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U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Statistical Analysis of Extreme Winds

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TABLE OF CONTENTS

STATISTICAL ANALYSIS OF EXTREME WINDS

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With a view to assessing the validity of current probabilistic approaches to the definition of design wind speeds, a study was undertaken of extreme wind speeds based on records taken at 21 U.S. weather stations. For the purpose of analyzing extreme value data, a computer program was developed which is described herein. The following results were obtained: (1) the assumption that a single probability distribution is universally applicable to all extreme wind data sets in a given type of climate was not confirmed, and (2) predictions of 100-year wind speeds based on overlapping 20-year sets of data taken at the same station differed between themselves by as much as 100%. Similar predictions for 1000-year winds differed by as much as a few hundred percent. Since wind pressures are proportional to the square of the wind speeds, errors of such magnitude are unacceptably high for structural design purposes. It is therefore suggested that while, in principle, probabilistic methods provide the most rational approach to specifying design wind speeds, it is of the utmost importance that the possible errors inherent in this approach be carefully taken into account.

Key words: Building codes; extreme value distributions; hurricanes; probability distribution functions; reliability; risk; statistical analysis; storms; structural engineering; wind loads; wind speeds.

SI CONVERSION UNITS

In view of the present practice in building technology in the United States and in publications of the National Oceanic and Atmospheric Administration (NOAA), common U.S. units of measurements have been used in this paper. However, in recognition of the position of the United States as a signatory to the General Conference on Weights and Measures, which gave official status to the metric SI system of units in 1960, conversion factors are given as follows:

Length

1 inch (in) = 0.0254* meter (m)

1 foot (ft) = 0.3048* meter (m)

1 mile (U.S. Statute) = 1.609344 x 10^3 meter (m)

Velocity

1 mile per hour (mph) = 4.470400 x 10^7 meters per second (m/s)

= 1.609344 kilometers per hour (km/hr)

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*exactly

CDF	Cumulative distribution function
D, D'	Probability distributions
F(v)	Mixed distribution given by Eq. 6
F_o	Specified value of the cumulative distribution function
$f_I(v), F_{II}(v)$	Extreme type I and type II cumulative distribution function
$F_{II}^E(v), F_{II}^T(v)$	Extreme type II cumulative distribution function for extratropical and tropical storm winds, respectively
$F_{X_\gamma}(x)$	Extreme type II cumulative distribution function with tail length parameter γ
$G_{X_\gamma}(p)$	Percentage point function given by Eq. 5, corresponding to distribution of random variable X
$M_i(D)$	Median of i-th ordered observation from a sample of size n from a distribution D
$\overline{M(D)}$	$\Sigma M_i(D)/n$
n	Sample size (number of observations)
$\bar{N}$	Mean recurrence interval, in years
p	Value of cumulative distribution function
P_E, P_T	Probability of largest yearly wind being produced by an extratropical and by a tropical storm, respectively
PPF	Percentage point function
r_D	Probability plot correlation coefficient defined by Eq. 7
SD(X)	Standard deviation of variable X
s_v	Standard deviation of the observed annual extreme wind speeds
v	Largest yearly wind speed
$\bar{v}$, v_{max}	Mean, maximum value of the observed annual extreme wind speeds, respectively
$v_{\bar{N}}, v_{\bar{N}}^{\infty}$	Extreme wind speed corresponding to a $\bar{N}$-year mean recurrence interval obtained using a distribution with $\gamma = \gamma_{opt}$, $\gamma = \infty$, respectively
X, x	Random variable, value taken on by X.
X_i	i-th ordered observation
$\bar{X}$	$\Sigma X_i/n$
γ, γ_{opt}	Tail length parameter, optimal value of γ, respectively
μ	Location parameter
σ	Probability distribution scale parameter

1. INTRODUCTION

In modern building codes and standards [1,3] basic design wind speeds are specified in probabilistic terms. At any given station at which wind records over a number of years are available, a random variable may be defined, which consists of the largest yearly wind speed for every year of record. Using these records the cumulative distribution function (CDF) of this random variable may, at least in theory, be estimated to characterize the probabilistic behavior of the largest yearly wind speeds. The basic design wind speed is then defined as the speed corresponding to a specified value F_o of the CDF or, equivalently (in view of the relation $\bar{N} = 1/(1-F_o)$, in which $\bar{N}$ = mean recurrence interval), as the speed corresponding to a specified mean recurrence interval. For example, the American National Standard A58.1 [1] specifies that a basic design wind speed corresponding to a 50-year mean recurrence interval (i.e., to a value F_o of the CDF equal to 0.98, or to a probability of exceedance of the basic wind speed in any one year equal to 0.02) be used in designing all permanent structures, except structures with an unusually high degree of hazard to life and property in case of failure, for which a 100-year mean recurrence interval (F_o = 0.96) must be used, and structures having no human occupants or where there is negligible risk to human life, for which a 25-year mean recurrence (F_o = 0.96) may be used. A wind speed corresponding to an $\bar{N}$-year recurrence interval is commonly referred to as the $\bar{N}$-year wind.

The mean recurrence intervals specified by building codes, rather than being based on a formal risk analysis--which is in practice not feasible in the present state of the art--are selected in such a manner as to yield basic wind speeds which, by professional consensus, are judged to be adequate from a structural safety viewpoint. Nevertheless, it is generally assumed that the current probabilistic approach to the definition of design wind speeds insures, at least in theory, a certain degree of consistency with regard to the effect of the wind loads upon structural safety; i.e., all other relevant factors being equal, if appropriate recurrence intervals are used in design, the probabilities of failure of buildings in different wind climates will, on the average, be approximately the same.

In the practical application of the probabilistic definition of design wind speeds, certain important questions arise. One such question pertains to the type of probability distribution of the National Building Code of Canada [3] are based upon the assumption that this behavior is best modeled by a Type I (Gumbel) distribution. The American National Standard A58.1 [1], on the other hand, assumes that the appropriate models are Type II (Frechet) distributions with location parameters equal to zero and with tail length parameters dependent only upon type of storm.

A second important question is whether records of approximately 20-year length, i.e., of such length as has been used in developing wind intensity maps in the American National Standard A58.1, are sufficient for making reliable predictions of extreme wind speeds.

The present work, which is part of an effort to evaluate and improve building code provisions on design for wind, was undertaken with the intent of seeking an answer to these two questions. A computer technique was developed for estimating the parameters of the probability distribution function of the largest values which best fits any given set of extreme wind speed data; using this program, an analysis was carried out of extreme winds recorded at 21 U.S. weather stations and published by Court [5]. The data consisted of 5-minute averages of the largest yearly wind speeds recorded during 37 consecutive years. All the data were obtained at stations where no change in the height and the exposure of the wind recording instruments was noted throughout the period of record. The results of the analyses are presented and, on their basis, answers to the two questions previously mentioned are suggested. These results point to the need for carefully taking into account the possible errors inherent in the probabilistic approach to the definition of wind speeds for purposes of structural design.

2. PROBABILITY DISTRIBUTIONS OF THE LARGEST YEARLY WIND SPEED

Probabilistic considerations [11, pp. 274-275], as well as available empirical evidence [6, 17, 18] suggest that the asymptotic probability distributions of the largest values with unlimited upper tail are an appropriate model for the behavior of the largest yearly wind speed. There are two such distributions, known as the type I and type II distributions of the largest values [11], whose cumulative distributions functions, $F_I(v)$ and $F_{II}(v)$, respectively, are of the form

$$F_I(v) = \exp\{-\exp[-(v-\mu)/\sigma]\} \qquad \begin{array}{c} \mu < v < \infty \\ -\infty < \mu < \infty \\ 0 < \sigma < \infty \end{array} \tag{1}$$

and

$$F_{II}(v) = \exp\{-[v-\mu)/\sigma]^{-\gamma}\} \qquad \begin{array}{c} \mu < v < \infty \\ -\infty < \gamma < \infty \\ -\infty < \sigma < \infty \\ \gamma > 0 \end{array} \tag{2}$$

in which μ, σ, and γ are location, scale and tail length parameters, respectively. Actually, the type I distribution may be shown to be a type II distribution with $\gamma = \infty$; however, it is convenient to refer to it separately.

It is convenient in many applications to use the inverse function of the CDF, known as the percent point function (PPF). For Eqs. 1 and 2, the PPF's are, respectively,

$$v(F_I) = \mu - \sigma \ln (-\ln F_I) \qquad 0 < F_I < 1 \qquad (3)$$

$$v(F_{II}) = \mu + \sigma (-\ln F_{II})^{-1/\gamma} \qquad 0 < F_{II} < 1 \qquad (4)$$

It is customary to denote the CDF value F_I or F_{II} as p and $v(F) = G_{X_\gamma}(p)$. With these notations, Eq. 4 becomes

$$G_{X_\gamma}(p) = \mu + \sigma (-\ln p)^{-1/\gamma} \qquad 0 < p < 1 \qquad (5)$$

The probability distribution of the largest value depends upon the form of the underlying (or initial) distribution, i.e., the distribution of the parent population of wind speeds from which the largest values have been extracted. The underlying distribution is of the exponential type if its CDF converges toward unity with increasing value of the variate as fast as, or faster than, the CDF of the exponential distribution; otherwise, it is said to be of the Cauchy type. Under the assumption of statistical independence, it can be shown that, asymptotically, i.e., for increasingly larger sample sizes, the largest sample value from an exponential and from a Cauchy type distributions have type I and type II distributions, respectively. Since there is empirical evidence to the effect that its parent population (say, the largest weekly wind speed) appears to follow a Rayleigh distribution, which is of the exponential type, it has been argued that the largest yearly wind speed should follow a type I distribution [6]. According to Thom [16, 17, 18, 19], however, the largest yearly wind speed follows type II distributions with location parameter $\mu \equiv 0$ and with tail length parameters $\gamma \simeq 9.0$ and $\gamma \simeq 4.5$ for winds associated with extratropical storms and with tropical storms, respectively. At locations at which both types of storms occur, Thom assumes that a mixed distribution holds,

$$F(v) = p_E F^E_{II}(v) + p_T F^T_{II}(v) \qquad (6)$$

in which $F^E_{II}(v)$, $F^T_{II}(v)$ are two type II CDF's for extratropical and for tropical storm winds, p_E = probability of largest yearly wind being produced by an extratropical storm (or the proportion of extratropical storm extreme winds) and $p_T = 1 - p_E$.

3. DESCRIPTION OF PROCEDURE FOR ESTIMATING CDF, ITS PARAMETERS AND THE $\overline{N}$-YEAR WINDS

The purpose of this section is to describe the computer technique which was utilized to estimate the CDF, the values of its parameters and the corresponding extreme wind speeds (i.e. wind speeds with given probabilities of being exceeded in any one year). The input to this procedure is the observed set of annual wind speeds from a given station. Based on any given set of observed annual wind speeds, the principal output from this procedure is the estimated wind speeds $v_{\overline{N}}$ for various mean recurrence intervals. In this study $\overline{N}$ = 50, 100, 500 and 1000 years were used.

The procedure consists of 3 distinct stages. In the first stage the value of γ (Eqs. 2 and 4) is determined which yields the closest fit to the observed data set (recall that $\gamma = \infty$ corresponds to an extreme value type I distribution). The "closest fit" criterion used in this stage is the so-called maximum probability plot correlation coefficient criterion [10]. The probability plot correlation coefficient is defined as

$$r_D = \mathrm{Corr}(X,M) = \frac{\Sigma(X_i - \bar{X})\ [M_i(D) - \overline{M(D)}]}{[\Sigma(X_i - \bar{X})^2\ \Sigma(M_i(D) - \overline{M(D)})^2]^{1/2}} \tag{7}$$

in which $\bar{X} = \Sigma X_i/n$, $\overline{M(D)} = \Sigma M_i(D)/n$, n = sample size, D = probability distribution tested. The quantities X_i are obtained by a rearrangement of the data set: X_1 is the smallest, X_2 the second smallest, X_i the i-th smallest of the observations in the set. The quantities $M_i(D)$ are obtained as follows. Given a random variable X with probability distribution D and given an integer sample size n, it is possible from probabilistic considerations, to derive mathematically the distributions of the smallest, second smallest, and in general the i-th smallest values of X in a sample of size n. There are various quantities that can be utilized to measure the location of the distribution of the i-th smallest value X_i (e.g., the mean, the median or the mode). As shown in Ref. 10, it is convenient to use the median as a measure of location in Eq. 7 - these medians of the distribution of the i-th smallest value being denoted by $M_i(D)$.

If the data set was generated by the distribution D, then aside from a location and scale factor, X_i will be approximately equal to $M_i(D)$ for all i, and so the plot of X_i versus $M_i(D)$ (referred to as probability plot) will be approximately linear. This linearity will, in turn, result in a near unity value in r_D. Thus, the better the fit of the distribution D to the data, the closer r_D will be to unity [10,22].

The procedure just described makes use of 43 extreme value type II distributions defined by various values of γ from 1 to 25 in steps of 1, from 25 to 50 in steps of 5, from 50 to 100 in steps of 10, from 100 to 250 in steps of 50, $\gamma = 350$, $\gamma = 500$, $\gamma = 750$, $\gamma = 1000$ and $\gamma = \infty$. For any given data set, 43 probability plot correlation coefficients are computed corresponding to these distributions, and the distribution with the maximum probability plot correlation coefficient is chosen as the one which best fits the data. The final result from this first stage is the value γ_{opt} of the γ corresponding to the estimated best fitting distributed.

The second stage in the procedure consists of estimating the location and scale parameters μ and σ, respectively, in Eqs. 1, 2, 3 and 4 for the observed data set and for the determined optimal value γ_{opt} as determined in stage 1. Estimates of the location and scale follow directly from the basic probability plot approach. If a least squares line is fit to the probability plot corresponding to γ_{opt}, then the computed intercept and slope of the fitted line serve as estimates for the unknown location and scale parameters μ and σ. In terms of the X_i and $M_i(D)$, these estimated location and scale values $\hat{\mu}$ and $\hat{\sigma}$ are as follows:

$$\hat{\sigma} = \frac{\Sigma(X_i - \overline{X})(M_i(D) - \overline{M(D)})}{\Sigma[M_i(D) - \overline{M(D)}]^2} \tag{9}$$

$$\hat{\mu} = \overline{X}_i - \hat{\sigma}\,\overline{M(D)} \tag{10}$$

The third and final stage in the procedure determines the predicted wind speed $v_{\overline{N}}$ for various intervals $\overline{N}$ of interest (say, $\overline{N}$ = 50, 100, 500, and 1000 years). The estimate for $v_{\overline{N}}$ is given by

$$\hat{v}_{\overline{N}} = \hat{\mu} + \hat{\sigma}\, G_{X_{\gamma_{opt}}}(1 - 1/\overline{N}) \tag{11}$$

where γ_{opt} is the optimal value of γ (as determined in stage 1), $\hat{\mu}$ and $\hat{\sigma}$ are the estimates of the location and scale parameters μ and σ in Eqs. 1, 2, 3, and 4 (as determined in stage 2), and $G_{X_{\gamma_{opt}}}(p)$ is the percent point function of the best fitting extreme value distribution. If $\gamma_{opt} \neq \infty$ (that is, if a member of the extreme value type II family provides the best fit), then

$$G_{X_{\gamma_{opt}}}(p) = (-\ell n\ p)^{-1/\gamma} \tag{12a}$$

If $\gamma_{opt} = \infty$ (that is, if the extreme value type 1 distribution provides the best fit), then

$$G_{X_{\gamma_{opt}}}(p) = -\ell n(-\ell n\ p) \tag{12b}$$

In effect, the procedure described in this section is an automated equivalent of probability paper plotting in which 43 types of probability paper, corresponding to 43 extreme value distributions, would be used and in which fitting would be carried out on the basis of the least squares method, rather than by eye.

