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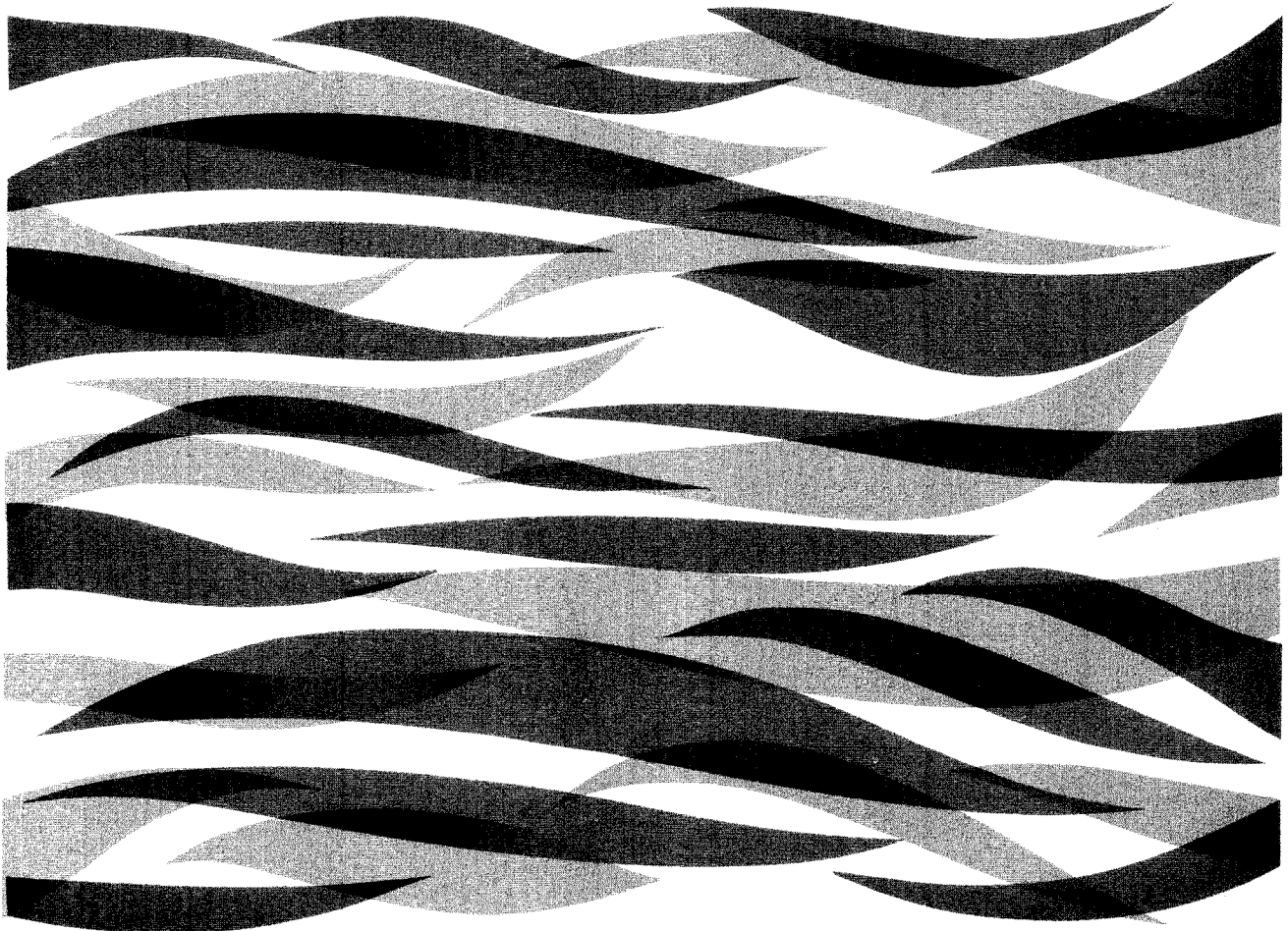
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Report No. 3

June, 1967

ANALYSIS OF QUASI-PERIODIC WEATHER DATA

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INSTITUTE OF WATER RESOURCES

of The University of Connecticut

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ANALYSIS OF QUASI-PERIODIC WEATHER DATA

Daily temperatures follow a pattern of variation that is familiar to us all. Although our very lives depend upon its not varying too much, our plans are often thwarted by its unexpected turns. The experience of thousands of years, if not tens of thousands, has shown that it is remarkably constant in some respects. We long to be able to predict its vagaries, yet about all we can say with certainty is that the temperature will be higher in summer than in winter. Or, if you don't like the temperature today, just wait, and it will change.

