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Statistical Analysis of Extreme Winds

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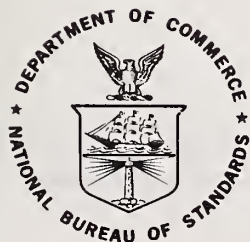
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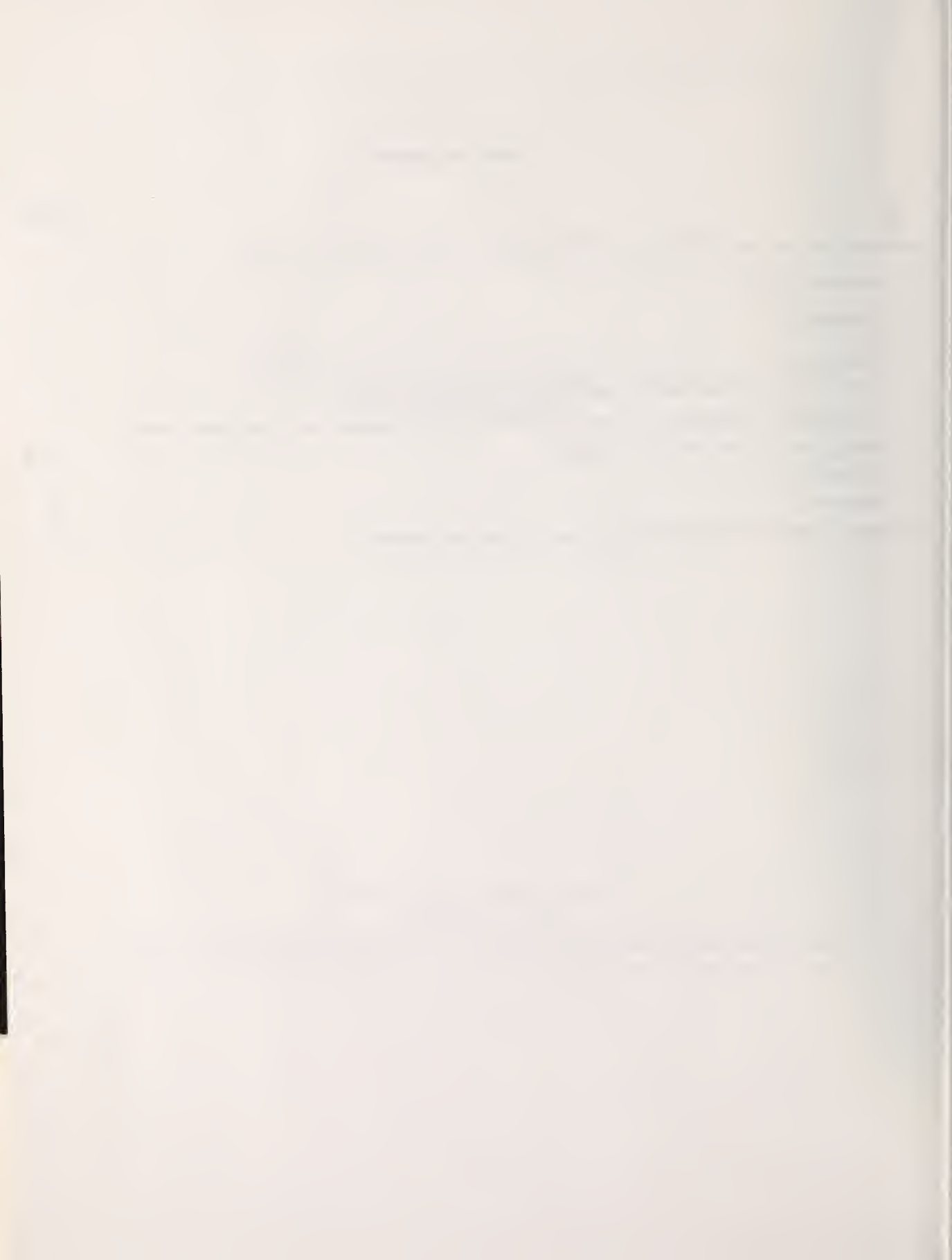
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TABLE OF CONTENTS

	<u>Page</u>
Abstract and Key Words.	1
SI Conversion Units.	1
List of Symbols.	2
1. Introduction.	3
2. Probability Distributions of the Largest Yearly Wind Speed.	4
3. Description of Procedure for Estimating CDF, its Parameters, and the $\bar{N}$ -year Winds.	5
4. Summary and Interpretation of Results.	8
5. Conclusions.	11
6. References.	12
Appendix: Computer Program Listing. Sample Input and Output.	20



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) = 1.609344×10^3 meter (m)

Velocity

1 mile per hour (mph) = 4.470400×10^{-2} meters per second (m/s)
= 1.609344 kilometers per hour (km/hr)

*exactly

LIST OF SYMBOLS

CDF	Cumulative distribution function
D, D'	Probability distributions
F(v)	Mixed distribution given by Eq. 6
F ₀	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_γ} (x)	Extreme type II cumulative distribution function with tail length parameter γ
G _{X_γ} (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)
$\overline{N}$	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
$\overline{v}$, v _{max}	Mean, maximum value of the observed annual extreme wind speeds, respectively
$v_{\overline{N}}, v_{\infty}^{\overline{N}}$	Extreme wind speed corresponding to a $\overline{N}$ -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
$\overline{X}$	$\Sigma X_i/n$
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_0 of the CDF or, equivalently (in view of the relation $\bar{N} = 1/(1-F_0)$, 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_0 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 ($F_0 = 0.96$) 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 ($F_0 = 0.96$) 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

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

and

$$F_{II}(v) = \exp \{-(v-\mu)/\sigma\}^{-\gamma} \quad \begin{array}{l} \mu < v < \infty \\ -\infty < \gamma < \infty \\ -\infty < \sigma < \infty \\ \gamma > 0 \end{array} \quad (2)$$

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,

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

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

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

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

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 $\gamma \approx 9.0$ and $\gamma \approx 4.5$ 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,

$$F(v) = p_E F_{II}^E(v) + p_T F_{II}^T(v) \quad (6)$$

in which $F_{II}^E(v)$, $F_{II}^T(v)$ 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 $\bar{N}$ -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 $v_{\bar{N}}$ for various mean recurrence intervals. In this study $\bar{N} = 50, 100, 500$ 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

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

in which $\bar{X} = \sum X_i / n$, $\overline{M(D)} = \sum M_i(D) / n$, 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:

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

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

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

$$\hat{v}_{\bar{N}} = \hat{\mu} + \hat{\sigma} G_{X_{\gamma_{\text{opt}}}}(1 - 1/\bar{N}) \quad (11)$$

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 $G_{X_{\gamma_{\text{opt}}}}(p)$ is the percent point function of the best fitting extreme value distribution. If $\gamma_{\text{opt}} \neq \infty$ (that is, if a member of the extreme value type II family provides the best fit), then

$$G_{X_{\gamma_{\text{opt}}}}(p) = (-\ln p)^{-1/\gamma} \quad (12a)$$

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

$$G_{X_{\gamma_{\text{opt}}}}(p) = -\ln(-\ln p) \quad (12b)$$

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 $(v_{\bar{N}}^{\max} - v_{\bar{N}}^{\min})/v_{\bar{N}}^{\min}$ for the four ranges of γ_{opt} : $\gamma_{\text{opt}} \geq 40$; $10 \leq \gamma_{\text{opt}} \leq 39$; $5 \leq \gamma_{\text{opt}} \leq 9$; $2 \leq \gamma_{\text{opt}} \leq 4$, where $v_{\bar{N}}^{\max}$, $v_{\bar{N}}^{\min}$ are the maximum and the minimum $\bar{N}$ -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 $(v_{\bar{N}}^{\max} - v_{\bar{N}}^{\min})/v_{\bar{N}}^{\min}$ for
Various Ranges of γ_{opt} and Various Mean
Recurrence Intervals

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

The lower bounds for the error in the estimation of the $\bar{N}$ -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]

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

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

where $\text{var}(\hat{\mu})$, $\text{var}(\hat{\sigma})$ 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 $3\text{SD}(V_{100})$, where $\text{SD}(V_{100})$ 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