It is noted that the procedure described is applicable without modification to the extreme value analysis of any physical phenomenon, i.e., it is in no way restricted to the analysis of extreme winds.

A listing of the computer program, and sample inputs and outputs, are given in an Appendix.

4. SUMMARY AND INTERPRETATION OF RESULTS

The data analyzed were obtained from Ref. 5 and are listed in table 1. The main results of the analysis are listed in table 2. The quantity γ_{opt} is the value of γ (see Eq. 2) for which the best distributional fit of the largest values is obtained. The quantities $v_{\bar{N}}$ are extreme wind speeds corresponding to a $\bar{N}$-year mean recurrence interval ($\bar{N}$ = 50, 100 and 1000) and were calculated using Eq. 2 with $\gamma = \gamma_{opt}$ or, if $\gamma_{opt} = \infty$, Eq. 1. The quantities $\bar{v}$, s_v, v_{max} are the mean, the standard deviation and the maximum value of the largest yearly winds, respectively. The quantities in parentheses are the values $v_{\bar{N}}^{\infty}$ of the extreme winds corresponding to a $\bar{N}$-year recurrence interval calculated assuming $\gamma = \infty$. These quantities were omitted in those cases in which $\gamma_{opt} = \infty$ or γ_{opt} was sufficiently large for the difference $v_{\bar{N}} - v_{\bar{N}}^{\infty}$ to be insignificant.

Optimum Probabilistic Models

The results of the analysis may be conveniently divided into four categories, characterized by the following ranges of values γ_{opt}: (1) $\gamma_{opt} \geq 40$; (2) $10 \leq \gamma_{opt} \leq 39$; (3) $5 \leq \gamma_{opt} \leq 9$; (4) $2 \leq \gamma_{opt} \leq 4$. Of the 21 37-year series of data considered, about 45% belong to the first category, 25% to the second, 10% to the third, and 20% to the fourth. Similar percentages were obtained from the analysis of the 30-, 25- and 20-year sets of data listed in table 2. It is seen that the assumption of a unique generally valid distribution, i.e., one characterized by a single value of γ_{opt} -- whether it be a type I distribution, or a type II distribution with $\mu = 0$ and a specified value of γ as proposed in Ref. 17, 18 and 19 -- is not confirmed by the results presented herein.

The results obtained also showed that a mixed probability distribution (Eq. 6) cannot improve the empirical fit of the data in any significant way. In addition, it is noted that during a normal period of record (20-40 years) the frequency at any one station of winds associated with hurricanes is small (of the order of one in 20 years or even less) and therefore the sample size is insufficient for carrying out a meaningful statistical analysis. That this is the case can be seen in table 1, which shows that in the period 1912-1948, 5-minute winds in excess of 70 mph were recorded only twice at both the Key West, Florida and the Corpus Christi, Texas weather stations.

Length of Record and Reliability of Predictions

According to Shellard [16], for extreme wind predictions to be acceptable the length of the record used should be of at least 15, or preferably 20 years. Thom proposed isotach maps for the United States using records of 15- to 21-year average length [17]. Implied in Shellard's statement and in Thom's work is the assumption that, at any given station, the mean value, the standard deviation and the sample distribution of the largest annual winds for a 20-year record are essentially the same as for any longer record at the station, i.e., that a 20-year record is a representative segment of a statistically stationary time series.

The extent to which this assumption is warranted was checked in each of the 21 cases included in table 2. The 37-year records were broken up into 30-, 25- and 20-year overlapping records which were separately analyzed. The results of the analysis are included in table 2 and are summarized in table 3, which shows the average values of the quantities $(v_{\overline{N}}^{max} - v_{\overline{N}}^{min})/v_{\overline{N}}^{min}$ for the four ranges of γ_{opt}: $\gamma_{opt} \geq 40$; $10 \leq \gamma_{opt} \leq 39$; $5 \leq \gamma_{opt} \leq 9$; $2 \leq \gamma_{opt} \leq 4$, where $v_{\overline{N}}^{max}$, $v_{\overline{N}}^{min}$ are the maximum and the minimum $\overline{N}$-year speed predicted on the basis of the 20-year records at one station and γ_{opt} is the tail length parameter of the distribution estimated from the 37 years of data at that station.

TABLE 3 - Average Values of $(v_{\overline{N}}^{max} - v_{\overline{N}}^{min})/v_{\overline{N}}^{min}$ for Various Ranges of γ_{opt} and Various Mean Recurrence Intervals

$\overline{N}$ (years)	50	100	1000
$\gamma_{opt} \geq 40$	.13	.17	.39
$10 \leq \gamma_{opt} \leq 39$	.23	.29	.55
$5 \leq \gamma_{opt} \leq 9$	.46	.53	2.40
$2 \leq \gamma_{opt} \leq 4$	.54	.96	7.20

The lower bounds for the error in the estimation of the $\overline{N}$-year winds may be calculated in the case of a type I distribution on the basis of a mathematical statistical result, viz., the Cramer-Rao relation, which states that for the EVI distribution [see Ref. 11, p. 282]

$$\mathrm{var}(\hat{\mu}) \geq \frac{1.10867\sigma^2}{n} \tag{13}$$

$$\mathrm{var}(\hat{\sigma}) \geq \frac{0.60793\sigma^2}{n} \tag{14}$$

where $\mathrm{var}(\hat{\mu})$, $\mathrm{var}(\hat{\sigma})$ are the variances of the estimated values of μ, σ; σ is the actual value of the scale parameter and n is the sample size. Using Eqs. 13, 14, the quantity $3SD(V_{100})$, where $SD(V_{100})$ is the standard deviation of the error in the estimation of the 100-year wind, was calculated for n = 20 years and n = 50 years and for typical values of σ obtained from the analysis of the data. The results of the calculations are shown in Fig. 1 and show that even for type I distributions, the estimation errors are not negligible. The results presented in tables 2 and 3 suggest that as γ_{opt} decreases such errors become intolerably large and that extreme caution is thus in order in the interpretation and use in

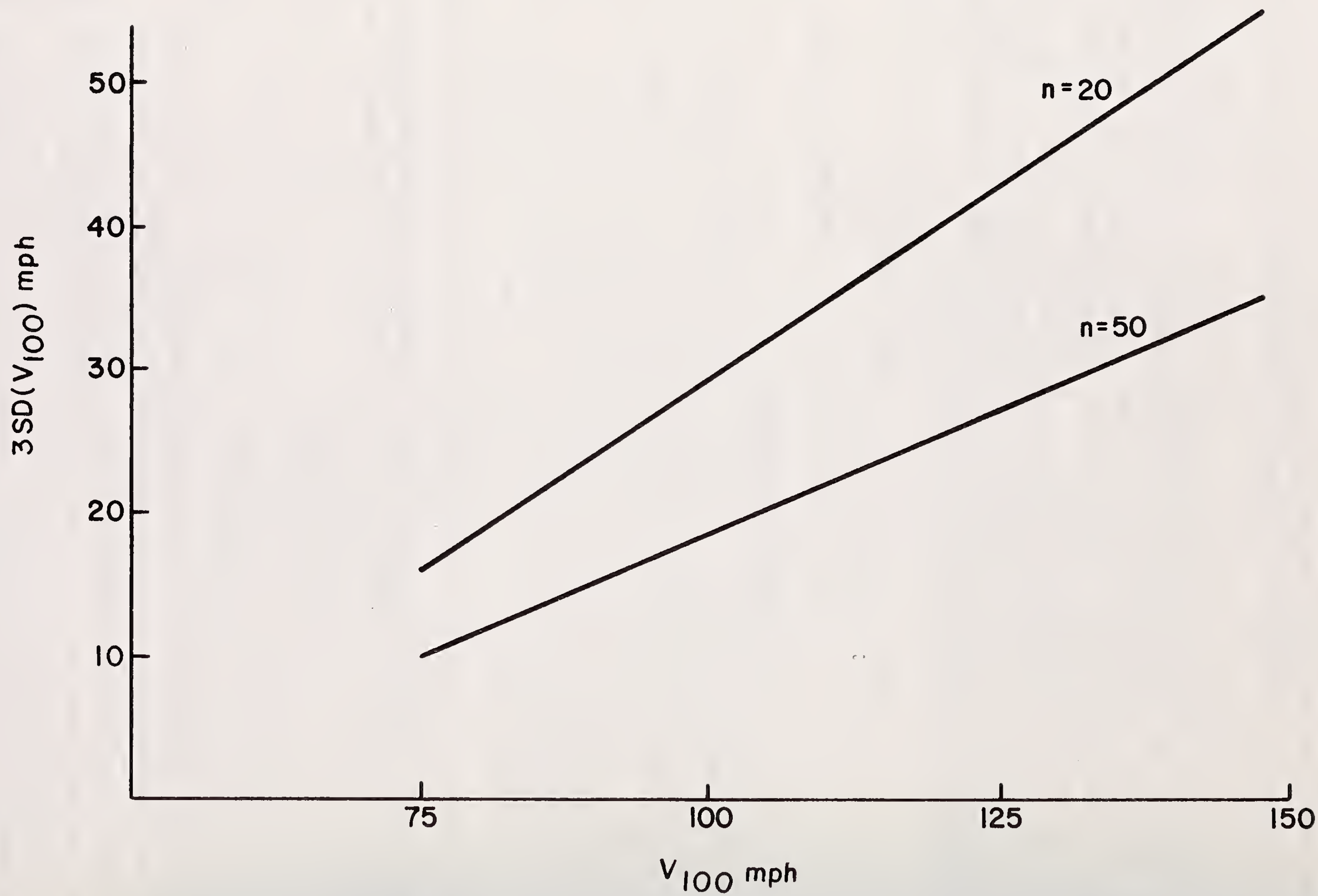

Fig. 1 - Dependence of 3SD(V_{100}) on Sample Size

structural design of probabilistically computed extreme winds. It is therefore the belief of the writers that further research is needed into the question of the validity of current probabilistic approaches to the definition of design wind speeds.

5. CONCLUSIONS

From the analysis of the sets of data reported herein, the following results were obtained:

1. No single distribution was universally applicable to all the data sets. The type I distribution was applicable in about 45% of the cases. In about 25% of the cases, the tail length parameter was $10 \le \gamma_{opt} \le 39$, in about 10% of the cases $5 \le \gamma_{opt} \le 9$ and in about 20% of the cases, $2 \le \gamma_{opt} \le 4$.

2. No necessary correlation was noted between type of wind climate and the magnitude of the tail length parameter, i.e., both type I distributions and type II distributions with small tail length parameters were found to fit series of data generated by tropical storms, as well as data generated by extratropical storms.

3. Predictions of extreme wind speeds based on records of 20-year length were found to vary, on the average, by about 15%-100% for 50-years or 100-year recurrence intervals and 40% to a few hundred percent for a 1000-year recurrence interval between different 20-year sets of data taken at the same station.

These results suggest that while in principle, probabilistic methods provide the most rational approach to specifying design wind speeds, it is of the utmost importance that the errors inherent in this approach be carefully taken into account. In particular, predictions of wind speeds corresponding to 1000-year recurrence intervals appear in most cases to be far too unreliable to be used with any reasonable degree of confidence for purposes of structural design. Therefore, unless very carefully substantiated the use for such purposes of 1000-year winds in conjunction with reduced values of the safety factor, which has been suggested recently, would, in the writers' opinion, be unwise. In the light of the results obtained, it also appears that the reliability of predictions based on records of 20-year length or so may in certain cases be quite unsatisfactory. This question is therefore believed to merit further investigation and is currently under study at the National Bureau of Standards.

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TABLE 1 - Strongest Maximum (5-min.) Wind Speed (mph) During Each Year, 1912-1948, at 21 places in the United States

	1912	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Cairo, Ill.	35	38	33	35	40	38	45	46	42	47	38	38	47	43	41	47	37	45	37	30	35	40	35	38	40	51	34	39	43	34	42	37	34	40	43	43	45
Alpena, Mich.	38	43	41	39	41	38	43	47	37	46	43	40	44	38	43	41	38	45	42	42	47	41	37	43	38	43	38	42	47	37	44	38	47	42	45	50	42
Tatoosh Island, Wash.	68	51	65	61	68	54	57	70	71	84	59	69	62	60	61	68	68	56	66	62	65	63	71	59	59	69	68	61	78	71	74	64	62	66	59	61	66
Williston, N.D.	38	50	40	35	38	41	38	50	38	38	44	41	50	35	34	35	42	36	35	37	40	46	39	40	37	46	37	39	33	44	34	34	35	42	46	41	44
Richmond, Va.	46	48	41	43	37	47	47	36	34	32	37	36	37	38	41	37	42	38	45	37	38	46	39	34	38	34	38	33	32	35	44	46	40	34	32	41	38
Burlington, Vt.	40	47	43	40	41	50	44	47	49	49	44	53	40	46	47	43	50	43	43	40	42	41	42	43	43	44	47	38	43	38	41	41	40	42	42	43	46
Eastport, Me.	53	41	54	49	60	54	52	56	48	39	57	46	46	51	38	50	45	50	48	52	42	46	51	48	46	46	45	47	46	49	46	42	51	55	44	52	48
Canton, N.Y.	51	53	50	44	46	47	49	47	46	54	43	49	43	62	39	39	47	48	36	38	39	39	38	39	44	35	38	39	35	40	38	42	32	34	39	34	35
Yuma, Ariz.	32	32	29	32	32	37	32	34	30	33	33	34	29	35	30	30	30	38	29	34	34	35	30	35	32	29	34	34	29	29	31	29	30	33	37	34	41
Duluth, Minn.	54	49	49	46	50	45	51	45	49	54	53	54	50	45	54	54	57	52	47	39	49	51	59	51	49	53	54	50	52	68	55	50	54	49	61	49	49
Valentine, Neb.	38	44	44	43	39	36	39	44	49	43	41	46	41	42	41	44	36	45	49	37	42	56	35	39	34	43	41	41	35	37	38	42	38	36	46	39	38
Charleston, S.C.	52	49	46	43	50	37	38	41	32	35	43	35	38	38	43	40	55	36	40	35	40	51	53	47	40	34	43	47	66	33	44	33	60	57	43	45	34
Eureka, Calif.	35	35	46	46	35	35	40	35	32	38	39	37	34	38	36	30	34	31	31	34	37	30	31	30	34	38	35	35	34	35	37	41	37	35	38	34	35
Oklahoma City, Okla.	56	41	44	57	48	43	57	46	43	37	40	38	46	35	36	38	34	38	38	29	32	32	34	38	30	34	32	33	33	31	33	26	34	28	31	37	33
Baker, Ore.	27	30	39	28	28	30	38	30	28	28	30	27	25	30	40	37	29	26	29	27	28	35	26	32	29	28	30	38	28	27	34	28	25	30	28	30	33
Sheridan, Wyo.	44	38	41	43	40	38	32	32	34	46	37	37	37	31	32	33	33	34	33	31	32	37	33	32	32	33	32	33	38	53	49	51	52	59	57	66	56
Block Island, R.I	60	54	65	66	56	59	54	54	56	56	56	47	60	56	56	59	54	52	54	51	59	60	57	62	58	47	82	56	50	52	57	70	82	63	56	67	57
Winnemucca, Nev.	36	32	36	32	38	41	37	36	43	38	40	38	38	31	32	37	34	32	34	34	32	40	30	35	36	32	35	36	35	58	52	45	33	42	42	39	40
North Head, Wash	69	65	70	63	73	65	68	68	57	95	60	68	64	70	73	65	66	63	66	66	79	70	87	68	73	72	67	70	84	67	65	77	65	64	67	66	69
Key West, Fla.	32	40	39	44	41	40	40	84	40	38	41	40	51	41	49	44	37	61	34	46	40	43	32	46	38	43	33	33	42	40	35	40	56	40	35	54	7[illegible]
Corpus Christi, Tex.	47	41	41	40	90	38	50	95	41	51	43	39	44	38	37	39	37	36	43	35	47	49	47	39	49	42	50	38	43	37	61	54	45	56	43	51	3