The purpose of the present study is to see what can be learned from long-time records taken at single stations, using a three-stage type of statistical analysis the second and third stages of which have not previously been applied to this kind of data. The particular series chosen is that of the daily maximum temperature, for which some of the longest reliable records are available. When the study was first started, the necessary computations had to be made by hand, but later high-speed computers became available, making possible the study of much longer records from data already available on punched cards. Before describing the method used, the limitations of two other methods which are often applied should be considered.

Fourier analysis is frequently used for records which vary over a certain range, but which have no tendency to continuously increase or decrease. There is plenty of geologic evidence of a long-time trend in the mean temperature, but if we limit "long-time" to a period of 100 or even 1000 years there is little reason to question the validity of Fourier analysis on this basis. (A careful watch on the long-time mean should be maintained, however, since it can be influenced by the addition of carbon dioxide from fossil fuels into the atmosphere, as well as whatever natural change may be in store for us). If the pattern of variation from the mean is strictly periodic, Fourier analysis is ideal, but if the duration and magnitude of the swings away from the mean differ from each other in a random manner, interpretation of the results becomes difficult. The coefficients of the corresponding series

terms determined for two such records of equal length will be different, even though the records are very long. If in every record analyzed, for a given station, the coefficient of the term corresponding to a certain frequency was large and nearly constant, we would suspect that there was some physical reason for the frequency. We would surely find a significant $365\frac{1}{4}$ day period in maximum daily temperatures, for example, but we could not assume that the coefficient for it would be the same in one record period as in another because of the effect of the non-periodic variations on its evaluation.

In his study of weather of the Northeast, Bingham (1963) carries the Fourier analysis out to no more than three terms, treating the remainder of the variation as randomly distributed according to normal error theory. Subject only to a presumably very slight inaccuracy due to the effect of the random variations on the Fourier coefficients determined, his report provides a valuable method of predicting the possible range of the important temperature statistics for any week of the year at any location in the Northeast. Something is lacking if prediction into the near future is desired. If we wish to predict the possible range of next week's weather, not that of a year from next week, we will surely want to take into account what the weather has been for the past few weeks, and how rapidly it may be expected to change. (It is assumed that our source of information is restricted to the location of our weather station).

A method that provides a way of taking this up-to-the minute information into account is known as the serial correlation method. The correlation coefficient between records separated by a time interval is determined as a function of the length of that interval. Then if we know today's maximum temperature, we can tell what the chances of tomorrow's maximum falling within various ranges will be. We can't be as definite about day after tomorrow's, and even less definite about the day after that. The method has nothing to say about the distant future. The assumption is made that as soon as the correlation coefficient goes to zero the values

separated by that time interval are completely independent. Often, however, it is found that the correlation coefficient dips below zero. This evidence of a cyclic tendency in the data, which means that measurement of the decay of dependency should be based upon the correlation ratio rather than the correlation coefficient, the use of which presupposes that the underlying relationship, upon which random fluctuations are imposed, is strictly linear. Actual use of the correlation ratio is prevented by lack of knowledge of the form of the underlying non-linear cyclic relationship.

The method applied in this study has little in common with the above methods. Its immediate goal is the establishment of a means of identification of quasi-periodic records. (Posey 1936, 1946, 1952) That is, we'd like to be able to say that one record is or is not "equivalent" to another. Not equivalent in the sense of geometrical congruence, but in that they must have been taken at the same location in the same manner, subject to the same kinds of periodic and non-periodic cyclic and non-cyclic variations about a common mean value. Thus the statistical measures to be determined might be likened to "fingerprints" of the time series, something from which it would surely be identified. Neither of the previously described methods of analysis has proved to be very useful for this purpose. Now there is no way to *prove* that the method of this study can accomplish this goal, short of application to a very large number of records from different situations.