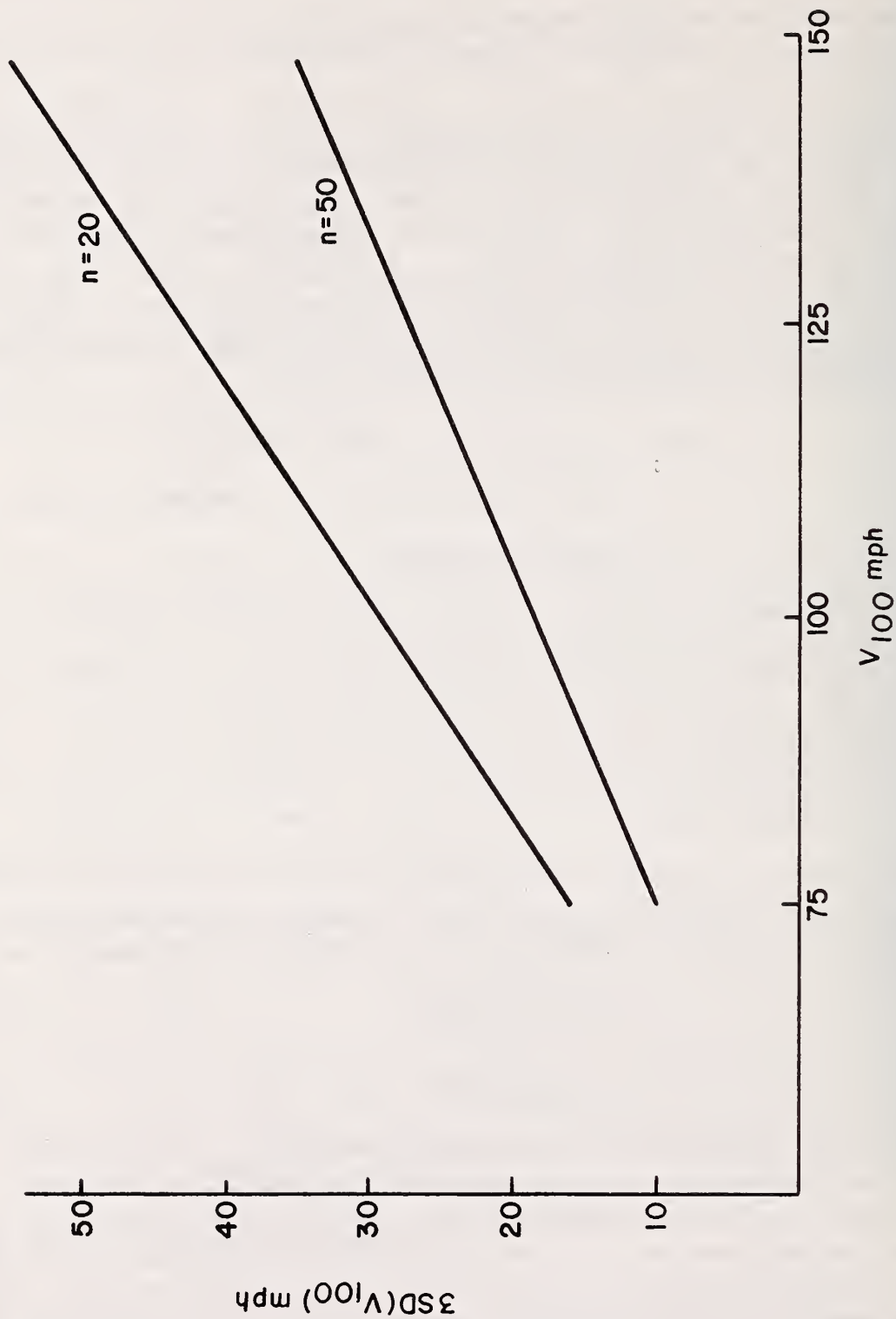


Fig. 1 - Dependence of $3SD(V_{100})$ on Sample Size

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 $10 \leq \gamma_{\text{opt}} \leq 39$, in about 10% of the cases $5 \leq \gamma_{\text{opt}} \leq 9$ and in about 20% of the cases, $2 \leq \gamma_{\text{opt}} \leq 4$.
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.

6. REFERENCES

1. "American National Standard Building Requirements for Minimum Design Loads in Buildings and Other Structures A58.1", American National Standards Institute, New York, N.Y., 1972.
2. Benjamin, J.R., and Cornell, C.A., "Probability, Statistics, and Decision for Civil Engineers", McGraw-Hill Book Company, New York, 1970.
3. Canadian Structural Design Manual, Supplement No. 4 to the National Building Code of Canada, National Research Council of Canada, 1970.
4. Caspar, W., "Maximale Windgeschwindigkeiten in der Bundesrepublik Deutschland", Bautechnik, Vol. 47, No. 10, October 1970, pp. 335-340.
5. Court, A., "Wind Extremes as Design Factors", Journal of the Franklin Institute, Vol. 256, July 1953, pp. 39-55.
6. Davenport, A.G., "The Dependence of Wind Loads upon Meteorological Parameters", Proceedings, Wind Effects on Buildings and Structures, Ottawa, Vol. 1, University of Toronto Press, Toronto, Canada, 1978.
7. Duchêne-Marullaz, P., "Etude des vitesses maximales du vent", Cahiers du Centre Scientifique et Technique du Bâtiment, Cahier 1118, No. 131, July-Aug, 1972.
8. Durst, C.S., "Wind Speeds over Short Periods of Time", Meteorological Magazine, vol. 89, 1960.
9. Filliben, J.J., "Simple and Robust Linear Estimation of the Location Parameter of a Symmetric Distribution", Ph.D. Dissertation, Princeton University, Princeton, N.J., 1969.
10. Filliben, J.J., "Techniques for Tail Length Analysis", Proceedings, 18th Conference on the Design of Experiments in Army Research, Development and Testing, Aberdeen, Md., October 1972.
11. Johnson, N.L., and Kotz, S., Continuous Univariate Distributions - 1, John Wiley and Sons, New York, 1970.
12. Lieblein, J., "Method of Analyzing Extreme Value Data", Technical Note 3053, National Advisory Committee for Aeronautics, Washington, D.C.
13. Local Climatological Data Annual and Monthly Summaries, U.S. Department of Commerce, National Environmental Data Service, National Climatic Center, Asheville, N.C.
14. Sachs, P., Wind Forces in Engineering, Pergamon Press, Oxford, 1972.
15. Shellard, H.C., "Extreme Wind Speeds over Great Britain and Northern Ireland", Meteorological Magazine, vol. 37, 1958.
16. Shellard, H.C., "The Estimation of Design Wind Speeds", Proceedings, Wind Effects on Buildings and Structures, Vol. 1, Her Majesty's Stationery Office, London, England, 1965.
17. Thom, H.C.S., "New Distributions of Extreme Winds in the United States", Journal of The Structural Division, ASCE, Vol. 94, No. ST7, Proc. Paper 6038, July 1968, pp. 1787-1801.
18. Thom, H.C.S., "Engineering Climatology of Design Winds, with Special Reference to the Chicago Area", Proceedings, Symposium on Wind Effects on High-Rise Buildings, Northwestern University, Evanston, IL., March 1970.

19. Thom, H.C.S., "Distributions of Extreme Winds Over Oceans", Journal of the Waterways, Harbors and Coastal Engineering Division, ASCE, Vol. 99, No. WW1, Proc. Paper 9556, Feb., 1973, pp. 1-17.
20. U.S. Weather Bureau, Manual of Surface Observations, Washington, D.C., 1951, p. 92.
21. Vellozzi, J., and Cohen, E., "Dynamic Response of Tall Flexible Structures to Wind Loading", Proceedings, Technical Meeting Concerning Wind Loads on Buildings and Structures, Building Science Series 30, National Bureau of Standards, SD Catalog No. C 13.29/2:30, U.S. Government Printing Office, Washington, D.C., 1970.
22. Filliben, J.J., "The Probability Plot Correlation Coefficient Test for Normality", Technometrics, Vol. 17, No. 1, Feb., 1975, pp. 111-117.

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	38	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
Winemucca, 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	73
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)									
Burlington (Vermont)	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
	25	1912-36	∞	54	57	63	44.5	3.6	53
		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
Eastport (Maine)	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
	25	1912-36	∞	64	67	77	48.9	5.5	60
		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
Canton (N.Y.)	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
	25	1912-36	∞	62	66	78	45.2	6.2	62
		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
Yuma (Ariz.)	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
	25	1912-36	∞	39	41	45	32.4	2.5	38
		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
Duluth (Minn.)	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
	25	1912-36	∞	62	64	72	50.2	4.3	59
		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)									
Valentine (Neb.)	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
	25	1912-36	∞	56	59	68	41.9	5.0	56
		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
Charleston (S.C.)	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
	25	1912-36	∞	60	64	76	42.3	6.5	55
		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
Eureka (Calif.)	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
	25	1912-36	12	48(47)	51(50)	64(58)	35.3	4.3	46
		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
Oklahoma City (Oklahoma)	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
	25	1912-36	∞	62	67	82	40.4	7.9	57
		1924-48	∞	45	47	55	33.8	4.1	46
	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
Baker (Oregon)	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
	25	1912-36	8	43(42)	47(44)	61(52)	30.2	4.2	40
		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)									
Corpus Christi (Texas)	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
	25	1912-36	2	109(82)	142(89)	390(114)	46.2	14.7	95
		1924-48	70	63	67	82	44.0	6.9	61
	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

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1      C      PURPOSE--THIS MAIN PROGRAM READS IN DATA UPON WHICH AN
2      C      EXTREME VALUE ANALYSIS IS TO BE PERFORMED.
3      C      AFTER READING IN THE DATA, THIS PROGRAM
4      C      CALLS IN A SUBROUTINE (EXTREM) WHICH
5      C      PERFORMS THE EXTREME VALUE ANALYSIS.
6      C      INPUT DATA--THE NUMBER OF SETS OF DATA TO BE ANALYZED
7      C      (FORMAT--I2)
8      C
9      C      THE IDENTIFYING TITLE FOR DATA SET 1
10     C      (FORMAT--80A1)
11     C      THE NUMBER OF OBSERVATIONS IN DATA SET 1
12     C      (FORMAT--I2)
13     C      THE DATA FOR SET 1
14     C      (EACH DATA CARD HAVING A 16F5.1 FORMAT)
15     C
16     C      THE IDENTIFYING TITLE FOR DATA SET 2
17     C      (FORMAT--80A1)
18     C      THE NUMBER OF OBSERVATIONS IN DATA SET 2
19     C      (FORMAT--I2)
20     C      THE DATA FOR SET 2
21     C      (EACH DATA CARD HAVING A 16F5.1 FORMAT)
22     C
23     C      .
24     C      .
25     C      .
26     C
27     C      THE IDENTIFYING TITLE FOR THE LAST DATA SET
28     C      (FORMAT--80A1)
29     C      THE NUMBER OF OBSERVATIONS IN THE LAST DATA SET
30     C      (FORMAT--I2)
31     C      THE DATA FOR THE LAST SET
32     C      (EACH DATA CARD HAVING A 16F5.1 FORMAT)
33     C      OUTPUT--THIS MAIN PROGRAM WILL (FOR EACH DATA SET)
34     C      SKIP TO A NEW PAGE, PRINT OUT THE TITLE,
35     C      PRINT OUT THE NUMBER OF OBSERVATIONS,
36     C      AND PRINT OUT THE INPUT DATA.
37     C      THIS WILL THEN BE FOLLOWED (FOR EACH DATA SET)
38     C      BY 4 OR 5 (DEPENDING ON THE DATA)
39     C      PAGES OF AUTOMATIC OUTPUT RESULTING
40     C      FROM THE EXTREME VALUE ANALYSIS
41     C      SUBROUTINE      EXTREM      WHICH IS
42     C      CALLED BY THIS MAIN PROGRAM.
43     C      SUBROUTINES NEEDED--EXTREM, SORT, UNIMED, EV1PLT, EV2PLT, AND PLOT
44     C      LANGUAGE--ANSI FORTRAN
45     C      COMMENT--THIS MAIN ROUTINE AND ALL SUBROUTINES
46     C      ASSUME THAT THE INPUT AND OUTPUT UNITS
47     C      HAVE A NUMERICAL DESIGNATION OF 5 AND 6,
48     C      RESPECTIVELY.
49     C      THIS DESIGNATION IS MADE WITH THE FORTRAN
50     C      STATEMENTS
51     C      IRD=5
52     C      IPR=6
53     C      ONE OR BOTH OF WHICH ARE FOUND AT THE
54     C      BEGINNING OF THE EXECUTABLE CODE
55     C      IN THIS MAIN ROUTINE AND ALL SUBROUTINES.
56     C      IF 5 AND 6 ARE NOT THE PROPER DESIGNATIONS
57     C      FOR YOUR COMPUTER, THEN SIMPLY CHANGE THE