TABLE 2 - Results of Analysis

Station	No. of Years	Years of Record	γ_{opt}	v_{50}	v_{100}	v_{1000}	$\bar{v}$	s_v	v_{max}
						(miles per hour)			
Cairo (Ill.)	37	1912-48	∞	53	56	65	39.9	4.8	51
	30	1912-41	∞	53	56	65	39.9	4.7	51
		1919-48	∞	53	56	64	40.6	4.6	51
	25	1912-36	∞	52	54	62	39.8	4.3	47
		1924-48	∞	53	56	65	40.2	4.6	51
	20	1912-31	∞	53	55	64	40.4	4.5	47
		1917-36	∞	52	55	62	40.8	4.2	47
		1923-42	∞	54	56	66	40.1	4.8	51
		1929-48	∞	52	55	64	39.6	4.6	51
Alpena (Mich.)	37	1912-48	∞	51	53	59	41.9	3.4	50
	30	1912-41	∞	50	52	57	41.4	3.1	47
		1919-48	∞	52	54	61	42.2	3.6	50
	25	1912-36	∞	50	51	57	41.4	3.0	47
		1924-48	∞	52	54	61	42.2	3.5	50
	20	1912-31	∞	50	51	57	41.5	2.9	47
		1917-36	∞	51	52	59	41.7	3.2	47
		1923-42	∞	50	52	58	41.5	3.1	47
		1929-48	∞	53	55	62	42.5	3.7	50
Tatoosh Island (Wash.)	37	1912-48	∞	83	86	99	64.8	6.6	84
	30	1912-41	∞	84	88	101	64.8	7.0	84
		1919-48	18	84	88	104	65.3	6.2	84
	25	1912-36	∞	83	87	99	63.9	6.9	84
		1924-48	∞	79	83	93	64.8	5.2	78
	20	1912-31	∞	84	89	103	64.0	7.4	84
		1917-36	12	86(84)	91(88)	111(101)	64.2	7.0	84
		1923-42	∞	81	85	96	65.5	5.7	78
		1929-48	∞	81	84	95	65.0	5.6	78
Williston (N.D.)	37	1912-48	∞	53	55	64	39.8	4.8	50
	30	1912-41	∞	53	56	65	39.9	4.8	50
		1919-48	∞	53	56	65	39.7	4.8	50
	25	1912-36	18	54	57	69	39.9	4.8	50
		1924-48	∞	52	55	64	39.2	4.7	50
	20	1912-31	12	55(54)	59(57)	73(66)	39.8	5.1	50
		1917-36	13	54(53)	58(56)	61(65)	39.8	4.7	50
		1923-42	24	53(52)	56(55)	67(64)	39.0	4.7	50
		1929-48	∞	51	54	62	39.3	4.3	46
Richmond (Virginia)	37	1912-48	∞	52	54	63	39.9	4.7	48
	30	1912-41	∞	52	54	63	38.9	4.7	48
		1919-48	∞	49	51	58	37.7	4.0	46
	25	1912-36	∞	52	55	63	39.8	4.6	48
		1924-48	∞	50	52	60	38.3	4.1	46
	20	1912-31	∞	53	56	65	40.0	4.7	48
		1917-36	∞	51	54	62	39.0	4.4	47
		1923-42	∞	49	51	59	38.1	3.9	46
		1929-48	∞	51	53	62	38.1	4.5	46

TABLE 2 - Results of Analysis (continued)

Station	No. of Years	Years of Record	γ_{opt}	v_{50}	v_{100}	v_{1000}	$\bar{v}$	s_v	v_{max}
						(miles per hour)			
	37	1912-48	∞	53	55	62	47.3	3.5	53
	30	1912-41	∞	54	56	63	44.1	3.7	53
		1919-48	∞	53	55	62	44.7	3.5	53
Burlington	25	1912-36	∞	54	57	63	44.5	3.6	53
(Vermont)		1924-48	∞	50	52	57	42.8	2.8	50
	20	1912-31	∞	56	58	65	45.1	3.8	53
		1917-36	∞	55	57	64	45.1	3.6	53
		1923-42	8	54(54)	58(56)	71(63)	43.5	3.7	53
		1929-48	∞	48	49	53	42.2	2.2	47
	37	1912-48	∞	62	65	74	48.5	4.9	60
	30	1912-41	∞	62	65	77	48.5	5.1	60
		1919-48	∞	60	62	71	47.7	4.5	57
Eastport	25	1912-36	∞	64	67	77	48.9	5.5	60
(Maine)		1924-48	∞	57	59	66	47.4	3.8	55
	20	1912-31	∞	65	69	79	49.5	5.8	60
		1917-36	∞	62	65	74	48.2	5.0	57
		1923-42	∞	55	57	63	46.9	3.3	52
		1929-48	∞	57	59	66	47.7	3.4	55
	37	1912-48	∞	61	64	77	42.5	6.6	62
	30	1912-41	∞	62	65	77	43.9	6.4	62
		1919-48	5	63(59)	70(63)	101(75)	41.0	6.5	62
Canton	25	1912-36	∞	62	66	78	45.2	6.2	62
(N.Y.)		1924-48	2	66(56)	81(59)	186(70)	39.7	6.0	62
	20	1912-31	∞	64	67	79	46.6	6.1	62
		1917-36	7	65(62)	71(66)	95(78)	44.3	6.4	62
		1923-42	2	70(58)	87(62)	203(73)	41.3	6.3	62
		1929-48	13	49	52	62	38.1	3.7	48
	37	1912-48	80	40	42	48	32.5	2.9	41
	30	1912-41	∞	39	41	45	32.2	2.5	38
		1919-48	60	41	43	48	32.5	3.1	41
Yuma	25	1912-36	∞	39	41	45	32.4	2.5	38
(Ariz.)		1924-48	18	42	44	52	32.4	3.3	41
	20	1912-31	∞	39	41	46	32.3	2.6	38
		1917-36	∞	40	42	47	32.7	2.7	38
		1923-42	∞	40	41	46	32.1	2.8	38
		1929-48	150	42	44	51	32.9	3.4	41
	37	1912-48	35	65	68	77	51.4	5.0	68
	30	1912-41	90	65	68	78	51.1	5.1	68
		1919-48	200	66	69	79	51.9	5.3	68
Duluth	25	1912-36	∞	62	64	72	50.2	4.3	59
(Minn.)		1924-48	22	68	72	84	52.0	5.5	68
	20	1912-31	∞	61	64	72	49.9	4.4	57
		1917-36	∞	63	66	74	50.4	4.7	59
		1923-42	∞	68	71	82	52.2	5.7	68
		1929-48	7	71(68)	76(71)	98(82)	52.1	5.9	68

TABLE 2 - Results of Analysis (continued)

Station	No. of Years	Years of Record	γ_{opt}	v_{50}	v_{100}	v_{1000}	$\bar{v}$	s_v	v_{max}
						(miles per hour)			
	37	1912-48	30	54	56	65	41.1	4.6	56
	30	1912-41	70	55	58	67	41.4	4.8	56
		1919-48	23	55	59	70	41.2	4.9	56
Valentine	25	1912-36	∞	56	59	68	41.9	5.0	56
(Neb.)		1924-48	6	57(54)	62(57)	82(67)	40.6	4.9	56
	20	1912-31	∞	53	55	62	42.1	3.8	49
		1917-36	70	57	61	71	42.0	5.4	56
		1923-42	7	59(56)	64(59)	84(69)	41.1	5.3	56
		1929-48	4	61(56)	67(59)	101(69)	40.1	5.4	56
	37	1912-48	24	66	72	91	42.8	8.2	66
	30	1912-41	10	66(64)	72(68)	96(83)	42.3	7.8	66
		1919-48	9	69(66)	76(71)	104(88)	42.3	8.7	66
Charleston	25	1912-36	∞	60	64	76	42.3	6.5	55
(S.C.)		1924-48	13	71(68)	77(74)	102(91)	43.4	9.0	66
	20	1912-31	∞	59	63	75	41.3	6.3	55
		1917-36	11	60(58)	65(62)	84(74)	40.9	6.3	55
		1923-42	4	73(66)	84(71)	137(87)	42.4	8.4	66
		1929-48	12	73(71)	81(76)	108(95)	43.5	6.9	66
	37	1912-48	23	46	48	55	35.6	3.7	46
	30	1912-41	11	47(46)	50(48)	61(56)	35.3	4.0	46
		1919-48	∞	43	44	50	34.8	2.9	41
Eureka	25	1912-36	12	48(47)	51(50)	64(58)	35.3	4.3	46
(Calif.)		1924-48	∞	42	44	49	34.6	2.9	41
	20	1912-31	11	49(48)	53(51)	65(59)	30.1	4.3	46
		1917-36	∞	43	45	51	34.3	3.2	40
		1923-42	∞	41	43	48	34.1	2.7	38
		1929-48	∞	43	44	50	34.6	2.9	41
	37	1912-48	15	60(59)	65(63)	85(77)	37.7	7.7	57
	30	1912-41	19	62(60)	67(65)	86(80)	39.1	7.8	57
		1919-48	∞	48	51	60	35.0	4.8	46
Oklahoma	25	1912-36	∞	62	67	82	40.4	7.9	57
City		1924-48	∞	45	47	55	33.8	4.1	46
(Oklahoma)	20	1912-31	∞	64	68	83	42.2	7.7	57
		1917-36	6	60(56)	66(60)	94(73)	38.2	6.5	57
		1923-42	9	47(45)	50(48)	62(55)	34.7	3.9	46
		1929-48	∞	42	44	50	32.8	3.3	38
	37	1912-48	11	42(41)	45(43)	56(50)	30.1	4.0	40
	30	1912-41	9	43(41)	46(44)	59(51)	30.2	4.2	40
		1919-48	7	42(40)	46(42)	59(49)	29.8	3.7	40
Baker	25	1912-36	8	43(42)	47(44)	61(52)	30.2	4.2	40
(Oregon)		1924-48	10	42(41)	46(43)	58(51)	30.0	4.0	40
	20	1912-31	6	45(42)	49(45)	67(53)	30.3	4.5	40
		1917-36	7	44(42)	48(44)	63(52)	30.2	4.2	40
		1923-42	10	44(42)	47(45)	61(53)	30.3	4.3	40
		1929-48	7	40(39)	43(41)	56(47)	29.5	3.3	38

TABLE 2 - Results of Analysis (continued)

Station	No. of Years	Years of Record	γ_{opt}	v_{50}	v_{100}	v_{1000}	$\bar{v}$	s_v	v_{max}
						(miles per hour)			
Sheridan (Wyoming)	37	1912-48	7	69(65)	77(70)	111(87)	39.8	9.4	66
	30	1912-41	4	54(50)	61(53)	92(63)	36.0	5.2	53
		1919-48	7	71(67)	80(73)	117(91)	39.8	10.3	66
	25	1912-36	12	49(48)	52(50)	64(58)	35.7	4.3	46
		1924-48	8	74(69)	83(76)	119(96)	40.4	11.0	66
	20	1912-31	200	49	52	61	36.3	4.6	46
		1917-36	2	51(44)	59(46)	124(52)	34.3	3.6	46
		1923-42	2	62(50)	96(53)	182(63)	35.3	5.8	53
		1929-48	35	75	82	107	42.2	11.7	66
Block Island (R.I.)	37	1912-48	5	83(79)	91(83)	126(97)	58.4	7.6	82
	30	1912-41	3	81(66)	91(78)	145(89)	56.9	6.5	82
		1919-48	4	86(80)	96(85)	144(99)	58.2	8.2	82
	25	1912-36	∞	68	71	78	56.8	4.2	66
		1924-48	5	88(82)	97(87)	138(103)	59.1	8.5	82
	20	1912-31	∞	68	71	79	56.3	4.4	66
		1917-36	∞	65	67	74	56.0	3.5	62
		1923-42	2	90(76)	107(80)	238(93)	56.45	7.4	82
		1929-48	6	91(86)	100(91)	140(109)	59.6	9.5	82
Winnemucca (Nevada)	37	1912-48	4	56(53)	74(56)	97(66)	37.3	5.7	58
	30	1912-41	2	58(50)	70(52)	156(62)	36.2	5.2	58
		1919-48	4	59(54)	67(58)	103(69)	37.6	6.1	58
	25	1912-36	∞	45	47	53	35.7	3.4	43
		1924-48	3	63(55)	73(59)	131(71)	37.4	6.6	58
	20	1912-31	∞	45	47	54	36.0	3.3	43
		1917-36	∞	46	48	55	35.9	3.6	43
		1923-42	2	68(55)	85(58)	211(71)	36.6	6.9	58
		1929-48	4	64(58)	73(62)	118(75)	38.1	7.1	58
North Head (Wash.)	37	1912-48	4	94(89)	103(93)	146(106)	69.3	7.3	95
	30	1912-41	4	94(91)	107(95)	153(110)	69.7	7.8	95
		1919-48	4	94(91)	107(96)	154(110)	69.7	7.9	95
	25	1912-36	3	100(91)	113(95)	183(110)	69.2	8.0	95
		1924-48	4	92(87)	100(90)	137(102)	69.7	6.2	87
	20	1912-31	2	102(87)	120(91)	255(104)	67.7	7.5	95
		1917-36	3	105(94)	119(99)	198(115)	69.6	8.8	95
		1923-42	4	94(88)	102(92)	142(104)	70.1	6.5	87
		1929-48	4	95(89)	103(93)	145(105)	70.3	6.7	87
Key West (Florida)	37	1912-48	3	83(71)	99(77)	188(97)	43.4	10.7	84
	30	1912-41	2	84(67)	106(72)	271(89)	42.4	9.9	84
		1919-48	3	88(75)	106(82)	206(103)	44.3	11.7	84
	25	1912-36	2	89(70)	114(75)	300(94)	43.2	10.4	84
		1924-48	5	77(70)	87(76)	135(95)	43.4	9.7	73
	20	1912-31	2	97(73)	125(79)	335(99)	44.1	11.3	84
		1917-36	2	92(74)	126(80)	336(100)	44.3	11.3	84
		1923-42	10	64(61)	69(66)	92(79)	41.4	7.1	61
		1929-48	3	82(73)	96(79)	162(99)	43.2	10.6	73

