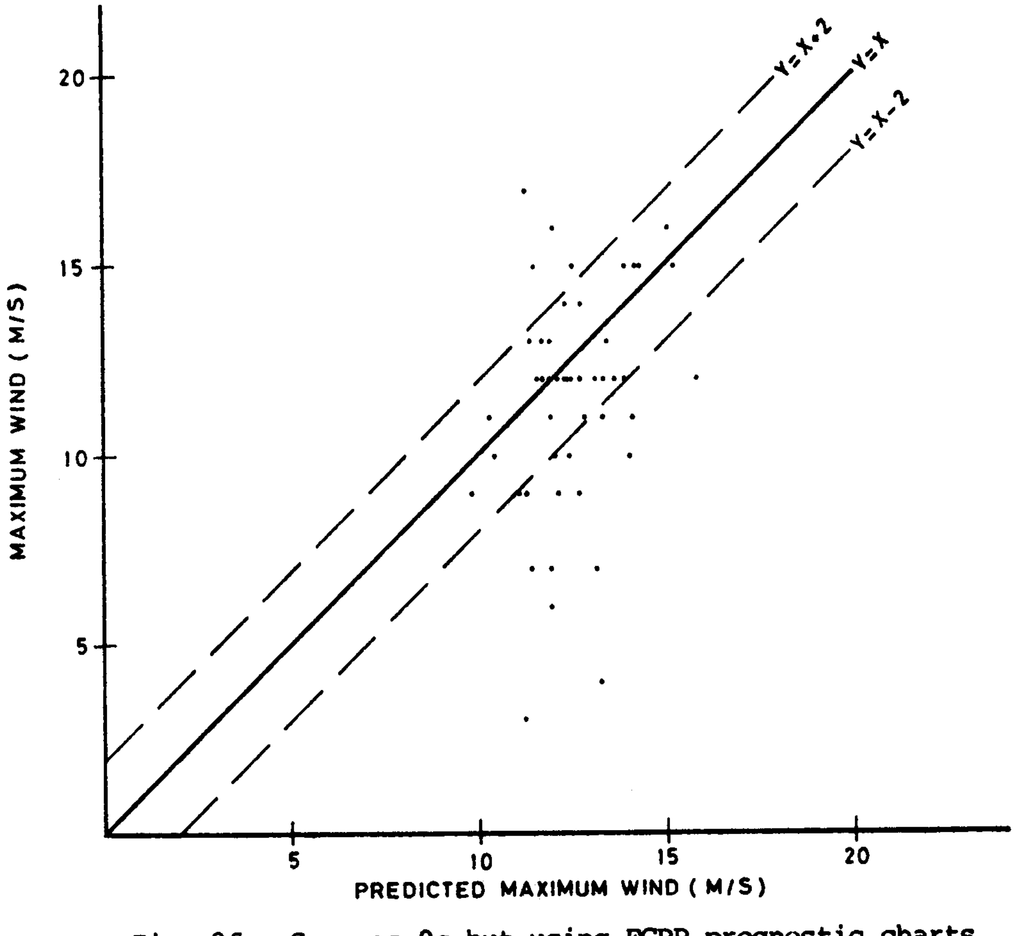

Fig. 9f Same as 9c but using EGRR prognostic charts.