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58      C          5 AND 6 IN THE IRD=5 AND IPR=6 STATEMENTS
59      C          TO THE APPROPRIATE VALUE FOR YOUR COMPUTER.
60      C  COMMENT--THIS MAIN ROUTINE AND ALL SUBROUTINES
61      C          WILL, AS THEY STAND, ACCEPT DATA SETS
62      C          WITH UP TO 200 OBSERVATIONS.
63      C          IF COMPUTER STORAGE IS LIMITED AND IF SMALLER DATA
64      C          SETS ARE EXPECTED, THEN COMPUTER STORAGE MAY BE SAVED
65      C          BY RESETTING THE DIMENSION LIMITS OF THE VECTORS
66      C              X IN THIS MAIN ROUTINE,
67      C              W, Y, AND Z IN THE SUBROUTINE EXTREM,
68      C              W AND Y IN THE SUBROUTINE EV1PLT, AND
69      C              W AND Y IN THE SUBROUTINE EV2PLT
70      C          FROM THEIR PRESENT VALUE OF 200
71      C          TO WHATEVER THE EXPECTED MAXIMUM DATA SET SIZE IS.
72      C          THE STATEMENT          IUPPER=200
73      C          (ABOUT STATEMENT 122 IN THIS SUBROUTINE,
74      C          AND UP NEAR THE BEGINNING OF THE EXECUTABLE
75      C          CODE IN THE SUBROUTINES EXTREM, EV1PLT, AND
76      C          EV2PLT) SHOULD ALSO BE CHANGED FROM 200
77      C          TO THE EXPECTED MAXIMUM DATA SET SIZE.
78      C  COMMENT--ON THE UNIVAC 1108, EXEC 8 COMPUTER SYSTEM-AT NBS,
79      C          THIS MAIN ROUTINE AND THE 6 NEEDED SUBROUTINES
80      C          HAVE A TOTAL (CODE + DIMENSIONS + COMMON) STORAGE
81      C          REQUIREMENT OF APPROXIMATELY 13000 WORDS (DECIMAL).
82      C
83      C          CODE      DIMENSIONS  COMMON
84      C  MAIN PROGRAM      130          320          0
85      C  EXTREM            770         1680          0
86      C  SORT              340          180          0
87      C  UNIMED            140           80          0
88      C  EV1PLT            210          550          0
89      C  EV2PLT            280          560          0
90      C  PLOT              380          190         7150
91      C          NOTE THE RELATIVELY LARGE STORAGE ALLOCATION
92      C          FOR THE LAST SUBROUTINE (PLOT). IF THE AMOUNT
93      C          OF USABLE STORAGE IN YOUR COMPUTER IS LESS THAN
94      C          13000, THEN AN ALTERNATIVE PLOT ROUTINE IS
95      C          AVAILABLE FROM THE AUTHOR WHICH WILL REDUCE
96      C          THE TOTAL STORAGE ALLOCATION FROM 13000
97      C          TO APPROXIMATELY 6000.
98      C  WRITTEN BY--JAMES J. FILLIBEN (205.03)
99      C          EMIL SIMIU (461.01)
100     C          NATIONAL BUREAU OF STANDARDS
101     C          WASHINGTON, C. C. 20234
102     C  UPDATED--DECEMBER 1974
103     C
104     C  DIMENSION X(200),ITITLE(80)
105     C
106     C  IRD=5
107     C  IPR=6
108     C
109     C  READ IN THE NUMBER OF SETS OF DATA TO BE ANALYZED
110     C
111     C  READ(IRD,105)NUMSET
112     C
113     C  OPERATE ON EACH SET
114     C
115     C  DO100ISET=1,NUMSET

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116 C READ IN THE TITLE AND THE NUMBER OF OBSERVATIONS
117 C FOR THIS SET
118 C
119 READ(IRD,205)(ITITLE(I),I=1,80)
120 READ(IRD,210)N
121 C
122 C ZERO-OUT THE X VECTOR, AND THEN READ THE DATA FOR THIS SET
123 C INTO THE X VECTOR
124 C
125 DO200I=1,N
126 X(I)=0.0
127 200 CONTINUE
128 READ(IRD,215)(X(I),I=1,N)
129 C
130 C WRITE OUT THE TITLE, THE NUMBER OF OBSERVATIONS,
131 C AND THE DATA FOR THIS SET
132 C
133 WRITE(IPR,998)
134 NSKIP=10
135 DO300ISKIP=1,NSKIP
136 WRITE(IPR,999)
137 300 CONTINUE
138 WRITE(IPR,305)(ITITLE(I),I=1,80)
139 WRITE(IPR,999)
140 WRITE(IPR,999)
141 WRITE(IPR,999)
142 WRITE(IPR,310)N
143 WRITE(IPR,999)
144 WRITE(IPR,315)
145 WRITE(IPR,320)(X(I),I=1,N)
146 C
147 C DO AN EXTREME VALUE ANALYSIS OF THE DATA FOR THIS SET
148 C
149 CALL EXTREM(X,N)
150 C
151 100 CONTINUE
152 C
153 105 FORMAT(I2)
154 205 FORMAT(80A1)
155 210 FORMAT(I2)
156 215 FORMAT(16F5.1)
157 305 FORMAT(1H ,20X,80A1)
158 310 FORMAT(1H ,29HTHE NUMBER OF OBSERVATIONS = ,I5)
159 315 FORMAT(1H ,10HINPUT DATA)
160 320 FORMAT(1H ,13X,16F5.1)
161 998 FORMAT(1H1)
162 999 FORMAT(1H )
163 STOP
164 END

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@PRT,S SIMIU.EXTREM

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1      SUBROUTINE EXTREM(X,N)
2      C
3      C   PURPOSE--THIS SUBROUTINE PERFORMS AN EXTREME VALUE ANALYSIS
4      C   ON THE DATA IN THE INPUT VECTOR X.
5      C   THIS ANALYSIS CONSISTS OF DETERMINING THAT PARTICULAR
6      C   EXTREME VALUE TYPE 1 OR EXTREME VALUE TYPE 2 DISTRIBUTION
7      C   WHICH BEST FITS THE DATA SET.
8      C   THE GOODNESS OF FIT CRITERION IS THE MAXIMUM PROBABILITY
9      C   PLOT CORRELATION COEFFICIENT CRITERION.
10     C   AFTER THE BEST-FIT DISTRIBUTION IS DETERMINED,
11     C   ESTIMATES ARE COMPUTED AND PRINTED OUT FOR THE
12     C   LOCATION AND SCALE PARAMETERS.
13     C   TWO PROBABILITY PLOTS ARE ALSO PRINTED OUT--
14     C   THE BEST-FIT TYPE 2 PROBABILITY PLOT
15     C   (IF THE BEST FIT WAS IN FACT A TYPE 2),
16     C   AND THE TYPE 1 PROBABILITY PLOT.
17     C   PREDICTED EXTREMES FOR VARIOUS RETURN PERIODS ARE
18     C   ALSO COMPUTED AND PRINTED OUT.
19     C   INPUT ARGUMENTS--X      = THE SINGLE PRECISION VECTOR OF
20     C                        (UNSORTED OR SORTED) OBSERVATIONS.
21     C                        N      = THE INTEGER NUMBER OF OBSERVATIONS
22     C                        IN THE VECTOR X.
23     C   OUTPUT--6 PAGES OF AUTOMATIC PRINTOUT
24     C   PRINTING--YES
25     C   RESTRICTION--THE MAXIMUM ALLOWABLE VALUE OF N
26     C                   AS INPUT TO THIS SUBROUTINE IS 7500
27     C   OTHER DATAPAC SUBROUTINES NEEDED--SORT,UNIMED,EV1PLT,EV2PLT,PLOT
28     C   FORTRAN LIBRARY SUBROUTINES NEEDED--SORT AND ALOG
29     C   MODE OF INTERNAL OPERATIONS--SINGLE PRECISION
30     C   LANGUAGE--MACHINE-INDEPENDENT ANSI FORTRAN
31     C   COMMENT--THIS SUBROUTINE AS IT STANDS WILL ACCEPT DATA SETS
32     C               WITH UP TO 200 OBSERVATIONS.
33     C               IF COMPUTER STORAGE IS LIMITED AND IF SMALLER DATA
34     C               SETS ARE EXPECTED, THEN COMPUTER STORAGE MAY BE SAVED
35     C               BY RESETTING THE DIMENSION LIMITS OF THE VECTORS
36     C               W, Y, AND Z BELOW FROM THEIR PRESENT VALUE OF 200
37     C               TO WHATEVER THE EXPECTED MAXIMUM DATA SET SIZE IS.
38     C               THE STATEMENT      IUPPER=200
39     C               (ABOUT STATEMENT 122 IN THIS SUBROUTINE)
40     C               SHOULD ALSO BE CHANGED FROM 200 TO THE EXPECTED
41     C               MAXIMUM DATA SET SIZE.
42     C               STORAGE SAVINGS CAN ALSO BE ACHIEVED BY JUDICIOUSLY
43     C               REDUCING THE DIMENSION LIMITS OF THE VECTORS W AND Y
44     C               IN THE NEEDED SUPPORT SUBROUTINES EV1PLT
45     C               AND EV2PLT.
46     C   REFERENCE--FILLIBEN (1972), 'TECHNIQUES FOR TAIL LENGTH
47     C               ANALYSIS', PROCEEDINGS OF THE EIGHTEENTH
48     C               CONFERENCE ON THE DESIGN OF EXPERIMENTS IN
49     C               ARMY RESEARCH AND TESTING, PAGES 425-450.
50     C               --FILLIBEN, 'THE PERCENT POINT FUNCTION',
51     C               UNPUBLISHED MANUSCRIPT.
52     C               --JOHNSON AND KOTZ (1970), CONTINUOUS UNIVARIATE
53     C               DISTRIBUTIONS-1, PAGES 272-295.
54     C   WRITTEN BY--JAMES J FILLIBEN      (JUNE 1972)
55     C               STATISTICAL ENGINEERING LABORATORY (205.03)
56     C               NATIONAL BUREAU OF STANDARDS
57     C               WASHINGTON, D. C. 20234