TABLE 2 - Results of Analysis (continued)

Station	No. of Years	Years of Record	γ_{opt}	v_{50}	v_{100}	v_{1000}	$\bar{v}$	s_v	v_{max}
						(miles per hour)			
	37	1912-48	2	97(78)	125(85)	327(107)	46.3	12.7	95
	30	1912-41	2	101(78)	131(85)	351(107)	45.5	13.6	95
		1919-48	2	93(74)	119(80)	310(100)	45.6	11.4	95
Corpus	25	1912-36	2	109(82)	142(89)	390(114)	46.2	14.7	95
Christi		1924-48	70	63	67	82	44.0	6.9	61
(Texas)	20	1912-31	2	119(86)	159(94)	448(122)	46.3	16.4	95
		1917-36	1	132(76)	228(82)	1952(103)	44.9	12.9	95
		1923-42	5	65(61)	72(64)	104(77)	42.5	6.5	61
		1929-48	∞	65	68	83	45.2	7.1	61

A P P E N D I X

COMPUTER PROGRAM LISTING

SAMPLE INPUT AND OUTPUT

```
JJF6*SIMIU.MAIN
C      PURPOSE--THIS MAIN PROGRAM READS IN DATA UPON WHICH AN
C               EXTREME VALUE ANALYSIS IS TO BE PERFORMED.
C               AFTER READING IN THE DATA, THIS PROGRAM
C               CALLS IN A SUBROUTINE (EXTREM) WHICH
C               PERFORMS THE EXTREME VALUE ANALYSIS.
C      INPUT DATA--THE NUMBER OF SETS OF DATA TO BE ANALYZED
C                    (FORMAT--I2)
C
C                    THE IDENTIFYING TITLE FOR DATA SET 1
C                          (FORMAT--80A1)
C                    THE NUMBER OF OBSERVATIONS IN DATA SET 1
C                          (FORMAT--I2)
C                    THE DATA FOR SET 1
C                          (EACH DATA CARD HAVING A 16F5.1 FORMAT)
C
C                    THE IDENTIFYING TITLE FOR DATA SET 2
C                          (FORMAT--80A1)
C                    THE NUMBER OF OBSERVATIONS IN DATA SET 2
C                          (FORMAT--I2)
C                    THE DATA FOR SET 2
C                          (EACH DATA CARD HAVING A 16F5.1 FORMAT)
C
C                    .
C                    .
C                    .
C
C                    THE IDENTIFYING TITLE FOR THE LAST DATA SET
C                          (FORMAT--80A1)
C                    THE NUMBER OF OBSERVATIONS IN THE LAST DATA SET
C                          (FORMAT--I2)
C                    THE DATA FOR THE LAST SET
C                          (EACH DATA CARD HAVING A 16F5.1 FORMAT)
C      OUTPUT--THIS MAIN PROGRAM WILL (FOR EACH DATA SET)
C              SKIP TO A NEW PAGE, PRINT OUT THE TITLE,
C              PRINT OUT THE NUMBER OF OBSERVATIONS,
C              AND PRINT OUT THE INPUT DATA.
C              THIS WILL THEN BE FOLLOWED (FOR EACH DATA SET)
C              BY 4 OR 5 (DEPENDING ON THE DATA)
C              PAGES OF AUTOMATIC OUTPUT RESULTING
C              FROM THE EXTREME VALUE ANALYSIS
C              SUBROUTINE      EXTREM      WHICH IS
C              CALLED BY THIS MAIN PROGRAM.
C      SUBROUTINES NEEDED--EXTREM, SORT, UNIMED, EV1PLT, EV2PLT, AND PLOT
C      LANGUAGE--ANSI FORTRAN
C      COMMENT--THIS MAIN ROUTINE AND ALL SUBROUTINES
C               ASSUME THAT THE INPUT AND OUTPUT UNITS
C               HAVE A NUMERICAL DESIGNATION OF 5 AND 6,
C               RESPECTIVELY.
C               THIS DESIGNATION IS MADE WITH THE FORTRAN
C               STATEMENTS
C                         IRD=5
C                         IPR=6
C               ONE OR BOTH OF WHICH ARE FOUND AT THE
C               BEGINNING OF THE EXECUTABLE CODE
C               IN THIS MAIN ROUTINE AND ALL SUBROUTINES.
C               IF 5 AND 6 ARE NOT THE PROPER DESIGNATIONS
C               FOR YOUR COMPUTER, THEN SIMPLY CHANGE THE
```

```
C                 5 AND 6 IN THE IRD=5 AND IPR=6 STATEMENTS
C                 TO THE APPROPRIATE VALUE FOR YOUR COMPUTER.
C        COMMENT--THIS MAIN ROUTINE AND ALL SUBROUTINES
C                 WILL, AS THEY STAND, ACCEPT DATA SETS
C                 WITH UP TO 200 OBSERVATIONS.
C                 IF COMPUTER STORAGE IS LIMITED AND IF SMALLER DATA
C                 SETS ARE EXPECTED, THEN COMPUTER STORAGE MAY BE SAVED
C                 BY RESETTING THE DIMENSION LIMITS OF THE VECTORS
C                         X IN THIS MAIN ROUTINE,
C                         W, Y, AND Z IN THE SUBROUTINE EXTREM,
C                         W AND Y IN THE SUBROUTINE EV1PLT, AND
C                         W AND Y IN THE SUBROUTINE EV2PLT
C                 FROM THEIR PRESENT VALUE OF 200
C                 TO WHATEVER THE EXPECTED MAXIMUM DATA SET SIZE IS.
C                 THE STATEMENT        IUPPER=200
C                 (ABOUT STATEMENT 122 IN THIS SUBROUTINE,
C                 AND UP NEAR THE BEGINNING OF THE EXECUTABLE
C                 CODE IN THE SUBROUTINES EXTREM, EV1PLT, AND
C                 EV2PLT) SHOULD ALSO BE CHANGED FROM 200
C                 TO THE EXPECTED MAXIMUM DATA SET SIZE.
C        COMMENT--ON THE UNIVAC 1108, EXEC 8 COMPUTER SYSTEM AT NBS,
C                 THIS MAIN ROUTINE AND THE 6 NEEDED SUBROUTINES
C                 HAVE A TOTAL (CODE + DIMENSIONS + COMMON) STORAGE
C                 REQUIREMENT OF APPROXIMATELY 13000 WORDS (DECIMAL).
C                                   CODE   DIMENSIONS  COMMON
C                 MAIN PROGRAM       130       320         0
C                 EXTREM             770      1680         0
C                 SORT               340       180         0
C                 UNIMED             140        80         0
C                 EV1PLT             210       550         0
C                 EV2PLT             280       560         0
C                 PLOT               380       190      7150
C                 NOTE THE RELATIVELY LARGE STORAGE ALLOCATION
C                 FOR THE LAST SUBROUTINE (PLOT).  IF THE AMOUNT
C                 OF USABLE STORAGE IN YOUR COMPUTER IS LESS THAN
C                 13000, THEN AN ALTERNATIVE PLOT ROUTINE IS
C                 AVAILABLE FROM THE AUTHOR WHICH WILL REDUCE
C                 THE TOTAL STORAGE ALLOCATION FROM 13000
C                 TO APPROXIMATELY 6000.
C        WRITTEN BY--JAMES J. FILLIBEN (205.03)
C                    EMIL SIMIU        (461.01)
C                    NATIONAL BUREAU OF STANDARDS
C                    WASHINGTON, C. C. 20234
C        UPDATED--DECEMBER 1974
C
         DIMENSION X(200),ITITLE(80)
C
         IRD=5
         IPR=6
C
C        READ IN THE NUMBER OF SETS OF DATA TO BE ANALYZED
C
         READ(IRD,105)NUMSET
C
C        OPERATE ON EACH SET
C
         DO100ISET=1,NUMSET
C
```

```
C     READ IN THE TITLE AND THE NUMBER OF OBSERVATIONS
C     FOR THIS SET
C
      READ(IRD,205)(ITITLE(I),I=1,80)
      READ(IRD,210)N
C
C     ZERO-OUT THE X VECTOR, AND THEN READ THE DATA FOR THIS SET
C     INTO THE X VECTOR
C
      DO200I=1,N
      X(I)=0.0
  200 CONTINUE
      READ(IRD,215)(X(I),I=1,N)
C
C     WRITE OUT THE TITLE, THE NUMBER OF OBSERVATIONS,
C     AND THE DATA FOR THIS SET
C
      WRITE(IPR,998)
      NSKIP=10
      DO300ISKIP=1,NSKIP
      WRITE(IPR,999)
  300 CONTINUE
      WRITE(IPR,305)(ITITLE(I),I=1,80)
      WRITE(IPR,999)
      WRITE(IPR,999)
      WRITE(IPR,999)
      WRITE(IPR,310)N
      WRITE(IPR,999)
      WRITE(IPR,315)
      WRITE(IPR,320)(X(I),I=1,N)
C
C     DO AN EXTREME VALUE ANALYSIS OF THE DATA FOR THIS SET
C
      CALL EXTREM(X,N)
C
  100 CONTINUE
C
  105 FORMAT(I2)
  205 FORMAT(80A1)
  210 FORMAT(I2)
  215 FORMAT(16F5.1)
  305 FORMAT(1H ,20X,80A1)
  310 FORMAT(1H ,29HTHE NUMBER OF OBSERVATIONS = ,I5)
  315 FORMAT(1H ,10HINPUT DATA)
  320 FORMAT(1H ,13X,16F5.1)
  998 FORMAT(1H1)
  999 FORMAT(1H )
      STOP
      END
```