DEFINITION OF THE THREE STATISTICAL MEASURES

The fluctuating quantity y is measured at regular constant intervals of time. (If y varies continuously with time, the interval between measurements should be short enough so that values linearly interpolated between the measured values will agree closely with the actual values.) If y is a discrete variable, the appropriate interval is of course that between adjacent values.

The first statistical measure of importance is the distribution of the values of y . This may be obtained either in frequency form, or preferably (for convenience of computation) in cumulative distribution form, giving the percent of time that y exceeds each value throughout its range. Let this distribution be designated as $C_d(y)$. If the values of y should prove to be normally distributed, the mean value and standard deviation would suffice to characterize

it. Experience with natural phenomena, however, indicates that distribution according to Gaussian law cannot be depended upon. At present we shall have to content ourselves with visual comparison of graphical plots of the cumulative distributions.

The second important statistical measure is the frequency distribution of values of the instantaneous rate of change of y . As a matter of practical computational procedure, it is approximated by the distribution of the differences between the consecutive values of y used in deriving the first measure. In cumulative distribution form it is designated $C_d(\Delta y)$. If the time series had no long-time trend and the values of Δy proved to be normally distributed, the standard deviation would suffice to characterize the distribution, since the mean would be zero.

The third important statistic is the distribution of the rate of change of the rate of change of y , which may be approximated by the distribution of the successive differences of the successive differences of y . In cumulative distribution form it may be designated $C_d(\Delta \Delta y)$.

The number of distributions could be carried further, to consider higher derivatives of the basic variable. The main reason for not doing so is that by the time that the rate of change (slope) and rate of change of rate of change (curvature) have been considered, it seems likely that the features of the variability of the series which might have important physical significance will have been inventoried with sufficient completeness. Another reason is that because of the approximation necessarily involved in measurement and computation, the relative accuracy of the higher derivatives becomes successively poorer.

A program which instructs an IBM 7040 digital computer to find the three distributions from data on punched cards is given in the Appendix.

TESTS OF THE VALIDITY OF THE PROPOSED MEASURES FOR DEFINITIVE IDENTIFICATION

If the fluctuating measurements at a fixed location in a basically unchanging physical situation are taken by an unvarying technique, if a sufficiently large number of cycles is included, and if there is no long-time trend, it is our assumption that the distributions of y , Δy , and $\Delta \Delta y$ for different portions of the record will be identical. This assumption cannot, of course, be proven, and it may be that

exceptions will be found. It is obviously correct for strictly periodic variations, one complete cycle being all that is necessary to characterize such a series. This property can be used to test equipment designed to evaluate the measures automatically. (Lonsdale, 1952). If a series is known to contain an appreciable component of variation having a fixed period the length of record chosen for analysis should contain an integral number of said periods, or else be so long that the effect of the values through one fractional period is inconsequential. Thus in all of the records subsequently analyzed, the periods correspond to numbers of calendar years, close enough to integral multiples of the true length of the year. The effect of lunar cycles is ignored as inconsequential, and that of sunspot cycles as small and not strictly periodic.

What about series lacking any definite periodic frequencies? How "equivalent" can the distributions from records of practical length be expected to be? How much, in comparison, will the distributions from different situations differ? Some evidence of favorable answers to these questions comes from applications of the $C_d(\Delta y)$ distribution to other problems. Ruhe (1950) found that it provided a reliable means of quickly identifying different areas of glaciation in Iowa from highway profile data alone. A comparable statistic, the mean square successive difference, was described by Von Neumann et al (1941). Liederman and Shapiro (1962) found this measure useful in the quantification of time-ordered data in physiological and psychological research. Incidentally, these investigations seem to indicate the effect of slow long-time trends of y on the $C_d(\Delta y)$ distribution is so small as to not interfere much with its usefulness for identification purposes.

It seems likely that for every different application it will be necessary to find out by trial how long a record must be taken for each C_d distribution to converge to a fixed curve characteristic of the series. At the present stage of investigation it seems sufficient to make a visual comparison in judging this. A more sophisticated criterion might be justified after more data have been analyzed.