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58      C      PHONE--301-921-2315
59      C      UPDATED--DECEMBER, 1974
60      C
61      INTEGER BLANK,ALPHAM,ALPHAA,ALPHAY
62      INTEGER ALPHAI,ALPHAN,ALPHAF,ALPHAT,ALPHAY
63      INTEGER ALPHAG,EQUAL
64      DIMENSION X(1)
65      DIMENSION W(200),Y(200),Z(200)
66      DIMENSION GAMTAB(50),CORR(50)
67      DIMENSION YI(50),YS(50),T(50)
68      DIMENSION IFLAG1(50),IFLAG2(50),IFLAG3(50)
69      DIMENSION C(10),AM(50),SCRAT(50)
70      DIMENSION AINDEX(50)
71      DIMENSION P0(10)
72      DIMENSION H(60,2)
73      DATA BLANK,ALPHAM,ALPHAA,ALPHAX/1H,1HM,1HA,1HX/
74      DATA ALPHAI,ALPHAN,ALPHAF,ALPHAT,ALPHAY/1HI,1HN,1HF,1HT,1HY/
75      DATA ALPHAG,EQUAL/1HG,1H=/
76      DATA GAMTAB(1),GAMTAB(2),GAMTAB(3),GAMTAB(4),GAMTAB(5),
77      1GAMTAB(6),GAMTAB(7),GAMTAB(8),GAMTAB(9),GAMTAB(10),
78      1GAMTAB(11),GAMTAB(12),GAMTAB(13),GAMTAB(14),GAMTAB(15),
79      1GAMTAB(16),GAMTAB(17),GAMTAB(18),GAMTAB(19),GAMTAB(20),
80      1GAMTAB(21),GAMTAB(22),GAMTAB(23),GAMTAB(24),GAMTAB(25)
81      1/1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,
82      113.,14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,24.,25./
83      DATA GAMTAB(26),GAMTAB(27),GAMTAB(28),GAMTAB(29),GAMTAB(30),
84      1GAMTAB(31),GAMTAB(32),GAMTAB(33),GAMTAB(34),GAMTAB(35),
85      1GAMTAB(36),GAMTAB(37),GAMTAB(38),GAMTAB(39),GAMTAB(40),
86      1GAMTAB(41),GAMTAB(42)
87      1/30.,35.,40.,45.,50.,60.,70.,80.,90.,100.,150.,200.,250.,
88      1350.,500.,750.,1000./
89      DATA C(1),C(2),C(3),C(4),C(5),C(6),C(7),C(8),C(9),C(10)
90      1/60.,75.,100.,150.,250.,500.,1000.,10000.,100000.,1000000./
91      DATA P0(1),P0(2),P0(3),P0(4),P0(5),P0(6),P0(7),P0(8),P0(9),P0(10)
92      1/.0.,.5.,.75.,.9.,.95.,.975.,.99.,.999.,.9999.,.99999/
93      DATA AINDEX(1),AINDEX(2),AINDEX(3),AINDEX(4),AINDEX(5),
94      1AINDEX(6),AINDEX(7),AINDEX(8),AINDEX(9),AINDEX(10),
95      1AINDEX(11),AINDEX(12),AINDEX(13),AINDEX(14),AINDEX(15),
96      1AINDEX(16),AINDEX(17),AINDEX(18),AINDEX(19),AINDEX(20),
97      1AINDEX(21),AINDEX(22),AINDEX(23),AINDEX(24),AINDEX(25)
98      1/1.,2.,3.,4.,5.,6.,7.,8.,9.,10.,11.,12.,
99      113.,14.,15.,16.,17.,18.,19.,20.,21.,22.,23.,24.,25./
100     DATA AINDEX(26),AINDEX(27),AINDEX(28),AINDEX(29),AINDEX(30),
101     1AINDEX(31),AINDEX(32),AINDEX(33),AINDEX(34),AINDEX(35),
102     1AINDEX(36),AINDEX(37),AINDEX(38),AINDEX(39),AINDEX(40),
103     1AINDEX(41),AINDEX(42),AINDEX(43),AINDEX(44),AINDEX(45),
104     1AINDEX(46),AINDEX(47),AINDEX(48),AINDEX(49),AINDEX(50)
105     1/26.,27.,28.,29.,30.,31.,32.,33.,34.,35.,36.,37.,38.,
106     139.,40.,41.,42.,43.,44.,45.,46.,47.,48.,49.,50./
107     DATA T(1),T(2),T(3),T(4),T(5),T(6),T(7),T(8),T(9),T(10),
108     1T(11),T(12),T(13),T(14),T(15),T(16),T(17),T(18),T(19),T(20),
109     1T(21),T(22),T(23),T(24),T(25)
110     1/10.18011,3.39672,2.47043,2.14609,1.98712,1.89429,1.83394,
111     11.79175,1.76069,1.73691,1.71814,1.70297,1.69045,1.67996,
112     11.67103,1.66335,1.65667,1.65082,1.64564,1.64102,1.63689,
113     11.63316,1.62979,1.62672,1.62391/
114     DATA T(26),T(27),T(28),T(29),T(30),
115     1T(31),T(32),T(33),T(34),T(35),T(36),T(37),T(38),T(39),T(40),

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116      1T(41),T(42),T(43)
117      1/1.61287,1.60516,1.59947,1.59510,1.59164,1.58651,1.58289,
118      11.58019,1.57811,1.57645,1.57152,1.56908,1.56763,1.56666,
119      11.56546,1.56377,1.56330,1.56187/
120  C
121      IPR=6
122      IUPPER=200
123      NUMDIS=43
124      AN=N
125  C
126  C      CHECK THE INPUT ARGUMENTS FOR ERRORS
127  C
128      IF(N.LT.1.OR.N.GT.IUPPER)GOTO50
129      IF(N.EQ.1)GOTO55
130      HOLD=X(1)
131      DO60I=2,N
132      IF(X(I).NE.HOLD)GOTO90
133  60  CONTINUE
134      WRITE(IPR,9)HOLD
135      RETURN
136  50  WRITE(IPR,17)IUPPER
137      WRITE(IPR,47)N
138      RETURN
139  55  WRITE(IPR,18)
140      RETURN
141  90  CONTINUE
142      9  FORMAT(1H ,109H***** NON-FATAL DIAGNOSTIC--THE FIRST INPUT ARGUME
143      1NT (A VECTOR) TO THE EXTREM SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
144      1H ***** )
145      17  FORMAT(1H ,98H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
146      1 EXTREM SUBROUTINE IS OUTSIDE THE ALLOWABLE (1,,I6,16H) INTERVAL *
147      1***** )
148      18  FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
149      1NT TO THE EXTREM SUBROUTINE HAS THE VALUE 1 ***** )
150      47  FORMAT(1H ,35H***** THE VALUE OF THE ARGUMENT IS ,I8 ,6H ***** )
151  C
152  C      COMPUTE THE SAMPLE MINIMUM AND SAMPLE MAXIMUM
153  C
154      XMIN=X(1)
155      XMAX=X(1)
156      DO140I=2,N
157      IF(X(I).LT.XMIN)XMIN=X(I)
158      IF(X(I).GT.XMAX)XMAX=X(I)
159  140  CONTINUE
160  C
161  C      COMPUTE THE PROB PLOT CORRELATION COEFFICIENTS FOR THE VARIOUS VALUES
162  C      OF GAMMA
163  C
164      CALL SORT(X,N,Y)
165      CALL UNIMED(N,Z)
166  C
167      DO100IDIS=1,NUMDIS
168      IF(IDIS.EQ.NUMDIS)GOTO150
169      A=GAMTAB(IDIS)
170      DO110I=1,N
171      W(I)=(-ALOG(Z(I)))*(-1.0/A)
172  110  CONTINUE
173      GOTO170

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174      150 D0160I=1,N
175          W(I)=-ALOG(ALOG(1.0/Z(I)))
176      160 CONTINUE
177  C
178      170 SUM1=0.0
179          SUM2=0.0
180          D0200I=1,N
181          SUM1=SUM1+W(I)
182          SUM2=SUM2+W(I)
183      200 CONTINUE
184          YBAR=SUM1/AN
185          WBAR=SUM2/AN
186          SUM1=0.0
187          SUM2=0.0
188          SUM3=0.0
189          D0300I=1,N
190          SUM2=SUM2+(Y(I)-YBAR)*(W(I)-WBAR)
191          SUM1=SUM1+(Y(I)-YBAR)*(Y(I)-YBAR)
192          SUM3=SUM3+(W(I)-WBAR)*(W(I)-WBAR)
193      300 CONTINUE
194          SY=SQR(SUM1/(AN-1.0))
195          CC=SUM2/SQR(SUM3*SUM1)
196          YSLOPE=SUM2/SUM3
197          YINT=YBAR-YSLOPE*WBAR
198          CORR(IDIS)=CC
199          YI(IDIS)=YINT
200          YS(IDIS)=YSLOPE
201      100 CONTINUE
202  C
203  C      DETERMINE THAT DISTRIBUTION WITH THE MAX PROB PLOT CORR COEFFICIENT
204  C
205          IDISMX=1
206          CORRMX=CORR(1)
207          D0400IDIS=1,NUMDIS
208          IF(CORR(IDIS).GT.CORRMX)IDISMX=IDIS
209          IF(CORR(IDIS).GT.CORRMX)CORRMX=CORR(IDIS)
210      400 CONTINUE
211          D0500IDIS=1,NUMDIS
212          IFLAG1(IDIS)=BLANK
213          IFLAG2(IDIS)=BLANK
214          IFLAG3(IDIS)=BLANK
215          IF(IDIS.EQ.IDISMX)GOTO550
216          GOTO500
217      550 IFLAG1(IDIS)=ALPHAM
218          IFLAG2(IDIS)=ALPHA
219          IFLAG3(IDIS)=ALPHAX
220      500 CONTINUE
221  C
222  C      WRITE OUT THE TABLE OF PROB PLOT CORR COEFFICIENTS FOR VARIOUS GAMMA
223  C
224          WRITE(IPR,998)
225          WRITE(IPR,305)
226          WRITE(IPR,999)
227          WRITE(IPR,310)N
228          WRITE(IPR,311)YBAR
229          WRITE(IPR,312)SY
230          WRITE(IPR,313)XMIN
231          WRITE(IPR,314)XMAX