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@PRT,S SIMIU.EXTREM
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JJF6*SIMIU.EXTREM

```
      SUBROUTINE EXTREM(X,N)
C
C     PURPOSE--THIS SUBROUTINE PERFOMS AN EXTREME VALUE ANALYSIS
C              ON THE DATA IN THE INPUT VECTOR X.
C              THIS ANALYSIS CONSISTS OF DETERMINING THAT PARTICULAR
C              EXTREME VALUE TYPE 1 OR EXTREME VALUE TYPE 2 DISTRIBUTION
C              WHICH BEST FITS THE DATA SET.
C              THE GOODNESS OF FIT CRITERION IS THE MAXIMUM PROBABILITY
C              PLOT CORRELATION COEFFICIENT CRITERION.
C              AFTER THE BEST-FIT DISTRIBUTION IS DETERMINED,
C              ESTIMATES ARE COMPUTED AND PRINTED OUT FOR THE
C              LOCATION AND SCALE PARAMETERS.
C              TWO PROBABILITY PLOTS ARE ALSO PRINTED OUT--
C              THE BEST-FIT TYPE 2 PROBABILITY PLOT
C              (IF THE BEST FIT WAS IN FACT A TYPE 2),
C              AND THE TYPE 1 PROBABILITY PLOT.
C              PREDICTED EXTREMES FOR VARIOUS RETURN PERIODS ARE
C              ALSO COMPUTED AND PRINTED OUT.
C     INPUT ARGUMENTS--X      = THE SINGLE PRECISION VECTOR OF
C                               (UNSORTED OR SORTED) OBSERVATIONS.
C                    N        = THE INTEGER NUMBER OF OBSERVATIONS
C                               IN THE VECTOR X.
C     OUTPUT--6 PAGES OF AUTOMATIC PRINTOUT
C     PRINTING--YES
C     RESTRICTION--THE MAXIMUM ALLOWABLE VALUE OF N
C                  AS INPUT TO THIS SUBROUTINE IS 7500
C     OTHER DATAPAC   SUBROUTINES NEEDED--SORT,UNIMED,EV1PLT,EV2PLT,PLOT
C     FORTRAN LIBRARY SUBROUTINES NEEDED--SQRT AND ALOG
C     MODE OF INTERNAL OPERATIONS--SINGLE PRECISION
C     LANGUAGE--MACHINE-INDEPENDENT ANSI FORTRAN
C     COMMENT--THIS SUBROUTINE AS IT STANDS WILL ACCEPT DATA SETS
C              WITH UP TO 200 OBSERVATIONS.
C              IF COMPUTER STORAGE IS LIMITED AND IF SMALLER DATA
C              SETS ARE EXPECTED, THEN COMPUTER STORAGE MAY BE SAVED
C              BY RESETTING THE DIMENSION LIMITS OF THE VECTORS
C              W, Y, AND Z BELOW FROM THEIR PRESENT VALUE OF 200
C              TO WHATEVER THE EXPECTED MAXIMUM DATA SET SIZE IS.
C              THE STATEMENT        IUPPER=200
C              (ABOUT STATEMENT 122 IN THIS SUBROUTINE)
C              SHOULD ALSO BE CHANGED FROM 200 TO THE EXPECTED
C              MAXIMUM DATA SET SIZE.
C              STORAGE SAVINGS CAN ALSO BE ACHIEVED BY JUDICIOUSLY
C              REDUCING THE DIMENSION LIMITS OF THE VECTORS W AND Y
C              IN THE NEEDED SUPPORT SUBROUTINES EV1PLT
C              AND EV2PLT.
C     REFERENCE--FILLIBEN (1972), 'TECHNIQUES FOR TAIL LENGTH
C                ANALYSIS', PROCEEDINGS OF THE EIGHTEENTH
C                CONFERENCE ON THE DESIGN OF EXPERIMENTS IN
C                ARMY RESEARCH AND TESTING, PAGES 425-450.
C              --FILLIBEN, 'THE PERCENT POINT FUNCTION',
C                UNPUBLISHED MANUSCRIPT.
C              --JOHNSON AND KOTZ (1970), CONTINUOUS UNIVARIATE
C                DISTRIBUTIONS-1, PAGES 272-295.
C     WRITTEN BY--JAMES J FILLIBEN                 (JUNE 1972)
C                 STATISTICAL ENGINEERING LABORATORY (205.03)
C                 NATIONAL BUREAU OF STANDARDS
C                 WASHINGTON, D. C. 20234
```

```
C                  PHONE--301-921-2315
C     UPDATED--DECEMBER, 1974
C
      INTEGER BLANK,ALPHAM,ALPHAA,ALPHAX
      INTEGER ALPHAI,ALPHAN,ALPHAF,ALPHAT,ALPHAY
      INTEGER ALPHAG,EQUAL
      DIMENSION X(1)
      DIMENSION W(200),Y(200),Z(200)
      DIMENSION GAMTAB(50),CORR(50)
      DIMENSION YI(50),YS(50),T(50)
      DIMENSION IFLAG1(50),IFLAG2(50),IFLAG3(50)
      DIMENSION C(10),AM(50),SCRAT(50)
      DIMENSION AINDEX(50)
      DIMENSION P0(10)
      DIMENSION H(60,2)
      DATA BLANK,ALPHAM,ALPHAA,ALPHAX/1H ,1HM,1HA,1HX/
      DATA ALPHAI,ALPHAN,ALPHAF,ALPHAT,ALPHAY/1HI,1HN,1HF,1HT,1HY/
      DATA ALPHAG,EQUAL/1HG,1H=/
      DATA GAMTAB(1),GAMTAB(2),GAMTAB(3),GAMTAB(4),GAMTAB(5),
     1GAMTAB(6),GAMTAB(7),GAMTAB(8),GAMTAB(9),GAMTAB(10),
     1GAMTAB(11),GAMTAB(12),GAMTAB(13),GAMTAB(14),GAMTAB(15),
     1GAMTAB(16),GAMTAB(17),GAMTAB(18),GAMTAB(19),GAMTAB(20),
     1GAMTAB(21),GAMTAB(22),GAMTAB(23),GAMTAB(24),GAMTAB(25)
     1/1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,
     113.,14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,24.,25./
      DATA GAMTAB(26),GAMTAB(27),GAMTAB(28),GAMTAB(29),GAMTAB(30),
     1GAMTAB(31),GAMTAB(32),GAMTAB(33),GAMTAB(34),GAMTAB(35),
     1GAMTAB(36),GAMTAB(37),GAMTAB(38),GAMTAB(39),GAMTAB(40),
     1GAMTAB(41),GAMTAB(42)
     1/30.,35.,40.,45.,50.,60.,70.,80.,90.,100.,150.,200.,250.,
     1350.,500.,750.,1000./
      DATA C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8),C(9),C(10)
     1/60.,75.,100.,150.,250.,500.,1000.,10000.,100000.,1000000./
      DATA P0(1),P0(2),P0(3),P0(4),P0(5),P0(6),P0(7),P0(8),P0(9),P0(10)
     1/.0,.5,.75,.9,.95,.975,.99,.999,.9999,.99999/
      DATA AINDEX(1),AINDEX(2),AINDEX(3),AINDEX(4),AINDEX(5),
     1AINDEX(6),AINDEX(7),AINDEX(8),AINDEX(9),AINDEX(10),
     1AINDEX(11),AINDEX(12),AINDEX(13),AINDEX(14),AINDEX(15),
     1AINDEX(16),AINDEX(17),AINDEX(18),AINDEX(19),AINDEX(20),
     1AINDEX(21),AINDEX(22),AINDEX(23),AINDEX(24),AINDEX(25)
     1/1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,
     113.,14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,24.,25./
      DATA AINDEX(26),AINDEX(27),AINDEX(28),AINDEX(29),AINDEX(30),
     1AINDEX(31),AINDEX(32),AINDEX(33),AINDEX(34),AINDEX(35),
     1AINDEX(36),AINDEX(37),AINDEX(38),AINDEX(39),AINDEX(40),
     1AINDEX(41),AINDEX(42),AINDEX(43),AINDEX(44),AINDEX(45),
     1AINDEX(46),AINDEX(47),AINDEX(48),AINDEX(49),AINDEX(50)
     1/26.,27.,28.,29.,30.,31.,32.,33.,34.,35.,36.,37.,38.,
     139.,40.,41.,42.,43.,44.,45.,46.,47.,48.,49.,50./
      DATA T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),
     1T(11),T(12),T(13),T(14),T(15),T(16),T(17),T(18),T(19),T(20),
     1T(21),T(22),T(23),T(24),T(25)
     1/10.18011,3.39672,2.47043,2.14609,1.98712,1.89429,1.83394,
     11.79175,1.76069,1.73691,1.71814,1.70297,1.69045,1.67996,
     11.67103,1.66335,1.65667,1.65082,1.64564,1.64102,1.63689,
     11.63316,1.62979,1.62672,1.62391/
      DATA T(26),T(27),T(28),T(29),T(30),
     1T(31),T(32),T(33),T(34),T(35),T(36),T(37),T(38),T(39),T(40),
```

```
      1T(41),T(42),T(43)
      1/1.61287,1.60516,1.59947,1.59510,1.59164,1.58651,1.58289,
      11.58019,1.57811,1.57645,1.57152,1.56908,1.56763,1.56666,
      11.56546,1.56377,1.56330,1.56187/
C
       IPR=6
       IUPPER=200
       NUMDIS=43
       AN=N
C
C      CHECK THE INPUT ARGUMENTS FOR ERRORS
C
       IF(N.LT.1.OR.N.GT.IUPPER)GOTO50
       IF(N.EQ.1)GOTO55
       HOLD=X(1)
       DO60I=2,N
       IF(X(I).NE.HOLD)GOTO90
    60 CONTINUE
       WRITE(IPR, 9)HOLD
       RETURN
    50 WRITE(IPR,17)IUPPER
       WRITE(IPR,47)N
       RETURN
    55 WRITE(IPR,18)
       RETURN
    90 CONTINUE
     9 FORMAT(1H ,109H***** NON-FATAL DIAGNOSTIC--THE FIRST  INPUT ARGUME
      1NT (A VECTOR) TO THE EXTREM SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
      1H *****)
    17 FORMAT(1H , 98H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
      1 EXTREM SUBROUTINE IS OUTSIDE THE ALLOWABLE (1,,I6,16H) INTERVAL *
      1****)
    18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
      1NT TO THE EXTREM SUBROUTINE HAS THE VALUE 1 *****)
    47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8   ,6H *****)
C
C      COMPUTE THE SAMPLE MINIMUM AND SAMPLE MAXIMUM
C
       XMIN=X(1)
       XMAX=X(1)
       DO140I=2,N
       IF(X(I).LT.XMIN)XMIN=X(I)
       IF(X(I).GT.XMAX)XMAX=X(I)
   140 CONTINUE
C
C      COMPUTE THE PROB PLOT CORRELATION COEFFICIENTS FOR THE VARIOUS VALUES
C      OF GAMMA
C
       CALL SORT(X,N,Y)
       CALL UNIMED(N,Z)
C
       DO100IDIS=1,NUMDIS
       IF(IDIS.EQ.NUMDIS)GOTO150
       A=GAMTAB(IDIS)
       DO110I=1,N
       W(I)=(-ALOG(Z(I)))**(-1.0/A)
   110 CONTINUE
       GOTO170
```

```
  150 DO160I=1,N
      W(I)=-ALOG(ALOG(1.0/Z(I)))
  160 CONTINUE
C
  170 SUM1=0.0
      SUM2=0.0
      DO200I=1,N
      SUM1=SUM1+Y(I)
      SUM2=SUM2+W(I)
  200 CONTINUE
      YBAR=SUM1/AN
      WBAR=SUM2/AN
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO300I=1,N
      SUM2=SUM2+(Y(I)-YBAR)*(W(I)-WBAR)
      SUM1=SUM1+(Y(I)-YBAR)*(Y(I)-YBAR)
      SUM3=SUM3+(W(I)-WBAR)*(W(I)-WBAR)
  300 CONTINUE
      SY=SQRT(SUM1/(AN-1.0))
      CC=SUM2/SQRT(SUM3*SUM1)
      YSLOPE=SUM2/SUM3
      YINT=YBAR-YSLOPE*WBAR
      CORR(IDIS)=CC
      YI(IDIS)=YINT
      YS(IDIS)=YSLOPE
  100 CONTINUE
C
C     DETERMINE THAT DISTRIBUTION WITH THE MAX PROB PLOT CORR COEFFICIENT
C
      IDISMX=1
      CORRMX=CORR(1)
      DO400IDIS=1,NUMDIS
      IF(CORR(IDIS).GT.CORRMX)IDISMX=IDIS
      IF(CORR(IDIS).GT.CORRMX)CORRMX=CORR(IDIS)
  400 CONTINUE
      DO500IDIS=1,NUMDIS
      IFLAG1(IDIS)=BLANK
      IFLAG2(IDIS)=BLANK
      IFLAG3(IDIS)=BLANK
      IF(IDIS.EQ.IDISMX)GOTO550
      GOTO500
  550 IFLAG1(IDIS)=ALPHAM
      IFLAG2(IDIS)=ALPHAA
      IFLAG3(IDIS)=ALPHAX
  500 CONTINUE
C
C     WRITE OUT THE TABLE OF PROB PLOT CORR COEFFICIENTS FOR VARIOUS GAMMA
C
      WRITE(IPR,998)
      WRITE(IPR,305)
      WRITE(IPR,999)
      WRITE(IPR,310)N
      WRITE(IPR,311)YBAR
      WRITE(IPR,312)SY
      WRITE(IPR,313)XMIN
      WRITE(IPR,314)XMAX
```

```
      WRITE(IPR,999)
      WRITE(IPR,323)
      WRITE(IPR,324)
      WRITE(IPR,325)
      WRITE(IPR,999)
C
      NUMDM1=NUMDIS-1
      IF(NUMDM1.LT.1)GOTO850
      DO800I=1,NUMDM1
      WRITE(IPR,805)GAMTAB(I),CORR(I),IFLAG1(I),IFLAG2(I),IFLAG3(I),
     1YI(I),YS(I)
  800 CONTINUE
  850 I=NUMDIS
      WRITE(IPR,806)ALPHAI,ALPHAN,ALPHAF,ALPHAI,ALPHAN,ALPHAI,
     1ALPHAT,ALPHAY,CORR(I),IFLAG1(I),IFLAG2(I),IFLAG3(I),
     1YI(I),YS(I)
C
C     PLOT THE PROB PLOT CORR COEFFICIENT VERSUS GAMMA VALUE INDEX
C
      CALL PLOT(CORR,AINDEX,NUMDIS)
      WRITE(IPR,810)ALPHAG,ALPHAA,ALPHAM,ALPHAM,ALPHAA,EQUAL,
     1GAMTAB(1),GAMTAB(12),GAMTAB(23),GAMTAB(34),
     1ALPHAI,ALPHAN,ALPHAF,ALPHAI,ALPHAN,ALPHAI,ALPHAT,ALPHAY
      WRITE(IPR,999)
      WRITE(IPR,812)
      WRITE(IPR,813)
C
C     IF THE OPTIMAL GAMMA IS FINITE, PLOT OUT THE EXTREME VALUE
C     TYPE 2 PROBABILITY PLOT FOR THE OPTIMAL VALUE
C     OF GAMMA.
C
      IF(IDISMX.LT.NUMDIS)CALL EV2PLT(X,N,GAMTAB(IDISMX))
C
C     PLOT OUT AN EXTREME VALUE TYPE 1 PROBABILITY PLOT
C
      CALL EV1PLT(X,N)
C
C     FORM THE VARIOUS RETURN PERIOD VALUES
C
 1650 K=0
      DO2100I=1,4
      DO2200J=1,9
      K=K+1
      AM(K)=J*(10**(I-1))
 2200 CONTINUE
 2100 CONTINUE
      K=K+1
      AM(K)=10000.
      K=K+1
      AM(K)=50000.
      K=K+1
      AM(K)=100000.
      K=K+1
      AM(K)=500000.
      K=K+1
      AM(K)=1000000.
      K=K+1
      AM(K)=N
```

```
      NUMAM=K
      CALL SORT(AM,NUMAM,SCRAT)
      DO2300I=1,NUMAM
      AM(I)=SCRAT(I)
 2300 CONTINUE
C
C     IF THE OPTIMAL GAMMA IS FINITE, COMPUTE THE
C     PREDICTED EXTREME (= F(1-(1/M)) FOR VARIOUS RETURN PERIODS M
C     FOR THE OPTIMAL EXTREME VALUE TYPE 2 DISTRIBUTION.
C
      IF(IDISMX.EQ.NUMDIS)GOTO2450
      A=GAMTAB(IDISMX)
      YINT=YI(IDISMX)
      YSLOPE=YS(IDISMX)
      DO2400I=2,NUMAM
      R=1.0/AM(I)
      P=1.0-R
      ARG=-ALOG(P)
      IF(ARG.LE.0.0)GOTO2400
      H(I,1)=YINT+YSLOPE*(ARG**(-1.0/A))
 2400 CONTINUE
C
C     COMPUTE THE PREDICTED EXTREME (= F(1-(1/M)) FOR VARIOUS RETURN
C     PERIODS M FOR THE EXTREME VALUE TYPE 1 DISTRIBUTION.
C
 2450 YINT=YI(NUMDIS)
      YSLOPE=YS(NUMDIS)
      DO2500I=2,NUMAM
      R=1.0/AM(I)
      P=1.0-R
      ARG=-ALOG(P)
      IF(ARG.LE.0.0)GOTO2500
      H(I,2)=YINT+YSLOPE*(-ALOG(ARG))
 2500 CONTINUE
C
C     WRITE OUT THE PAGE WITH THE RETURN PERIODS AND THE PREDICTED EXTREMES
C     FOR THE 2 DISTRIBUTIONS--OPTIMAL EXTREME VALUE TYPE 2, AND EXTREME
C     VALUE TYPE 1.
C
      WRITE(IPR,998)
      IF(IDISMX.EQ.NUMDIS)GOTO2750
      WRITE(IPR,2602)
      WRITE(IPR,2604)
      WRITE(IPR,2606)
      WRITE(IPR,2608)
      WRITE(IPR,2610)GAMTAB(IDISMX)
      WRITE(IPR,999)
      DO2700I=2,NUMAM
      WRITE(IPR,2705)AM(I),H(I,1),H(I,2)
      J=I-1
      JSKIP=J-5*(J/5)
      IF(JSKIP.EQ.0)WRITE(IPR,999)
 2700 CONTINUE
      RETURN
C
 2750 WRITE(IPR,2802)
      WRITE(IPR,2804)
      WRITE(IPR,2806)
```

```
      WRITE(IPR,2808)
      WRITE(IPR,999)
      DO2900I=2,NUMAM
      WRITE(IPR,2705)AM(I),H(I,2)
      J=I-1
      JSKIP=J-5*(J/5)
      IF(JSKIP.EQ.0)WRITE(IPR,999)
 2900 CONTINUE
C
  998 FORMAT(1H1)
  999 FORMAT(1H )
  305 FORMAT(1H ,40X,22HEXTREME VALUE ANALYSIS)
  310 FORMAT(1H ,37X,20HTHE SAMPLE SIZE N = ,I7)
  311 FORMAT(1H ,34X,18HTHE SAMPLE MEAN = ,F14.7)
  312 FORMAT(1H ,28X,32HTHE SAMPLE STANDARD DEVIATION = ,F14.7)
  313 FORMAT(1H ,32X,21HTHE SAMPLE MINIMUM = ,F14.7)
  314 FORMAT(1H ,32X,21HTHE SAMPLE MAXIMUM = ,F14.7)
  323 FORMAT(1H ,67H     EXTREME VALUE      PROBABILITY PLOT     LOCATIO
     1N         SCALE)
  324 FORMAT(1H ,69H  TYPE 2 TAIL LENGTH      CORRELATION        ESTIMAT
     1E        ESTIMATE)
  325 FORMAT(1H ,37H   PARAMETER (GAMMA)      COEFFICIENT)
  805 FORMAT(1H ,3X,F10.2,13X,F8.5,1X,3A1,2X,F14.7,2X,F14.7)
  806 FORMAT(1H ,5X,8A1,13X,F8.5,1X,3A1,2X,F14.7,2X,F14.7)
  810 FORMAT(1H ,12X,5A1,1X,A1,F14.7,11X,F14.7,11X,F14.7,11X,F14.7,
     115X,8A1)
  812 FORMAT(1H ,96HTHE ABOVE IS A PLOT OF THE 43 PROBABILITY PLOT CORRE
     1LATION COEFFICIENTS (FROM THE PREVIOUS PAGE))
  813 FORMAT(1H ,16X,41HVERSUS THE 43 EXTREME VALUE DISTRIBUTIONS)
 2602 FORMAT(1H ,43H   RETURN PERIOD     PREDICTED EXTREME WIND,
     1 27H     PREDICTED EXTREME WIND)
 2604 FORMAT(1H ,43H    (IN YEARS)          BASED ON OPTIMAL
     1 20H          BASED ON)
 2606 FORMAT(1H ,42H                          EXTREME VALUE TYPE 2,
     1 27H       EXTREME VALUE TYPE 1)
 2608 FORMAT(1H ,43H                              DISTRIBUTION
     1 22H         DISTRIBUTION)
 2610 FORMAT(1H ,30H                         (GAMMA = ,F12.5,1H))
 2705 FORMAT(1H ,2X,F9.1,13X,F10.2,17X,F10.2)
 2802 FORMAT(1H ,43H   RETURN PERIOD     PREDICTED EXTREME WIND)
 2804 FORMAT(1H ,36H    (IN YEARS)              BASED ON)
 2806 FORMAT(1H ,42H                          EXTREME VALUE TYPE 1)
 2808 FORMAT(1H ,38H                              DISTRIBUTION)
C
      RETURN
      END
```

```
@PRT,S SIMIU.SORT
```

```
JJF6*SIMIU.SORT
      SUBROUTINE SORT(X,N,Y)
C
C     THIS ROUTINE SORTS THE ELEMENTS OF THE INPUT VECTOR X AND PUTS THE SORTED
C     ELEMENTS INTO THE VECTOR Y.
C     THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR X OF
C     (UNSORTED) OBSERVATIONS, THE INTEGER VALUE N (= SAMPLE SIZE),
C     AND AN EMPTY SINGLE PRECISION VECTOR Y INTO WHICH THE SORTED OBSERVATIONS
C     WILL BE PLACED.
C     THE OUTPUT FROM THIS ROUTINE IS THE SINGLE PRECISION VECTOR Y INTO WHICH
C     THE SORTED OBSERVATIONS HAVE BEEN PLACED.
C     RESTRICTIONS ON THE MAXIMUM ALLOWABLE VALUE OF N--THE DIMENSIONS
C     OF VECTORS IU AND IL (DEFINED AND USED INTERNALLY WITHIN THIS ROUTINE)
C     DETERMINE THE MAXIMUM ALLOWABLE VALUE OF N FOR THIS
C     ROUTINE.  IF IU AND IL EACH HAVE DIMENSION K, THEN N MAY NOT EXCEED
C     2**(K+1) - 1.  FOR THIS ROUTINE AS WRITTEN, THE DIMENSIONS OF IU AND IL
C     HAVE BEEN SET TO 36, THUS THE MAXIMUM ALLOWABLE VALUE OF N IS
C     APPROXIMATELY 137 BILLION.  SINCE THIS EXCEEDS THE MAXIMUM ALLOWABLE
C     VALUE FOR AN INTEGER VARIABLE IN MANY COMPUTERS, AND SINCE A SORT OF 137
C     BILLION ELEMENTS IS PRESENTLY IMPRACTICAL AND UNLIKELY, THEREFORE NO
C     TEST FOR WHETHER THE INPUT SAMPLE SIZE N EXCEEDS 137 BILLION HAS BEEN
C     INCORPORATED INTO THIS ROUTINE.  IT IS THUS ASSUMED THAT THERE IS NO
C     (PRACTICAL) RESTRICTION ON THE MAXIMUM VALUE OF N FOR THIS ROUTINE.
C     PRINTING--NONE UNLESS AN ERROR CONDITION EXISTS
C     THIS ROUTINE IS SINGLE PRECISION IN INTERNAL OPERATION.
C     SUBROUTINES NEEDED--NONE
C     SORTING METHOD--BINARY SORT
C     REFERENCE--CACM MARCH 1969, PAGE 186 (BINARY SORT ALGORITHM BY RICHARD
C                C. SINGLETON.
C              --CACM JANUARY 1970, PAGE 54.
C              --CACM OCTOBER 1970, PAGE 624.
C              --JACM JANUARY 1961, PAGE 41.
C
C     THE BINARY SORT ALGORITHM USED HEREIN IS EXTREMELY FAST AS THE
C     FOLLOWING TIME TRIALS (PERFORMED BY SORTING RANDOM NUMBERS)
C     ON THE UNIVAC 1108 EXEC 8 SYSTEM INDICATE.
C     THESE TIME TRIALS WERE CARRIED OUT IN AUGUST, 1974.
C     BY WAY OF COMPARISON, THE TIME TRIAL VALUES FOR THE EASY-TO-PROGRAM
C     BUT EXTREMELY INEFFICIENT BUBBLE SORT METHOD HAVE ALSO BEEN
C     INCLUDED:
C          NUMBER OF RANDOM              BINARY SORT       BUBBLE SORT
C           NUMBERS SORTED
C            N = 10                        .002 SEC          .002 SEC
C            N = 100                       .011 SEC          .045 SEC
C            N = 1000                      .141 SEC         4.332 SEC
C            N = 3000                      .476 SEC        37.683 SEC
C            N = 10000                    1.887 SEC      NOT COMPUTED
C
C     WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
C     NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234       JUNE 1972
C
      DIMENSION X(1),Y(1)
      DIMENSION IU(36),IL(36)
C
      IPR=6
C
C     CHECK THE INPUT ARGUMENTS FOR ERRORS
C
```

```
      IF(N.LT.1)GOTO50
      IF(N.EQ.1)GOTO55
      HOLD=X(1)
      DO60I=2,N
      IF(X(I).NE.HOLD)GOTO90
   60 CONTINUE
      WRITE(IPR, 9)HOLD
      DO61I=1,N
      Y(I)=X(I)
   61 CONTINUE
      RETURN
   50 WRITE(IPR,15)
      WRITE(IPR,47)N
      RETURN
   55 WRITE(IPR,18)
      Y(1)=X(1)
      RETURN
   90 CONTINUE
    9 FORMAT(1H ,108H***** NON-FATAL DIAGNOSTIC--THE FIRST  INPUT ARGUME
     1NT (A VECTOR) TO THE SORT   SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
     1H *****)
   15 FORMAT(1H , 91H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
     1 SORT   SUBROUTINE IS NON-POSITIVE *****)
   18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
     1NT TO THE SORT   SUBROUTINE HAS THE VALUE 1 *****)
   47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8   ,6H *****)
C
C     COPY THE VECTOR X INTO THE VECTOR Y
      DO100I=1,N
      Y(I)=X(I)
  100 CONTINUE
C
C     CHECK TO SEE IF THE INPUT VECTOR IS ALREADY SORTED
C
      NM1=N-1
      DO200I=1,NM1
      IP1=I+1
      IF(Y(I).LE.Y(IP1))GOTO200
      GOTO250
  200 CONTINUE
      RETURN
  250 M=1
      I=1
      J=N
  305 IF(I.GE.J)GOTO370
  310 K=I
      MID=(I+J)/2
      AMED=Y(MID)
      IF(Y(I).LE.AMED)GOTO320
      Y(MID)=Y(I)
      Y(I)=AMED
      AMED=Y(MID)
  320 L=J
      IF(Y(J).GE.AMED)GOTO340
      Y(MID)=Y(J)
      Y(J)=AMED
      AMED=Y(MID)
      IF(Y(I).LE.AMED)GOTO340
```

```
      Y(MID)=Y(I)
      Y(I)=AMED
      AMED=Y(MID)
      GOTO340
  330 Y(L)=Y(K)
      Y(K)=TT
  340 L=L-1
      IF(Y(L).GT.AMED)GOTO340
      TT=Y(L)
  350 K=K+1
      IF(Y(K).LT.AMED)GOTO350
      IF(K.LE.L)GOTO330
      LMI=L-I
      JMK=J-K
      IF(LMI.LE.JMK)GOTO360
      IL(M)=I
      IU(M)=L
      I=K
      M=M+1
      GOTO380
  360 IL(M)=K
      IU(M)=J
      J=L
      M=M+1
      GOTO380
  370 M=M-1
      IF(M.EQ.0)RETURN
      I=IL(M)
      J=IU(M)
  380 JMI=J-I
      IF(JMI.GE.11)GOTO310
      IF(I.EQ.1)GOTO305
      I=I-1
  390 I=I+1
      IF(I.EQ.J)GOTO370
      AMED=Y(I+1)
      IF(Y(I).LE.AMED)GOTO390
      K=I
  395 Y(K+1)=Y(K)
      K=K-1
      IF(AMED.LT.Y(K))GOTO395
      Y(K+1)=AMED
      GOTO390
      END
```

```
@PRT,S SIMIU.UNIMED
```