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232      WRITE(IPR,999)
233      WRITE(IPR,323)
234      WRITE(IPR,324)
235      WRITE(IPR,325)
236      WRITE(IPR,999)
237  C
238      NUMDM1=NUMDIS-1
239      IF(NUMDM1.LT.1)GOTO850
240      DO800I=1,NUMDM1
241      WRITE(IPR,805)GAMTAB(I),CORR(I),IFLAG1(I),IFLAG2(I),IFLAG3(I),
242      1YI(I),YS(I)
243      800 CONTINUE
244      850 I=NUMDIS
245      WRITE(IPR,806)ALPHAI,ALPHAN,ALPHAF,ALPHAI,ALPHAN,ALPHAI,
246      1ALPHAT,ALPHAY,CORR(I),IFLAG1(I),IFLAG2(I),IFLAG3(I),
247      1YI(I),YS(I)
248  C
249  C      PLOT THE PROB PLOT CORR COEFFICIENT VERSUS GAMMA VALUE INDEX
250  C
251      CALL PLOT(CORR,AINDEX,NUMDIS)
252      WRITE(IPR,810)ALPHAG,ALPHAA,ALPHAM,ALPHAM,ALPHAA,EQUAL,
253      1GAMTAB(1),GAMTAB(12),GAMTAB(23),GAMTAB(34),
254      1ALPHAI,ALPHAN,ALPHAF,ALPHAI,ALPHAN,ALPHAI,ALPHAT,ALPHAY
255      WRITE(IPR,999)
256      WRITE(IPR,812)
257      WRITE(IPR,813)
258  C
259  C      IF THE OPTIMAL GAMMA IS FINITE, PLOT OUT THE EXTREME VALUE
260  C      TYPE 2 PROBABILITY PLOT FOR THE OPTIMAL VALUE
261  C      OF GAMMA.
262  C
263      IF(IDISMX.LT.NUMDIS)CALL EV2PLT(X,N,GAMTAB(IDISMX))
264  C
265  C      PLOT OUT AN EXTREME VALUE TYPE 1 PROBABILITY PLOT
266  C
267      CALL EV1PLT(X,N)
268  C
269  C      FORM THE VARIOUS RETURN PERIOD VALUES
270  C
271      1650 K=0
272      DO2100I=1,4
273      DO2200J=1,9
274      K=K+1
275      AM(K)=J*(10**(I-1))
276      2200 CONTINUE
277      2100 CONTINUE
278      K=K+1
279      AM(K)=10000.
280      K=K+1
281      AM(K)=50000.
282      K=K+1
283      AM(K)=100000.
284      K=K+1
285      AM(K)=500000.
286      K=K+1
287      AM(K)=1000000.
288      K=K+1
289      AM(K)=N

```

```

290      NUMAM=K
291      CALL SORT(AM,NUMAM,SCRAT)
292      DO2300I=1,NUMAM
293      AM(I)=SCRAT(I)
294      2300 CONTINUE
295  C
296  C      IF THE OPTIMAL GAMMA IS FINITE, COMPUTE THE
297  C      PREDICTED EXTREME (= F(1-(1/M))) FOR VARIOUS RETURN PERIODS M
298  C      FOR THE OPTIMAL EXTREME VALUE TYPE 2 DISTRIBUTION.
299  C
300      IF(IDISMX.EQ.NUMDIS)GOTO2450
301      A=GAMTAB(IDISMX)
302      YINT=YI(IDISMX)
303      YSLOPE=YS(IDISMX)
304      DO2400I=2,NUMAM
305      R=1.0/AM(I)
306      P=1.0-R
307      ARG=-ALOG(P)
308      IF(ARG.LE.0.0)GOTO2400
309      H(I,1)=YINT+YSLOPE*(ARG**(-1.0/A))
310      2400 CONTINUE
311  C
312  C      COMPUTE THE PREDICTED EXTREME (= F(1-(1/M))) FOR VARIOUS RETURN
313  C      PERIODS M FOR THE EXTREME VALUE TYPE 1 DISTRIBUTION.
314  C
315      2450 YINT=YI(NUMDIS)
316      YSLOPE=YS(NUMDIS)
317      DO2500I=2,NUMAM
318      R=1.0/AM(I)
319      P=1.0-R
320      ARG=-ALOG(P)
321      IF(ARG.LE.0.0)GOTO2500
322      H(I,2)=YINT+YSLOPE*(-ALOG(ARG))
323      2500 CONTINUE
324  C
325  C      WRITE OUT THE PAGE WITH THE RETURN PERIODS AND THE PREDICTED EXTREMES
326  C      FOR THE 2 DISTRIBUTIONS--OPTIMAL EXTREME VALUE TYPE 2, AND EXTREME
327  C      VALUE TYPE 1.
328  C
329      WRITE(IPR,998)
330      IF(IDISMX.EQ.NUMDIS)GOTO2750
331      WRITE(IPR,2602)
332      WRITE(IPR,2604)
333      WRITE(IPR,2606)
334      WRITE(IPR,2608)
335      WRITE(IPR,2610)GAMTAB(IDISMX)
336      WRITE(IPR,999)
337      DO2700I=2,NUMAM
338      WRITE(IPR,2705)AM(I),H(I,1),H(I,2)
339      J=I-1
340      JSKIP=J-5*(J/5)
341      IF(JSKIP.EQ.0)WRITE(IPR,999)
342      2700 CONTINUE
343      RETURN
344  C
345      2750 WRITE(IPR,2802)
346      WRITE(IPR,2804)
347      WRITE(IPR,2806)

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348      WRITE(IPR,2808)
349      WRITE(IPR,999)
350      DO2900 I=2,NUMAM
351      WRITE(IPR,2705) AM(I),H(I,2)
352      J=I-1
353      JSKIP=J-5*(J/5)
354      IF(JSKIP.EQ.0) WRITE(IPR,999)
355      2900 CONTINUE
356  C
357      998 FORMAT(1H1)
358      999 FORMAT(1H )
359      305 FORMAT(1H ,40X,22HEXTREME VALUE ANALYSIS)
360      310 FORMAT(1H ,37X,20HTHE SAMPLE SIZE N = ,I7)
361      311 FORMAT(1H ,34X,18HTHE SAMPLE MEAN = ,F14.7)
362      312 FORMAT(1H ,28X,32HTHE SAMPLE STANDARD DEVIATION = ,F14.7)
363      313 FORMAT(1H ,32X,21HTHE SAMPLE MINIMUM = ,F14.7)
364      314 FORMAT(1H ,32X,21HTHE SAMPLE MAXIMUM = ,F14.7)
365      323 FORMAT(1H ,67H      EXTREME VALUE      PROBABILITY PLOT      LOCATIO
366      1N      SCALE)
367      324 FORMAT(1H ,69H TYPE 2 TAIL LENGTH      CORRELATION      ESTIMAT
368      1E      ESTIMATE)
369      325 FORMAT(1H ,37H      PARAMETER (GAMMA)      COEFFICIENT)
370      805 FORMAT(1H ,3X,F10.2,13X,F8.5,1X,3A1,2X,F14.7,2X,F14.7)
371      806 FORMAT(1H ,5X,8A1,13X,F8.5,1X,3A1,2X,F14.7,2X,F14.7)
372      810 FORMAT(1H ,12X,5A1,1X,A1,F14.7,11X,F14.7,11X,F14.7,11X,F14.7,
373      115X,8A1)
374      812 FORMAT(1H ,96HTHE ABOVE IS A PLOT OF THE 43 PROBABILITY PLOT CORRE
375      1LATION COEFFICIENTS (FROM THE PREVIOUS PAGE))
376      813 FORMAT(1H ,16X,41HVERSUS THE 43 EXTREME VALUE DISTRIBUTIONS)
377      2602 FORMAT(1H ,43H      RETURN PERIOD      PREDICTED EXTREME WIND,
378      1 27H      PREDICTED EXTREME WIND)
379      2604 FORMAT(1H ,43H      (IN YEARS)      BASED ON OPTIMAL
380      1 20H      BASED ON)
381      2606 FORMAT(1H ,42H      EXTREME VALUE TYPE 2,
382      1 27H      EXTREME VALUE TYPE 1)
383      2608 FORMAT(1H ,43H      DISTRIBUTION
384      1 22H      DISTRIBUTION)
385      2610 FORMAT(1H ,30H      (GAMMA = ,F12.5,1H))
386      2705 FORMAT(1H ,2X,F9.1,13X,F10.2,17X,F10.2)
387      2802 FORMAT(1H ,43H      RETURN PERIOD      PREDICTED EXTREME WIND)
388      2804 FORMAT(1H ,36H      (IN YEARS)      BASED ON)
389      2806 FORMAT(1H ,42H      EXTREME VALUE TYPE 1)
390      2808 FORMAT(1H ,38H      DISTRIBUTION)
391  C
392      RETURN
393      END

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@PRT,S SIMIU.SORT

JJF6*SIMIU.SORT

```

1      SUBROUTINE SORT(X,N,Y)
2      C
3      C   THIS ROUTINE SORTS THE ELEMENTS OF THE INPUT VECTOR X AND PUTS THE SORTED
4      C   ELEMENTS INTO THE VECTOR Y.
5      C   THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR X OF
6      C   (UNSORTED) OBSERVATIONS, THE INTEGER VALUE N (= SAMPLE SIZE),
7      C   AND AN EMPTY SINGLE PRECISION VECTOR Y INTO WHICH THE SORTED OBSERVATIONS
8      C   WILL BE PLACED.
9      C   THE OUTPUT FROM THIS ROUTINE IS THE SINGLE PRECISION VECTOR Y INTO WHICH
10     C   THE SORTED OBSERVATIONS HAVE BEEN PLACED.
11     C   RESTRICTIONS ON THE MAXIMUM ALLOWABLE VALUE OF N--THE DIMENSIONS
12     C   OF VECTORS IU AND IL (DEFINED AND USED INTERNALLY WITHIN THIS ROUTINE)
13     C   DETERMINE THE MAXIMUM ALLOWABLE VALUE OF N FOR THIS
14     C   ROUTINE. IF IU AND IL EACH HAVE DIMENSION K, THEN N MAY NOT EXCEED
15     C   2**(K+1) - 1. FOR THIS ROUTINE AS WRITTEN, THE DIMENSIONS OF IU AND IL
16     C   HAVE BEEN SET TO 36, THUS THE MAXIMUM ALLOWABLE VALUE OF N IS
17     C   APPROXIMATELY 137 BILLION. SINCE THIS EXCEEDS THE MAXIMUM ALLOWABLE
18     C   VALUE FOR AN INTEGER VARIABLE IN MANY COMPUTERS, AND SINCE A SORT OF 137
19     C   BILLION ELEMENTS IS PRESENTLY IMPRACTICAL AND UNLIKELY, THEREFORE NO
20     C   TEST FOR WHETHER THE INPUT SAMPLE SIZE N EXCEEDS 137 BILLION HAS BEEN
21     C   INCORPORATED INTO THIS ROUTINE. IT IS THUS ASSUMED THAT THERE IS NO
22     C   (PRACTICAL) RESTRICTION ON THE MAXIMUM VALUE OF N FOR THIS ROUTINE.
23     C   PRINTING--NONE UNLESS AN ERROR CONDITION EXISTS
24     C   THIS ROUTINE IS SINGLE PRECISION IN INTERNAL OPERATION.
25     C   SUBROUTINES NEEDED--NONE
26     C   SORTING METHOD--BINARY SORT
27     C   REFERENCE--CACM MARCH 1969, PAGE 186 (BINARY SORT ALGORITHM BY RICHARD
28     C               C. SINGLETON.
29     C               --CACM JANUARY 1970, PAGE 54.
30     C               --CACM OCTOBER 1970, PAGE 624.
31     C               --JACM JANUARY 1961, PAGE 41.
32     C
33     C   THE BINARY SORT ALGORITHM USED HEREIN IS EXTREMELY FAST AS THE
34     C   FOLLOWING TIME TRIALS (PERFORMED BY SORTING RANDOM NUMBERS)
35     C   ON THE UNIVAC 1108 EXEC 8 SYSTEM INDICATE.
36     C   THESE TIME TRIALS WERE CARRIED OUT IN AUGUST, 1974.
37     C   BY WAY OF COMPARISON, THE TIME TRIAL VALUES FOR THE EASY-TO-PROGRAM
38     C   BUT EXTREMELY INEFFICIENT BUBBLE SORT METHOD HAVE ALSO BEEN
39     C   INCLUDED:
40     C
41     C       NUMBER OF RANDOM          BINARY SORT          • BUBBLE SORT
42     C       NUMBERS SORTED
43     C       N = 10                      .002 SEC             .002 SEC
44     C       N = 100                     .011 SEC             .045 SEC
45     C       N = 1000                    .141 SEC             4.332 SEC
46     C       N = 3000                    .476 SEC             37.683 SEC
47     C       N = 10000                   1.887 SEC             NOT COMPUTED
48     C
49     C   WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
50     C   NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234          JUNE 1972
51     C
52     C   DIMENSION X(1),Y(1)
53     C   DIMENSION IU(36),IL(36)
54     C
55     C   IPR=6
56     C
57     C   CHECK THE INPUT ARGUMENTS FOR ERRORS

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```

58      IF(N.LT.1)GOTO50
59      IF(N.EQ.1)GOTO55
60      HOLD=X(1)
61      DO60I=2,N
62      IF(X(I).NE.HOLD)GOTO90
63      60 CONTINUE
64      WRITE(IPR,9)HOLD
65      DO61I=1,N
66      Y(I)=X(I)
67      61 CONTINUE
68      RETURN
69      50 WRITE(IPR,15)
70      WRITE(IPR,47)N
71      RETURN
72      55 WRITE(IPR,18)
73      Y(1)=X(1)
74      RETURN
75      90 CONTINUE
76      9 FORMAT(1H ,10AH***** NON-FATAL DIAGNOSTIC--THE FIRST INPUT ARGUME
77      INT (A VECTOR) TO THE SORT  SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
78      1H *****
79      15 FORMAT(1H , 91H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
80      1 SORT  SUBROUTINE IS NON-POSITIVE *****)
81      18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
82      INT TO THE SORT  SUBROUTINE HAS THE VALUE 1 *****)
83      47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8 ,6H *****)
84      C
85      C      COPY THE VECTOR X INTO THE VECTOR Y
86      DO100I=1,N
87      Y(I)=X(I)
88      100 CONTINUE
89      C
90      C      CHECK TO SEE IF THE INPUT VECTOR IS ALREADY SORTED
91      C
92      NM1=N-1
93      DO200I=1,NM1
94      IP1=I+1
95      IF(Y(I).LE.Y(IP1))GOTO200
96      GOTO250
97      200 CONTINUE
98      RETURN
99      250 M=1
100     I=1
101     J=N
102     305 IF(I.GE.J)GOTO370
103     310 K=I
104     MID=(I+J)/2
105     AMED=Y(MID)
106     IF(Y(I).LE.AMED)GOTO320
107     Y(MID)=Y(I)
108     Y(I)=AMED
109     AMED=Y(MID)
110     320 L=J
111     IF(Y(J).GE.AMED)GOTO340
112     Y(MID)=Y(J)
113     Y(J)=AMED
114     AMED=Y(MID)
115     IF(Y(I).LE.AMED)GOTO340

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```

116      Y(MID)=Y(I)
117      Y(I)=AMED
118      AMED=Y(MID)
119      GOT0340
120      330 Y(L)=Y(K)
121      Y(K)=TT
122      340 L=L-1
123      IF (Y(L).GT.AMED) GOT0340
124      TT=Y(L)
125      350 K=K+1
126      IF (Y(K).LT.AMED) GOT0350
127      IF (K.LE.L) GOT0330
128      LMI=L-I
129      JMK=J-K
130      IF (LMI.LE.JMK) GOT0360
131      IL(M)=I
132      IU(M)=L
133      I=K
134      M=M+1
135      GOT0380
136      360 IL(M)=K
137      IU(M)=J
138      J=L
139      M=M+1
140      GOT0380
141      370 M=M-1
142      IF (M.EQ.0) RETURN
143      I=IL(M)
144      J=IU(M)
145      380 JMI=J-I
146      IF (JMI.GE.11) GOT0310
147      IF (I.EQ.1) GOT0305
148      I=I-1
149      390 I=I+1
150      IF (I.EQ.J) GOT0370
151      AMED=Y(I+1)
152      IF (Y(I).LE.AMED) GOT0390
153      K=I
154      395 Y(K+1)=Y(K)
155      K=K-1
156      IF (AMED.LT.Y(K)) GOT0395
157      Y(K+1)=AMED
158      GOT0390
159      END

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@PRT,S SIMIU.UNIMED

JJF6*SIM1U.UNIMED

```

1      SUBROUTINE UNIMED(N,X)
2      C
3      C   THIS ROUTINE COMPUTES AN APPROXIMATION TO THE MEDIAN OF THE I-TH ORDER
4      C   STATISTIC (FOR I = 1,2,...,N) FROM A UNIFORM DISTRIBUTION (ON THE UNIT
5      C   INTERVAL (0,1)).
6      C   THIS IS IDENTICAL TO THE MEDIAN OF THE BETA DISTRIBUTION WITH PARAMETERS
7      C   I AND N-I+1 FOR I=1,2,...,N.
8      C   THE INPUT TO THIS ROUTINE IS THE DESIRED INTEGER SAMPLE SIZE N
9      C   AND AN EMPTY SINGLE PRECISION VECTOR X (OF DIMENSION AT LEAST N) INTO
10     C   WHICH THE N GENERATED UNIFORM ORDER STATISTIC MEDIANS WILL BE PLACED.
11     C   THE OUTPUT FROM THIS ROUTINE IS THE SINGLE PRECISION VECTOR X
12     C   INTO WHICH THE N GENERATED UNIFORM ORDER STATISTIC MEDIANS
13     C   HAVE BEEN PLACED.
14     C   ALL OF THE PROBABILITY PLOT ROUTINES MAKE USE OF THIS ROUTINE.
15     C   JUSTIFICATION AND ACCURACY OF THE ALGORITHM USED IS FOUND IN AN
16     C   UNPUBLISHED JJF MANUSCRIPT.
17     C   THERE IS NO RESTRICTION ON THE MAXIMUM VALUE OF N FOR THIS ROUTINE.
18     C   PRINTING--NONE UNLESS AN ERROR CONDITION EXISTS
19     C   THIS ROUTINE IS SINGLE PRECISION IN INTERNAL OPERATION
20     C   SUBROUTINES NEEDED--NONE
21     C   REFERENCE--UNPUBLISHED JJF MANUSCRIPT
22     C   WRITTEN BY JAMES J. FILLIREN, STATISTICAL ENGINEERING LABORATORY (205.03)
23     C   NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234      JUNE 1972
24     C
25     C   DIMENSION X(1)
26     C
27     C   AN=N
28     C   IPR=6
29     C
30     C   CHECK THE INPUT ARGUMENTS FOR ERRORS
31     C
32     C   IF(N.LT.1)GOTO50
33     C   IF(N.EQ.1)GOTO55
34     C   GOTO90
35     C   50 WRITE(IPR, 5)
36     C   WRITE(IPR,47)N
37     C   RETURN
38     C   55 WRITE(IPR, 8)
39     C   90 CONTINUE
40     C   5 FORMAT(1H , 91H***** FATAL ERROR--THE FIRST INPUT ARGUMENT TO THE
41     C   1 UNIMED SUBROUTINE IS NON-POSITIVE ***** )
42     C   8 FORMAT(1H , 100H***** NON-FATAL DIAGNOSTIC--THE FIRST INPUT ARGUME
43     C   1NT TO THE UNIMED SUBROUTINE HAS THE VALUE 1 ***** )
44     C   47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8 , 6H ***** )
45     C
46     C   X(N)=0.5**((1.0/AN)
47     C   X(1)=1.0-X(N)
48     C   NHALF=(N/2)+1
49     C   NEVODD=2*(N/2)
50     C   IF(N.NE.NEVODD)X(NHALF)=0.5
51     C   IF(N.LE.3)RETURN
52     C   GAM=0.3175
53     C   IMAX=N/2
54     C   DO100I=2,IMAX
55     C   AI=I
56     C   IREV=N-I+1
57     C   X(I)=(AI-GAM)/(AN-2.0*GAM+1.0)

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58      X(IREV)=1.0-X(I)
59      100 CONTINUE
60      RETURN
61      END
```

QPRTS SIMIU.EVIPLT

JJF6*SIMIU.EV1PLT