JJF6*SIM1U.UNIMED

```
      SUBROUTINE UNIMED(N,X)
C
C     THIS ROUTINE COMPUTES AN APPROXIMATION TO THE MEDIAN OF THE I-TH ORDER
C     STATISTIC (FOR I = 1,2,...,N) FROM A UNIFORM DISTRIBUTION (ON THE UNIT
C     INTERVAL (0,1)).
C     THIS IS IDENTICAL TO THE MEDIAN OF THE BETA DISTRIBUTION WITH PARAMETERS
C     I AND N-I+1 FOR I=1,2,...,N.
C     THE INPUT TO THIS ROUTINE IS THE DESIRED INTEGER SAMPLE SIZE N
C     AND AN EMPTY SINGLE PRECISION VECTOR X (OF DIMENSION AT LEAST N) INTO
C     WHICH THE N GENERATED UNIFORM ORDER STATISTIC MEDIANS WILL BE PLACED.
C     THE OUTPUT FROM THIS ROUTINE IS THE SINGLE PRECISION VECTOR X
C     INTO WHICH THE N GENERATED UNIFORM ORDER STATISTIC MEDIANS
C     HAVE BEEN PLACED.
C     ALL OF THE PROBABILITY PLOT ROUTINES MAKE USE OF THIS ROUTINE.
C     JUSTIFICATION AND ACCURACY OF THE ALGORITHM USED IS FOUND IN AN
C     UNPUBLISHED JJF MANUSCRIPT.
C     THERE IS NO RESTRICTION ON THE MAXIMUM VALUE OF N FOR THIS ROUTINE.
C     PRINTING--NONE UNLESS AN ERROR CONDITION EXISTS
C     THIS ROUTINE IS SINGLE PRECISION IN INTERNAL OPERATION
C     SUBROUTINES NEEDED--NONE
C     REFERENCE--UNPUBLISHED JJF MANUSCRIPT
C     WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
C     NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234        JUNE 1972
C
      DIMENSION X(1)
C
      AN=N
      IPR=6
C
C     CHECK THE INPUT ARGUMENTS FOR ERRORS
C
      IF(N.LT.1)GOTO50
      IF(N.EQ.1)GOTO55
      GOTO90
   50 WRITE(IPR, 5)
      WRITE(IPR,47)N
      RETURN
   55 WRITE(IPR, 8)
   90 CONTINUE
    5 FORMAT(1H , 91H***** FATAL ERROR--THE FIRST  INPUT ARGUMENT TO THE
     1 UNIMED SUBROUTINE IS NON-POSITIVE *****)
    8 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE FIRST  INPUT ARGUME
     1NT TO THE UNIMED SUBROUTINE HAS THE VALUE 1 *****)
   47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8   ,6H *****)
C
      X(N)=0.5**(1.0/AN)
      X(1)=1.0-X(N)
      NHALF=(N/2)+1
      NEVODD=2*(N/2)
      IF(N.NE.NEVODD)X(NHALF)=0.5
      IF(N.LE.3)RETURN
      GAM=0.3175
      IMAX=N/2
      DO100I=2,IMAX
      AI=I
      IREV=N-I+1
      X(I)=(AI-GAM)/(AN-2.0*GAM+1.0)
```

```
      X(IREV)=1.0-X(I)
  100 CONTINUE
      RETURN
      END
```

```
@PRT,S SIMIU.EV1PLT
```

```
JJF6*SIMIU.EV1PLT
      SUBROUTINE EV1PLT(X,N)
C
C     THIS ROUTINE GENERATES AN EXTREME VALUE TYPE 1 (EXPONENTIAL TYPE)
C     PROBABILITY PLOT
C     THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR X OF
C     (UNSORTED OR SORTED) OBSERVATIONS AND THE INTEGER VALUE N (= SAMPLE SIZE)
C     THE OUTPUT FROM THIS ROUTINE IS A ONE-PAGE EXTREME VALUE TYPE 1
C     PROBABILITY PLOT
C     PRINTING--YES
C     SUBROUTINES NEEDED--SORT, UNIMED, AND PLOT
C     REFERENCE--UNPUB. JJF MANUSCRIPT 'THE PERCENT POINT FUNCTION', PAGE 26
C     WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
C     NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234        JUNE 1972
C
      DIMENSION X(1)
      DIMENSION Y(200),W(200)
C
      DATA TAU/1.56186687/
C
      AN=N
      IPR=6
      IUPPER=7500
C
C     CHECK THE INPUT ARGUMENTS FOR ERRORS
C
      IF(N.LT.1.OR.N.GT.IUPPER)GOTO50
      IF(N.EQ.1)GOTO55
      HOLD=X(1)
      DO60I=2,N
      IF(X(I).NE.HOLD)GOTO90
   60 CONTINUE
      WRITE(IPR, 9)HOLD
      GOTO90
   50 WRITE(IPR,17)IUPPER
      WRITE(IPR,47)N
      RETURN
   55 WRITE(IPR,18)
      RETURN
   90 CONTINUE
    9 FORMAT(1H ,109H***** NON-FATAL DIAGNOSTIC--THE FIRST  INPUT ARGUME
     1NT (A VECTOR) TO THE EV1PLT SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
     1H *****)
   17 FORMAT(1H , 98H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
     1 EV1PLT SUBROUTINE IS OUTSIDE THE ALLOWABLE (1,,I6,16H) INTERVAL *
     1****)
   18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
     1NT TO THE EV1PLT SUBROUTINE HAS THE VALUE 1 *****)
   47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8   ,6H *****)
C
      CALL SORT(X,N,Y)
      CALL UNIMED(N,W)
      DO100I=1,N
      W(I)=-ALOG(ALOG(1.0/W(I)))
  100 CONTINUE
      CALL PLOT(Y,W,N)
      WRITE(IPR,105)TAU,N
      SUM1=0.0
```

```
      SUM2=0.0
      DO200I=1,N
      SUM1=SUM1+Y(I)
      SUM2=SUM2+W(I)
  200 CONTINUE
      YBAR=SUM1/AN
      WBAR=SUM2/AN
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO300I=1,N
      SUM1=SUM1+(Y(I)-YBAR)*(Y(I)-YBAR)
      SUM2=SUM2+(Y(I)-YBAR)*(W(I)-WBAR)
      SUM3=SUM3+(W(I)-WBAR)*(W(I)-WBAR)
  300 CONTINUE
      CC=SUM2/SQRT(SUM3*SUM1)
      YSLOPE=SUM2/SUM3
      YINT=YBAR-YSLOPE*WBAR
      WRITE(IPR,305)CC,YINT,YSLOPE
  105 FORMAT(1H ,64HEXTREME VALUE TYPE 1 (EXPONENTIAL TYPE) PROBABILITY
     1PLOT (TAU = ,E15.8,1H),23X,20HTHE SAMPLE SIZE N = ,I7)
  305 FORMAT(1H ,43HPROBABILITY PLOT CORRELATION COEFFICIENT = ,F8.5,5X,
     122HESTIMATED INTERCEPT = ,E15.8,3X,18HESTIMATED SLOPE = ,E15.8)
      RETURN
      END
```

```
@PRT,S SIMIU.EV2PLT
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```
JJF6*SIMIU.EV2PLT
      SUBROUTINE EV2PLT(X,N,GAMMA)
C
C     THIS ROUTINE GENERATES AN EXTREME VALUF TYPE 2 (CAUCHY TYPE)
C     PROBABILITY PLOT
C     THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR X OF
C     (UNSORTED OR SORTED) OBSERVATIONS, THE INTEGER VALUE N (= SAMPLE SIZE),
C     AND THE SINGLE PRECISION VALUE GAMMA (THE EXPONENT PARAMETER)
C     THE OUTPUT FROM THIS ROUTINE IS A ONE-PAGE EXTREME VALUE TYPE 2
C     PROBABILITY PLOT
C     THE MAXIMUM ALLOWABLE VALUE OF N FOR THIS ROUTINE IS 7500
C     PRINTING--YES
C     SUBROUTINES NEEDED--SORT, UNIMED, AND PLOT
C     REFERENCE--UNPUB. JJF MANUSCRIPT 'THE PERCENT POINT FUNCTION', PAGE 26
C     WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
C     NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234   DECEMBER 1972
C
      DIMENSION X(1)
      DIMENSION Y(200),W(200)
C
      AN=N
      IPR=6
      IUPPER=7500
C
C     CHECK THE INPUT ARGUMENTS FOR ERRORS
C
      IF(N.LT.1.OR.N.GT.IUPPER)GOTO50
      IF(N.EQ.1)GOTO55
      HOLD=X(1)
      DO60I=2,N
      IF(X(I).NE.HOLD)GOTO90
   60 CONTINUE
      WRITE(IPR, 9)HOLD
      GOTO90
   50 WRITE(IPR,17)IUPPER
      WRITE(IPR,47)N
      RETURN
   55 WRITE(IPR,18)
      RETURN
   90 CONTINUE
    9 FORMAT(1H ,109H***** NON-FATAL DIAGNOSTIC--THE FIRST  INPUT ARGUME
     1NT (A VECTOR) TO THE EV2PLT SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
     1H *****)
   17 FORMAT(1H , 98H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
     1 EV2PLT SUBROUTINE IS OUTSIDE THE ALLOWABLE (1,,I6,16H) INTERVAL *
     1****)
   18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
     1NT TO THE EV2PLT SUBROUTINE HAS THE VALUE 1 *****)
   47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8   ,6H *****)
C
      CALL SORT(X,N,Y)
      CALL UNIMED(N,W)
      DO100I=1,N
      W(I)=(-ALOG(W(I)))**(-1.0/GAMMA)
  100 CONTINUE
      CALL PLOT(Y,W,N)
      Q=.9975
      PP9975=(-ALOG(Q))**(-1.0/GAMMA)
```

```
      Q=.0025
      PP0025=(-ALOG(Q))**(-1.0/GAMMA)
      Q=.975
      PP975 =(-ALOG(Q))**(-1.0/GAMMA)
      Q=.025
      PP025 =(-ALOG(Q))**(-1.0/GAMMA)
      TAU=(PP9975-PP0025)/(PP975-PP025)
      WRITE(IPR,105)GAMMA,TAU,N
      SUM1=0.0
      SUM2=0.0
      DO200I=1,N
      SUM1=SUM1+Y(I)
      SUM2=SUM2+W(I)
  200 CONTINUE
      YBAR=SUM1/AN
      WBAR=SUM2/AN
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO300I=1,N
      SUM1=SUM1+(Y(I)-YBAR)*(Y(I)-YBAR)
      SUM2=SUM2+(Y(I)-YBAR)*(W(I)-WBAR)
      SUM3=SUM3+(W(I)-WBAR)*(W(I)-WBAR)
  300 CONTINUE
      CC=SUM2/SQRT(SUM3*SUM1)
      YSLOPE=SUM2/SUM3
      YINT=YBAR-YSLOPE*WBAR
      WRITE(IPR,305)CC,YINT,YSLOPE
  105 FORMAT(1H ,63HEXTREME VALUE TYPE 2 (CAUCHY TYPE) PROB. PLOT WITH E
     1XP. PAR. = ,E17.10,1X,7H(TAU = ,E15.8,1H),1X,16HSAMPLE SIZE N = ,I
     17)
  305 FORMAT(1H ,43HPROBABILITY PLOT CORRELATION COEFFICIENT = ,F8.5,5X,
     122HESTIMATED INTERCEPT = ,E15.8,3X,18HESTIMATED SLOPE = ,E15.8)
      RETURN
      END
```

```
@PRT,S SIMIU.PLOT
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```
JJF6*SIMIU.PLOT
      SUBROUTINE PLOT(Y,X,N)
C
C     THIS ROUTINE YIELDS A ONE-PAGE PLOT OF Y(I) VERSUS X(I).
C     THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR Y OF
C     OBSERVATIONS, THE SINGLE PRECISION VECTOR X OF CORRESPONDING
C     OBSERVATIONS, AND THE INTEGER VALUE N (= SAMPLE SIZE).
C     MULTIPLE PLOT POINTS ARE NOT INDICATED AS SUCH.
C     THERE IS NO RESTRICTION ON THE MAXIMUM VALUE OF N FOR THIS ROUTINE.
C     PRINTING--YES
C     SUBROUTINES NEEDED--NONE
C     WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
C     NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234        JUNE 1972
C                                                            UPDATED OCT    1974
C                                                            UPDATED NOV    1974
C
      INTEGER BLANK,HYPHEN,ALPHAI,ALPHAX
      INTEGER ALPHAM,ALPHAA,ALPHAD,ALPHAN,EQUAL
      DIMENSION Y(1),X(1)
      COMMON IGRAPH(55,130)
      DIMENSION YLABLE(11)
C
      DATA BLANK,HYPHEN,ALPHAI,ALPHAX/1H ,1H-,1HI,1HX/
      DATA ALPHAM,ALPHAA,ALPHAD,ALPHAN,EQUAL/1HM,1HA,1HD,1HN,1H=/
C
C     CHECK THE INPUT ARGUMENTS FOR ERRORS
C
      IPR=6
C
      IF(N.LT.1)GOTO50
      IF(N.EQ.1)GOTO55
      HOLD=Y(1)
      DO60I=2,N
      IF(Y(I).NE.HOLD)GOTO65
   60 CONTINUE
      WRITE(IPR, 9)HOLD
   65 HOLD=X(1)
      DO70I=2,N
      IF(X(I).NE.HOLD)GOTO90
   70 CONTINUE
      WRITE(IPR,19)HOLD
      GOTO90
   50 WRITE(IPR,25)
      WRITE(IPR,47)N
      RETURN
   55 WRITE(IPR,28)
      RETURN
   90 CONTINUE
    9 FORMAT(1H ,108H***** NON-FATAL DIAGNOSTIC--THE FIRST  INPUT ARGUME
     1NT (A VECTOR) TO THE PLOT   SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
     1H *****)
   19 FORMAT(1H ,108H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
     1NT (A VECTOR) TO THE PLOT   SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
     1H *****)
   25 FORMAT(1H , 91H***** FATAL ERROR--THE THIRD  INPUT ARGUMENT TO THE
     1 PLOT   SUBROUTINE IS NON-POSITIVE *****)
   28 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE THIRD  INPUT ARGUME
     1NT TO THE PLOT   SUBROUTINE HAS THE VALUE 1 *****)
```

```
   47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8    ,6H *****)
C
C     DETERMINE THE Y VALUES TO BE LISTED ON THE LEFT VERTICAL AXIS
C
      YMIN=Y(1)
      YMAX=Y(1)
      DO105I=1,N
      IF(Y(I).LT.YMIN)YMIN=Y(I)
      IF(Y(I).GT.YMAX)YMAX=Y(I)
  105 CONTINUE
      DO110I=1,11
      AIM1=I-1
      YLABLE(I)=YMAX-(AIM1/10.0)*(YMAX-YMIN)
  110 CONTINUE
C
C     DETERMINE XMIN, XMAX, XMID, X25 (=THE 25% POINT), AND
C     X75 (=THE 75% POINT)
      XMIN=X(1)
      XMAX=X(1)
      DO115I=1,N
      IF(X(I).LT.XMIN)XMIN=X(I)
      IF(X(I).GT.XMAX)XMAX=X(I)
  115 CONTINUE
      XMID=(XMIN+XMAX)/2.0
      X25=0.75*XMIN+0.25*XMAX
      X75=0.25*XMIN+0.75*XMAX
C
C     BLANK OUT THE GRAPH
C
      DO100I=1,55
      DO200J=1,129
      IGRAPH(I,J)=BLANK
  200 CONTINUE
  100 CONTINUE
C
C     PRODUCE THE Y AXIS
C
      DO300I=3,43
      IGRAPH(I,25)=ALPHAI
      IGRAPH(I,129)=ALPHAI
  300 CONTINUE
      DO350I=3,43,4
      IGRAPH(I,25)=HYPHEN
      IGRAPH(I,129)=HYPHEN
  350 CONTINUE
      IGRAPH(3,21)=EQUAL
      IGRAPH(3,22)=ALPHAM
      IGRAPH(3,23)=ALPHAA
      IGRAPH(3,24)=ALPHAX
      IGRAPH(23,21)=EQUAL
      IGRAPH(23,22)=ALPHAM
      IGRAPH(23,23)=ALPHAI
      IGRAPH(23,24)=ALPHAD
      IGRAPH(43,21)=EQUAL
      IGRAPH(43,22)=ALPHAM
      IGRAPH(43,23)=ALPHAI
      IGRAPH(43,24)=ALPHAN
C
```

```
C     PRODUCE THE X AXIS
C
      DO400J=27,127
      IGRAPH(1,J)=HYPHEN
      IGRAPH(45,J)=HYPHEN
  400 CONTINUE
      DO450J=27,127,25
      IGRAPH(1,J)=ALPHAI
      IGRAPH(45,J)=ALPHAI
  450 CONTINUE
      DO460J=40,127,25
      IGRAPH(1,J)=ALPHAI
      IGRAPH(45,J)=ALPHAI
  460 CONTINUE
C
C     DETERMINE THE (X,Y) PLOT POSITIONS
C
      RATIOY=40.0/(YMAX-YMIN)
      RATIOX=100.0/(XMAX-XMIN)
      DO600I=1,N
      MX=RATIOX*(X(I)-XMIN)+0.5
      MX=MX+27
      MY=RATIOY*(Y(I)-YMIN)+0.5
      MY=43-MY
      IGRAPH(MY,MX)=ALPHAX
  600 CONTINUE
C
C     WRITE OUT THE GRAPH
C
      WRITE(IPR,998)
      DO700I=1,45
      IP1=I+1
      IFLAG=IP1-(IP1/4)*4
      K=IP1/4
      IF(IFLAG.NE.0)WRITE(IPR,705)(IGRAPH(I,J),J=1,129)
      IF(IFLAG.EQ.0)WRITE(IPR,706)YLABLE(K),(IGRAPH(I,J),J=21,129)
  700 CONTINUE
      WRITE(IPR,707)XMIN,X25,XMID,X75,XMAX
  705 FORMAT(1H ,129A1)
  706 FORMAT(1H ,F20.7,109A1)
  707 FORMAT(1H ,14X,F20.7,5X,F20.7,5X,F20.7,5X,F20.7,1X,F20.7)
  998 FORMAT(1H1)
      RETURN
      END
```

```
@PRT,S SIMIU.DATA4
```