```

1      SUBROUTINE EV1PLT(X,N)
2      C
3      C   THIS ROUTINE GENERATES AN EXTREME VALUF TYPE 1 (FXPONENTIAL TYPE)
4      C   PROBABILITY PLOT
5      C   THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR X OF
6      C   (UNSORTED OR SORTED) OBSERVATIONS AND THE INTEGER VALUE N (= SAMPLE SIZE)
7      C   THE OUTPUT FROM THIS ROUTINE IS A ONE-PAGE EXTREME VALUE TYPE 1
8      C   PROBABILITY PLOT
9      C   PRINTING--YES
10     C   SUBROUTINES NEEDED--SORT, UNIMED, AND PLOT
11     C   REFERENCE--UNPUB. JJF MANUSCRIPT 'THE PERCENT POINT FUNCTION', PAGE 26
12     C   WRITTEN BY JAMES J. FILLIREN, STATISTICAL ENGINEERING LABORATORY (205.03)
13     C   NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234      JUNE 1972
14     C
15     DIMENSION X(1)
16     DIMENSION Y(200),W(200)
17     C
18     DATA TAU/1.56186687/
19     C
20     AN=N
21     IPR=6
22     IUPPER=7500
23     C
24     C   CHECK THE INPUT ARGUMENTS FOR ERRORS
25     C
26     IF(N.LT.1.OR.N.GT.IUPPER)GOTO50
27     IF(N.EQ.1)GOTO55
28     HOLD=X(1)
29     DO60I=2,N
30     IF(X(I).NE.HOLD)GOTO90
31     60 CONTINUE
32     WRITE(IPR, 9)HOLD
33     GOTO90
34     50 WRITE(IPR,17)IUPPER
35     WRITE(IPR,47)N
36     RETURN
37     55 WRITE(IPR,18)
38     RETURN
39     90 CONTINUE
40     9 FORMAT(1H ,109H***** NON-FATAL DIAGNOSTIC--THE FIRST INPUT ARGUME
41     1NT (A VECTOR) TO THE EV1PLT SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
42     1H *****
43     17 FORMAT(1H , 98H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
44     1 EV1PLT SUBROUTINE IS OUTSIDE THE ALLOWABLE (1,,I6,16H) INTERVAL *
45     1****)
46     18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
47     1NT TO THE EV1PLT SURROUTINE HAS THE VALUE 1 *****
48     47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8 ,6H *****
49     C
50     CALL SORT(X,N,Y)
51     CALL UNIMED(N,W)
52     DO100I=1,N
53     W(I)=-ALOG(ALOG(1.0/W(I)))
54     100 CONTINUE
55     CALL PLOT(Y,W,N)
56     WRITE(IPR,105)TAU,N
57     SUM1=0.0

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58      SUM2=0.0
59      DO200I=1,N
60      SUM1=SUM1+Y(I)
61      SUM2=SUM2+W(I)
62  200 CONTINUE
63      YBAR=SUM1/AN
64      WBAR=SUM2/AN
65      SUM1=0.0
66      SUM2=0.0
67      SUM3=0.0
68      DO300I=1,N
69      SUM1=SUM1+(Y(I)-YBAR)*(Y(I)-YBAR)
70      SUM2=SUM2+(Y(I)-YBAR)*(W(I)-WBAR)
71      SUM3=SUM3+(W(I)-WBAR)*(W(I)-WBAR)
72  300 CONTINUE
73      CC=SUM2/SQRT(SUM3*SUM1)
74      YSLOPE=SUM2/SUM3
75      YINT=YBAR-YSLOPE*WBAR
76      WRITE(IPR,305)CC,YINT,YSLOPE
77  105 FORMAT(1H ,64HEXTREME VALUE TYPE 1 (EXPONENTIAL TYPE) PROBABILITY
78      1PLOT (TAU = ,E15.8,1H),23X,20HTHE SAMPLE SIZE N = ,I7)
79  305 FORMAT(1H ,43HPROBABILITY PLOT CORRELATION COEFFICIENT = ,F8.5,5X,
80      122HESTIMATED INTERCEPT = ,E15.8,3X,18HESTIMATED SLOPE = ,E15.8)
81      RETURN
82      END

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QPRT,S SIMIU.EV2PLT

```

1      SUBROUTINE EV2PLT(X,N,GAMMA)
2
3      C      THIS ROUTINE GENERATES AN EXTREME VALUF TYPE 2 (CAUCHY TYPE)
4      C      PROBABILITY PLOT
5      C      THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR X OF
6      C      (UNSORTED OR SORTED) OBSERVATIONS, THE INTEGER VALUE N (= SAMPLE SIZE),
7      C      AND THE SINGLE PRECISION VALUE GAMMA (THE EXPONENT PARAMETER)
8      C      THE OUTPUT FROM THIS ROUTINE IS A ONE-PAGE EXTREME VALUE TYPE 2
9      C      PROBABILITY PLOT
10     C      THE MAXIMUM ALLOWABLE VALUE OF N FOR THIS ROUTINE IS 7500
11     C      PRINTING--YES
12     C      SUBROUTINES NEEDED--SORT, UNIMED, AND PLOT
13     C      REFERENCE--UNPUB. JJF MANUSCRIPT 'THE PERCENT POINT FUNCTION', PAGE 26
14     C      WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
15     C      NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234  DECEMBER 1972
16     C
17     DIMENSION X(1)
18     DIMENSION Y(200),W(200)
19
20     C
21     AN=N
22     IPR=6
23     IUPPER=7500
24
25     C      CHECK THE INPUT ARGUMENTS FOR ERRORS
26
27     IF(N.LT.1.OR.N.GT.IUPPER)GOTO50
28     IF(N.EQ.1)GOTO55
29     HOLD=X(1)
30     DO60I=2,N
31     IF(X(I).NE.HOLD)GOTO90
32     60 CONTINUE
33     WRITE(IPR,9)HOLD
34     GOTO90
35     50 WRITE(IPR,17)IUPPER
36     WRITE(IPR,47)N
37     RETURN
38
39     55 WRITE(IPR,18)
40     RETURN
41
42     90 CONTINUE
43     9 FORMAT(1H ,109H***** NON-FATAL DIAGNOSTIC--THE FIRST INPUT ARGUME
44     1NT (A VECTOR) TO THE EV2PLT SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
45     1H *****
46     17 FORMAT(1H , 98H***** FATAL ERROR--THE SECOND INPUT ARGUMENT TO THE
47     1 EV2PLT SUBROUTINE IS OUTSIDE THE ALLOWABLE (1, ,I6,16H) INTERVAL *
48     1****)
49     18 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
50     1NT TO THE EV2PLT SUBROUTINE HAS THE VALUE 1 *****
51     47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8 ,6H *****
52
53     C
54     CALL SORT(X,N,Y)
55     CALL UNIMED(N,W)
56     DO100I=1,N
57     W(I)=(-ALOG(W(I)))*(-1.0/GAMMA)
58
59     100 CONTINUE
60     CALL PLOT(Y,W,N)
61     Q=.9975
62     PP9975=(-ALOG(Q))*(-1.0/GAMMA)

```

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58      Q=.0025
59      PP0025=(-ALOG(Q))*(-1.0/GAMMA)
60      Q=.975
61      PP975 =(-ALOG(Q))*(-1.0/GAMMA)
62      Q=.025
63      PP025 =(-ALOG(Q))*(-1.0/GAMMA)
64      TAU=(PP975-PP0025)/(PP975-PP025)
65      WRITE(IPR,105) GAMMA,TAU,N
66      SUM1=0.0
67      SUM2=0.0
68      DO200I=1,N
69      SUM1=SUM1+Y(I)
70      SUM2=SUM2+W(I)
71 200 CONTINUE
72      YBAR=SUM1/AN
73      WBAR=SUM2/AN
74      SUM1=0.0
75      SUM2=0.0
76      SUM3=0.0
77      DO300I=1,N
78      SUM1=SUM1+(Y(I)-YBAR)*(Y(I)-YBAR)
79      SUM2=SUM2+(Y(I)-YBAR)*(W(I)-WBAR)
80      SUM3=SUM3+(W(I)-WBAR)*(W(I)-WBAR)
81 300 CONTINUE
82      CC=SUM2/SQRT(SUM3*SUM1)
83      YSLOPE=SUM2/SUM3
84      YINT=YBAR-YSLOPE*WBAR
85      WRITE(IPR,305) CC,YINT,YSLOPE
86 105 FORMAT(1H ,63HEXTREME VALUE TYPE 2 (CAUCHY TYPE) PROB. PLOT WITH E
87 1XP. PAR. = ,E17.10,1X,7H(TAU = ,E15.8,1H),1X,16HSAMPLE SIZE N = ,I
88 17)
89 305 FORMAT(1H ,43HPROBABILITY PLOT CORRELATION COEFFICIENT = ,F8.5,5X,
90 122HESTIMATED INTERCEPT = ,E15.8,3X,18HESTIMATED SLOPE = ,E15.8)
91      RETURN
92      END

```

@PRT,S SIMIU.PLOT

JJF6*SIMIU.PLOT

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1      SUBROUTINE PLOT(Y,X,N)
2      C
3      C      THIS ROUTINE YIELDS A ONE-PAGE PLOT OF Y(I) VERSUS X(I).
4      C      THE INPUT TO THIS ROUTINE IS THE SINGLE PRECISION VECTOR Y OF
5      C      OBSERVATIONS, THE SINGLE PRECISION VECTOR X OF CORRESPONDING
6      C      OBSERVATIONS, AND THE INTEGER VALUE N (= SAMPLE SIZE).
7      C      MULTIPLE PLOT POINTS ARE NOT INDICATED AS SUCH.
8      C      THERE IS NO RESTRICTION ON THE MAXIMUM VALUE OF N FOR THIS ROUTINE.
9      C      PRINTING--YES
10     C      SUBROUTINES NEEDED--NONE
11     C      WRITTEN BY JAMES J. FILLIBEN, STATISTICAL ENGINEERING LABORATORY (205.03)
12     C      NATIONAL BUREAU OF STANDARDS, WASHINGTON, D.C. 20234      JUNE 1972
13     C                                          UPDATED OCT      1974
14     C                                          UPDATED NOV      1974
15     C
16     C      INTEGER BLANK,HYPHEN,ALPHA I,ALPHA X
17     C      INTEGER ALPHA M,ALPHA A,ALPHA D,ALPHA N,EQUAL
18     C      DIMENSION Y(1),X(1)
19     C      COMMON IGRAPH(55,130)
20     C      DIMENSION YLABEL(11)
21     C
22     C      DATA BLANK,HYPHEN,ALPHA I,ALPHA X/1H ,1H-,1HI,1HX/
23     C      DATA ALPHA M,ALPHA A,ALPHA D,ALPHA N,EQUAL/1HM,1HA,1HD,1HN,1H=/
24     C
25     C      CHECK THE INPUT ARGUMENTS FOR ERRORS
26     C
27     C      IPR=6
28     C
29     C      IF(N.LT.1)GOTO50
30     C      IF(N.EQ.1)GOTO55
31     C      HOLD=Y(1)
32     C      DO60I=2,N
33     C      IF(Y(I).NE.HOLD)GOTO65
34     C      CONTINUE
35     C      WRITE(IPR,9)HOLD
36     C      65 HOLD=X(1)
37     C      DO70I=2,N
38     C      IF(X(I).NE.HOLD)GOTO90
39     C      70 CONTINUE
40     C      WRITE(IPR,19)HOLD
41     C      GOTO90
42     C      50 WRITE(IPR,25)
43     C      WRITE(IPR,47)N
44     C      RETURN
45     C      55 WRITE(IPR,28)
46     C      RETURN
47     C      90 CONTINUE
48     C      9 FORMAT(1H ,108H***** NON-FATAL DIAGNOSTIC--THE FIRST INPUT ARGUME
49     C      1NT (A VECTOR) TO THE PLOT SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
50     C      1H *****
51     C      19 FORMAT(1H ,108H***** NON-FATAL DIAGNOSTIC--THE SECOND INPUT ARGUME
52     C      1NT (A VECTOR) TO THE PLOT SUBROUTINE HAS ALL ELEMENTS = ,E15.8,6
53     C      1H *****
54     C      25 FORMAT(1H ,91H***** FATAL ERROR--THE THIRD INPUT ARGUMENT TO THE
55     C      1 PLOT SUBROUTINE IS NON-POSITIVE *****
56     C      28 FORMAT(1H ,100H***** NON-FATAL DIAGNOSTIC--THE THIRD INPUT ARGUME
57     C      1NT TO THE PLOT SUBROUTINE HAS THE VALUE 1 *****

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58      47 FORMAT(1H , 35H***** THE VALUE OF THE ARGUMENT IS ,I8 ,6H ***** )
59      C
60      C      DETERMINE THE Y VALUES TO BE LISTED ON THE LEFT VERTICAL AXIS
61      C
62          YMIN=Y(1)
63          YMAX=Y(1)
64          D0105I=1,N
65          IF(Y(I).LT.YMIN)YMIN=Y(I)
66          IF(Y(I).GT.YMAX)YMAX=Y(I)
67      105 CONTINUE
68          D0110I=1,11
69          AIM1=I-1
70          YLABLE(I)=YMAX-(AIM1/10.0)*(YMAX-YMIN)
71      110 CONTINUE
72      C
73      C      DETERMINE XMIN, XMAX, XMID, X25 (=THE 25% POINT), AND
74      C      X75 (=THE 75% POINT)
75          XMIN=X(1)
76          XMAX=X(1)
77          D0115I=1,N
78          IF(X(I).LT.XMIN)XMIN=X(I)
79          IF(X(I).GT.XMAX)XMAX=X(I)
80      115 CONTINUE
81          XMID=(XMIN+XMAX)/2.0
82          X25=0.75*XMIN+0.25*XMAX
83          X75=0.25*XMIN+0.75*XMAX
84      C
85      C      BLANK OUT THE GRAPH
86      C
87          D0100I=1,55
88          D0200J=1,129
89          IGRAPH(I,J)=BLANK
90      200 CONTINUE
91      100 CONTINUE
92      C
93      C      PRODUCE THE Y AXIS
94      C
95          D0300I=3,43
96          IGRAPH(I,25)=ALPHAI
97          IGRAPH(I,129)=ALPHAI
98      300 CONTINUE
99          D0350I=3,43,4
100         IGRAPH(I,25)=HYPHEN
101         IGRAPH(I,129)=HYPHEN
102      350 CONTINUE
103         IGRAPH(3,21)=EQUAL
104         IGRAPH(3,22)=ALPHAM
105         IGRAPH(3,23)=ALPHAA
106         IGRAPH(3,24)=ALPHAX
107         IGRAPH(23,21)=EQUAL
108         IGRAPH(23,22)=ALPHAM
109         IGRAPH(23,23)=ALPHAI
110         IGRAPH(23,24)=ALPHAD
111         IGRAPH(43,21)=EQUAL
112         IGRAPH(43,22)=ALPHAM
113         IGRAPH(43,23)=ALPHAI
114         IGRAPH(43,24)=ALPHAN
115      C

```

```

116      C      PRODUCE THE X AXIS
117      C
118          D0400J=27,127
119          IGRAPH(1,J)=HYPHEN
120          IGRAPH(45,J)=HYPHEN
121      400  CONTINUE
122          D0450J=27,127,25
123          IGRAPH(1,J)=ALPHA I
124          IGRAPH(45,J)=ALPHA I
125      450  CONTINUE
126          D0460J=40,127,25
127          IGRAPH(1,J)=ALPHA I
128          IGRAPH(45,J)=ALPHA I
129      460  CONTINUE
130      C
131      C      DETERMINE THE (X,Y) PLOT POSITIONS
132      C
133          RATIOY=40.0/(YMAX-YMIN)
134          RATIOX=100.0/(XMAX-XMIN)
135          D0600I=1,N
136          MX=RATIOX*(X(I)-XMIN)+0.5
137          MY=MX+27
138          MY=RATIOY*(Y(I)-YMIN)+0.5
139          MY=43-MY
140          IGRAPH(MY,MX)=ALPHAX
141      600  CONTINUE
142      C
143      C      WRITE OUT THE GRAPH
144      C
145          WRITE(IPR,998)
146          D0700I=1,45
147          IP1=I+1
148          IFLAG=IP1-(IP1/4)*4
149          K=IP1/4
150          IF(IFLAG.NE.0)WRITE(IPR,705)(IGRAPH(I,J),J=1,129)
151          IF(IFLAG.EQ.0)WRITE(IPR,706)YLABLE(K),(IGRAPH(I,J),J=21,129)
152      700  CONTINUE
153          WRITE(IPR,707)XMIN,X25,XMID,X75,XMAX
154      705  FORMAT(1H ,129A1)
155      706  FORMAT(1H ,F20.7,109A1)
156      707  FORMAT(1H ,14X,F20.7,5X,F20.7,5X,F20.7,5X,F20.7,1X,F20.7)
157      998  FORMAT(1H1)
158          RETURN
159          END

```

@PRT,S SIMIU.DATA4

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

THE NUMBER OF OBSERVATIONS = 37

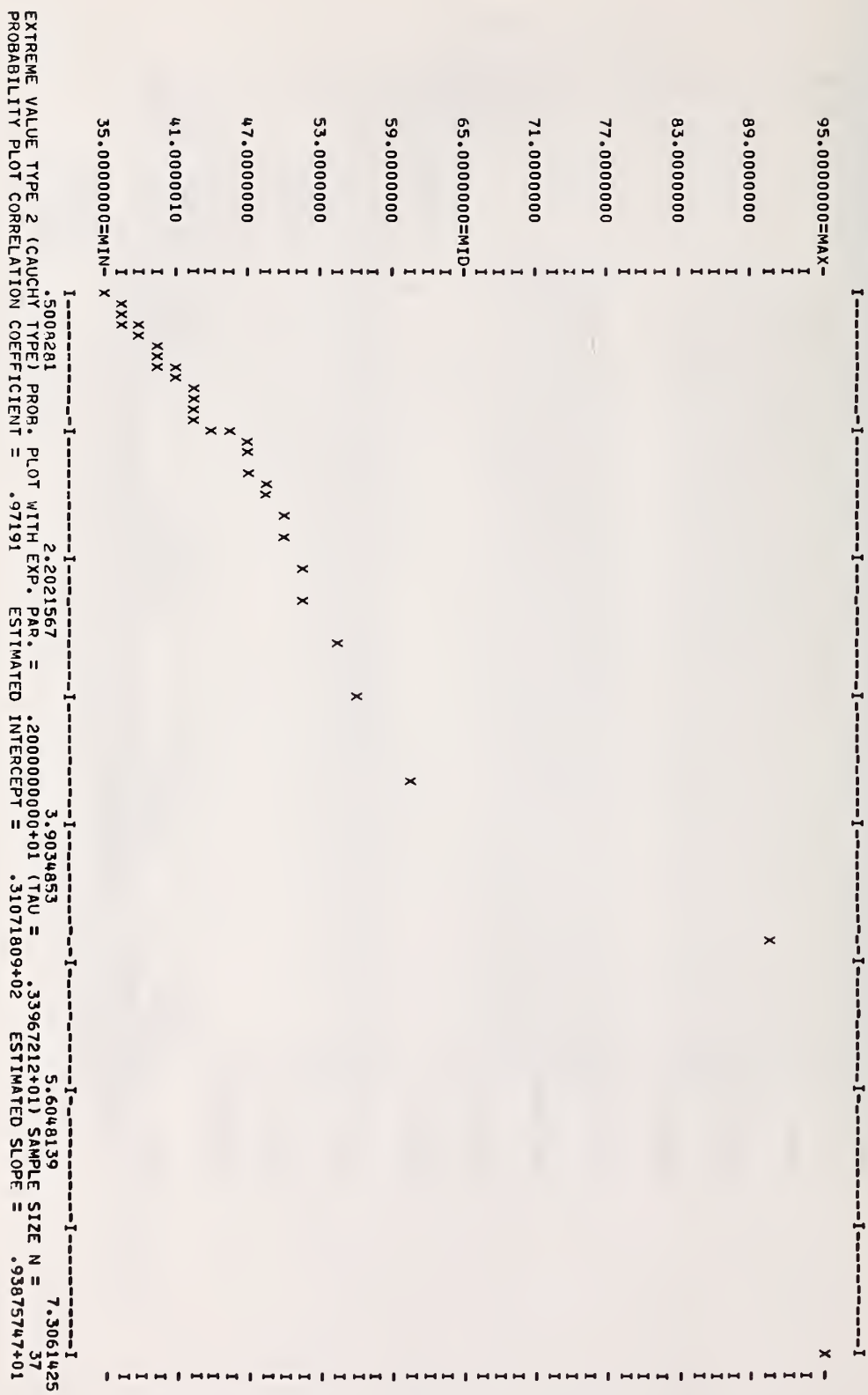
INPUT DATA

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



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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