MAXIMUM YEARLY WIND SPEEDS, CORPUS CHRISTI, TEXAS, 1912-1948

THE NUMBER OF OBSERVATIONS = 37

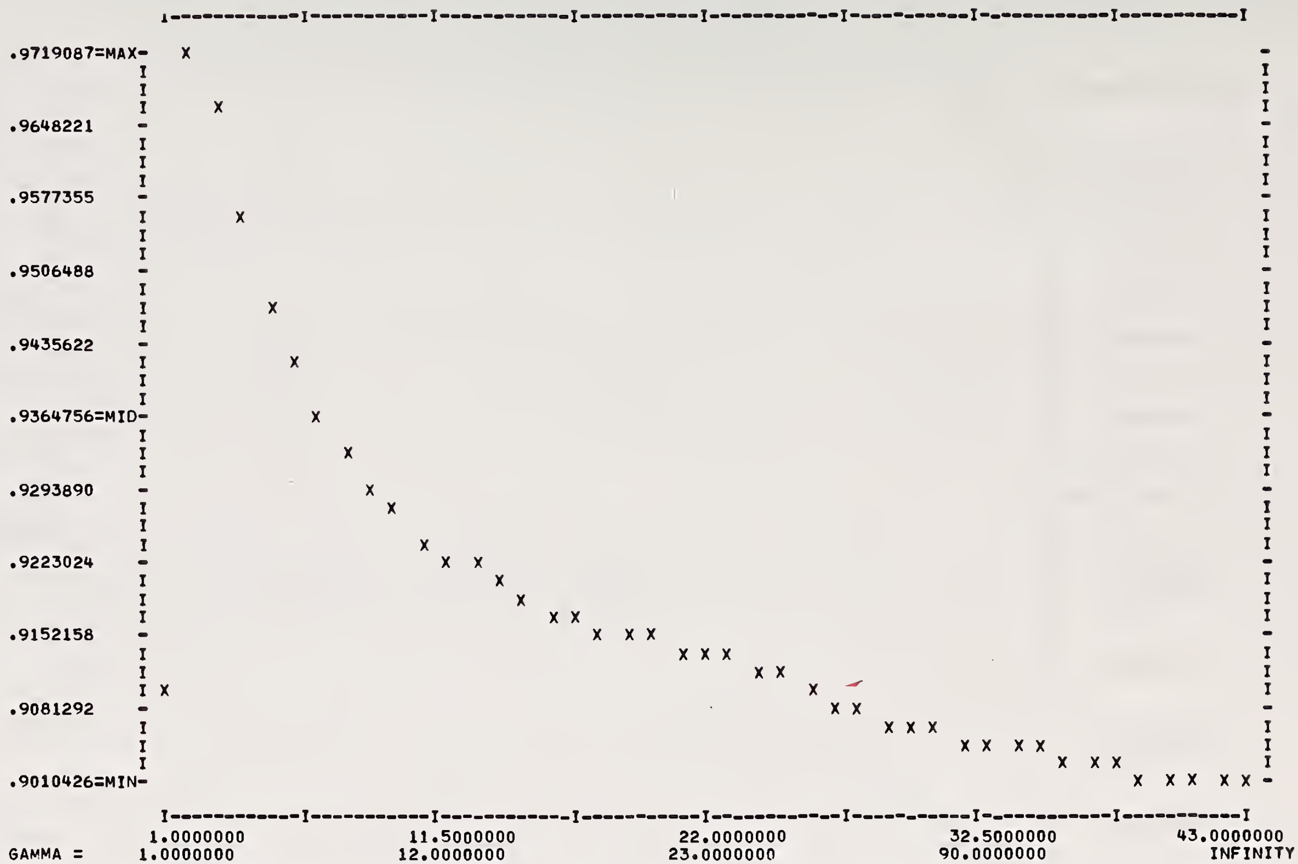
INPUT DATA

47.0 41.0 41.0 40.0 90.0 38.0 50.0 95.0 41.0 51.0 43.0 39.0 44.0 38.0 37.0 39.0
37.0 36.0 43.0 35.0 47.0 49.0 47.0 39.0 49.0 42.0 50.0 38.0 42.0 37.0 61.0 54.0
45.0 56.0 43.0 51.0 39.0

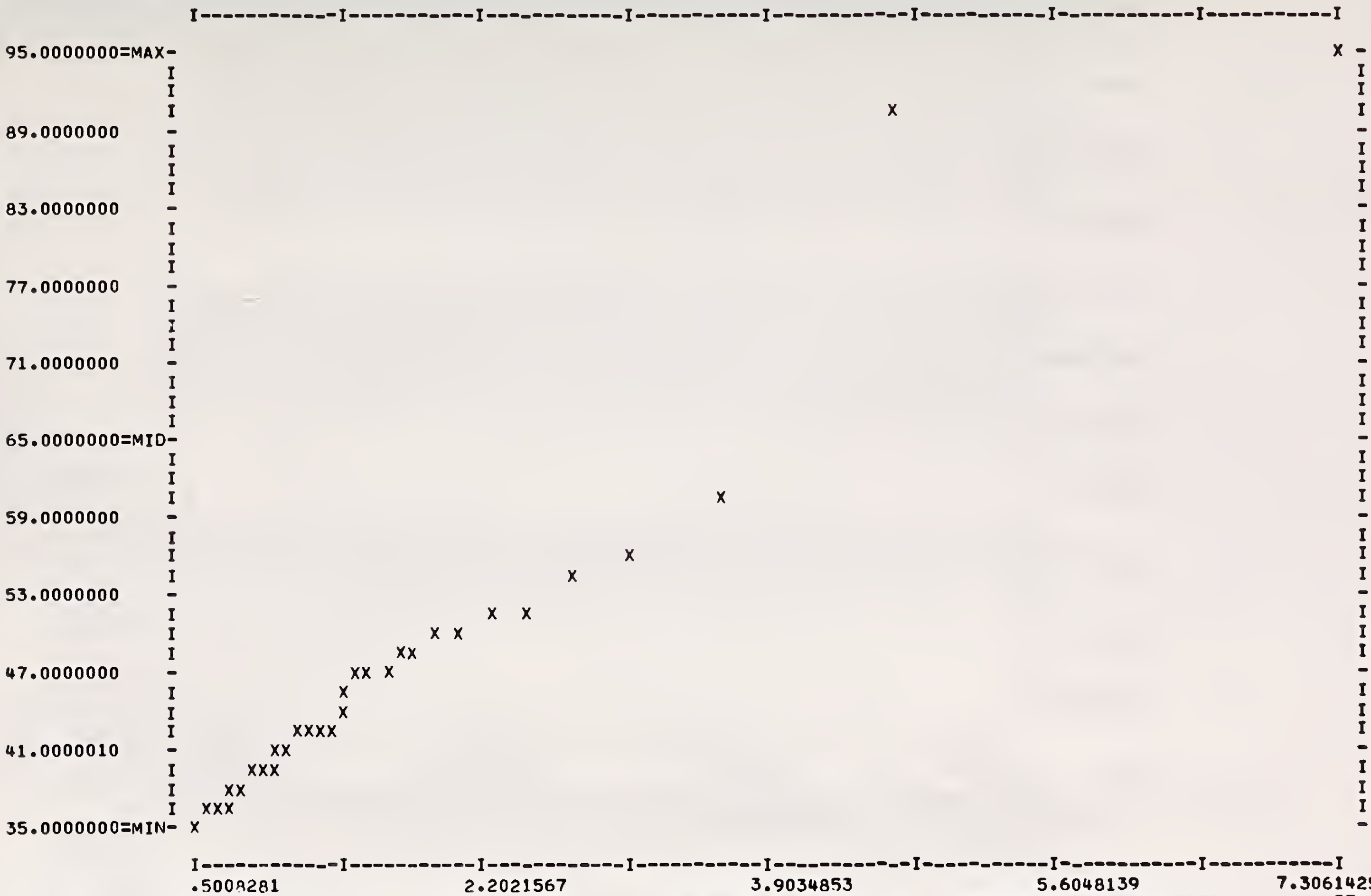
EXTREME VALUE ANALYSIS

THE SAMPLE SIZE N = 37
THE SAMPLE MEAN = 46.3243241
THE SAMPLE STANDARD DEVIATION = 12.7498453
THE SAMPLE MINIMUM = 35.0000000
THE SAMPLE MAXIMUM = 95.0000000

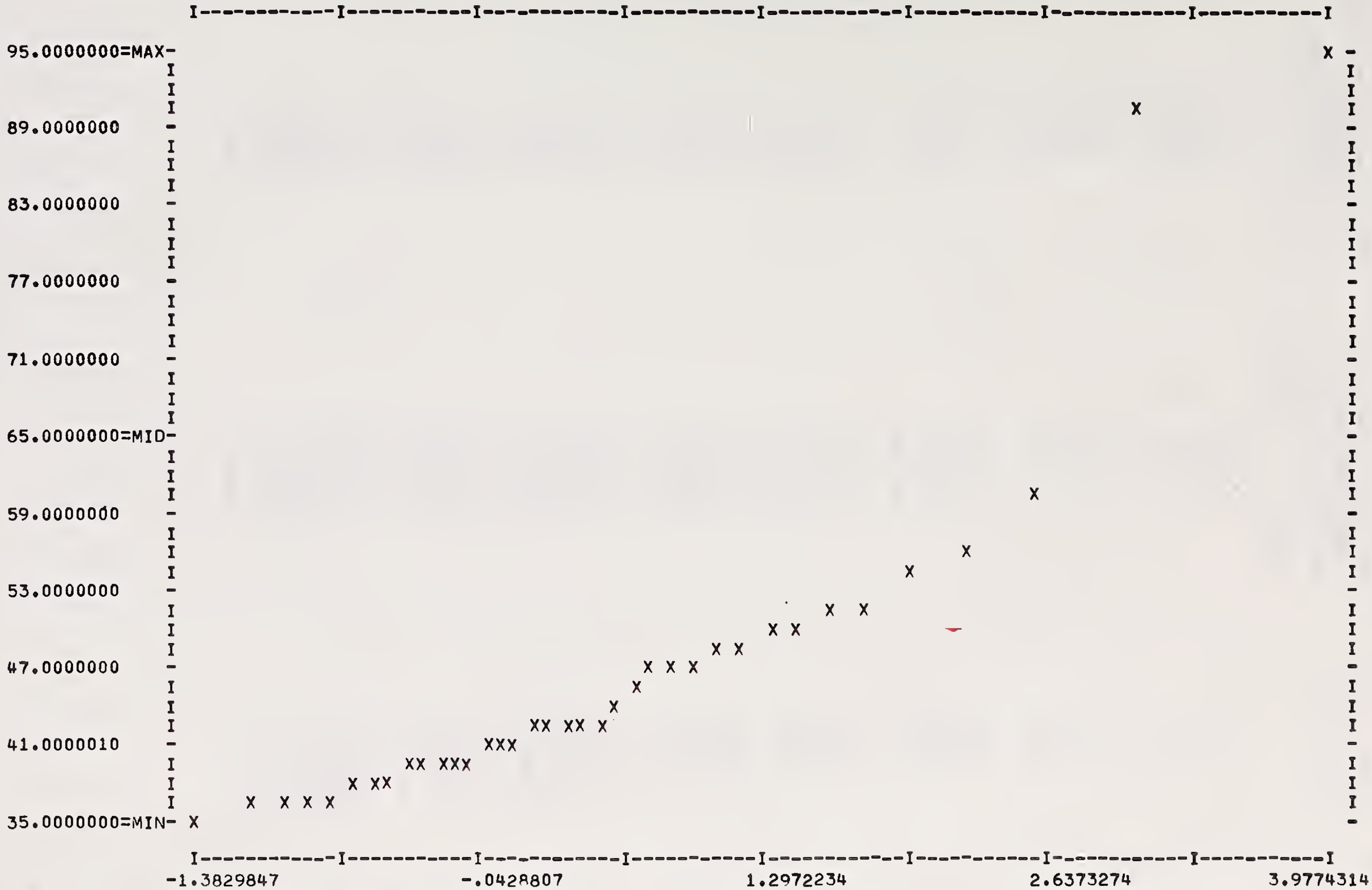
EXTREME VALUE TYPE 2 TAIL LENGTH PARAMETER (GAMMA)	PROBABILITY PLOT CORRELATION COEFFICIENT	LOCATION ESTIMATE	SCALE ESTIMATE
1.00	.91022	40.9147968	1.2478256
2.00	.97191 MAX	31.0718093	9.3875747
3.00	.96594	20.9988256	19.2656157
4.00	.95601	11.1366539	29.1725538
5.00	.94787	1.4036670	38.9815693
6.00	.94158	-8.2550049	48.7112250
7.00	.93668	-17.8684359	58.3850513
8.00	.93279	-27.4526310	68.0197020
9.00	.92965	-37.0169468	77.6262465
10.00	.92706	-46.5671854	87.2121058
11.00	.92489	-56.1070957	96.7823524
12.00	.92305	-65.6392174	106.3405638
13.00	.92147	-75.1653366	115.8893194
14.00	.92010	-84.6867085	125.4305038
15.00	.91891	-94.2042866	134.9655533
16.00	.91785	-103.7187805	144.4955559
17.00	.91691	-113.2307281	154.0213642
18.00	.91607	-122.7405472	163.5436363
19.00	.91531	-132.2485828	173.0629253
20.00	.91463	-141.7550869	182.5796452
21.00	.91400	-151.2603016	192.0941658
22.00	.91344	-160.7643795	201.6067638
23.00	.91292	-170.2674828	211.1176987
24.00	.91244	-179.7697258	220.6271515
25.00	.91200	-189.2712097	230.1353092
30.00	.91022	-236.7699699	277.6610641
35.00	.90894	-284.2588081	325.1694984
40.00	.90797	-331.7414551	372.6669960
45.00	.90721	-379.2199707	420.1571693
50.00	.90660	-426.6956291	467.6422195
60.00	.90569	-521.6410751	562.6018524
70.00	.90503	-616.5816116	657.5525970
80.00	.90454	-711.5190506	752.4977341
90.00	.90415	-806.4543991	847.4390717
100.00	.90384	-901.3884811	942.3779907
150.00	.90291	-1376.0462189	1417.0503082
200.00	.90245	-1850.6961517	1891.7076111
250.00	.90217	-2325.3416443	2366.3575439
350.00	.90185	-3274.6292419	3315.6502075
500.00	.90161	-4698.5545654	4739.5795898
750.00	.90142	-7071.7604980	7112.7887573
1000.00	.90132	-9444.9562988	9485.9863281
INFINITY	.90104	41.0333295	9.4928209



THE ABOVE IS A PLOT OF THE 43 PROBABILITY PLOT CORRELATION COEFFICIENTS (FROM THE PREVIOUS PAGE)
VERSUS THE 43 EXTREME VALUE DISTRIBUTIONS



EXTREME VALUE TYPE 2 (CAUCHY TYPE) PROB. PLOT WITH EXP. PAR. = .2000000000+01 (TAU = .33967212+01) SAMPLE SIZE N = 37
PROBABILITY PLOT CORRELATION COEFFICIENT = .97191 ESTIMATED INTERCEPT = .31071809+02 ESTIMATED SLOPE = .93875747+01



EXTREME VALUE TYPE 1 (EXPONENTIAL TYPE) PROBABILITY PLOT (TAU = .15618669+01) THE SAMPLE SIZE N = 37
PROBABILITY PLOT CORRELATION COEFFICIENT = .90104 ESTIMATED INTERCEPT = .41033329+02 ESTIMATED SLOPE = .94928209+01

RETURN PERIOD (IN YEARS)	PREDICTED EXTREME WIND BASED ON OPTIMAL EXTREME VALUE TYPE 2 DISTRIBUTION (GAMMA = 2.00000)	PREDICTED EXTREME WIND BASED ON EXTREME VALUE TYPE 1 DISTRIBUTION
2.0	42.35	44.51
3.0	45.81	49.60
4.0	48.57	52.86
5.0	50.94	55.27
6.0	53.06	57.19
7.0	54.98	58.78
8.0	56.76	60.15
9.0	58.43	61.34
10.0	59.99	62.40
20.0	72.52	69.23
30.0	82.06	73.16
37.0	87.79	75.18
40.0	90.07	75.93
50.0	97.12	78.07
60.0	103.48	79.82
70.0	109.33	81.30
80.0	114.77	82.57
90.0	119.88	83.70
100.0	124.71	84.70
200.0	163.67	91.31
300.0	193.53	95.16
400.0	218.71	97.90
500.0	240.88	100.02
600.0	260.92	101.75
700.0	279.36	103.21
800.0	296.51	104.48
900.0	312.62	105.60
1000.0	327.86	106.60
2000.0	450.85	113.19
3000.0	545.21	117.04
4000.0	624.76	119.77
5000.0	694.86	121.89
6000.0	758.23	123.62
7000.0	816.50	125.08
8000.0	870.73	126.35
9000.0	921.66	127.47
10000.0	969.87	128.47
50000.0	2130.33	143.74
100000.0	2999.87	150.32
500000.0	6674.48	165.62
1000000.0	9426.27	172.20

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

With a view to assessing the validity of current probabilistic approaches to the definition of design wind speeds, a study was undertaken of extreme wind speeds based on records taken at 21 U.S. weather stations. For the purpose of analyzing extreme value data, a computer program was developed, which is described herein. The following results were obtained: (1) the assumption that a single probability distribution is universally applicable to all extreme wind data sets in a given type of climate was not confirmed, and (2) predictions of 100-year wind speeds based on overlapping 20-year sets of data taken at the same station differed between themselves by as much as 100%. Similar predictions for 1000-year winds differed by as much as a few hundred percent. Since wind pressures are proportional to the square of the wind speeds, errors of such magnitude are unacceptably high for structural design purposes. It is therefore suggested that while, in principle, probabilisitc methods provide the most rational approach to specifying design wind speeds, it is of the utmost importance that the possible errors inherent in this approach be carefully taken into account.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Building codes; extreme value distributions; hurricanes; probability distribution functions; reliability; risk; statistical analysis; storms; structural engineering; wind loads; wind speeds

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