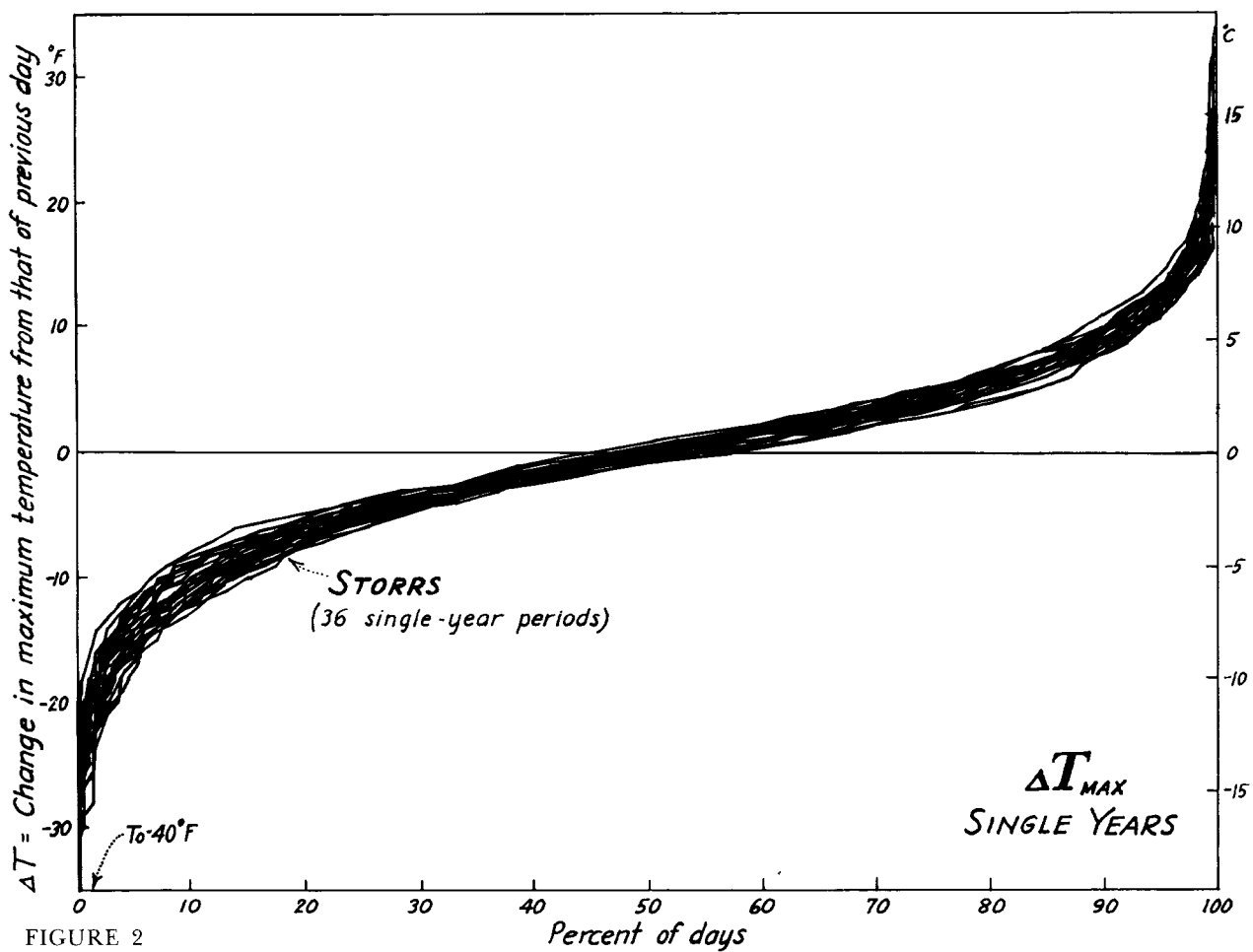
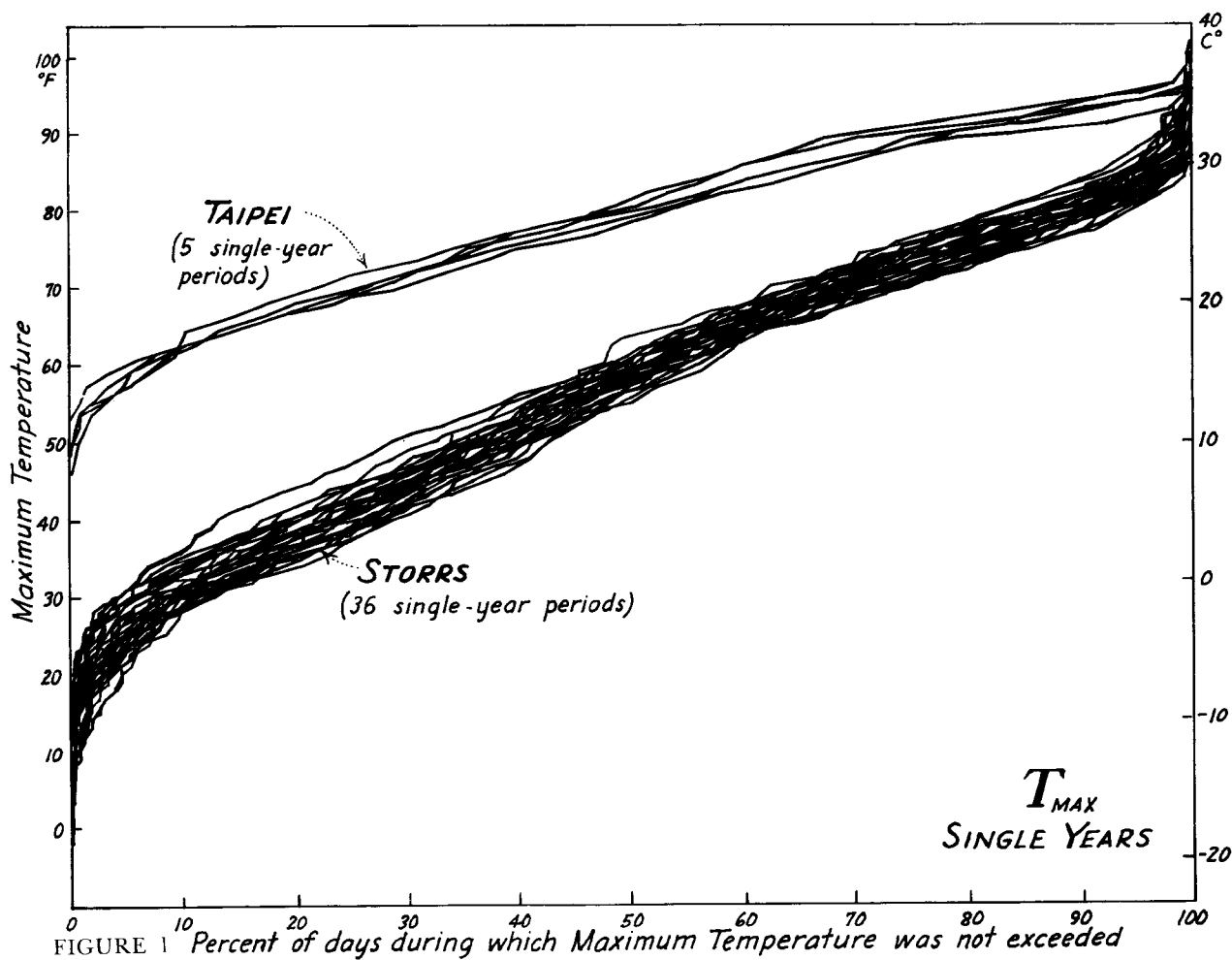
CONVERGENCE OF THE THREE DISTRIBUTIONS

Figure 1 shows curves representing the percentage

of days during which the indicated maximum daily temperatures at Storrs, Connecticut, and Taipei, Taiwan, were not exceeded. Each curve represents the distribution $C_d(T_{max})$ for a single year. The corresponding ΔT_{max} and $\Delta\Delta T_{max}$ distributions for the same single years are shown in Figures 2 and 3 respectively. (The curves for Taipei are not included on Figures 2 and 3 because they would overlap those from Storrs too much.) Notice that the dispersion of the $C_d(\Delta T_{max})$ curves of Fig. 2 is less than that of the $C_d(T_{max})$ and $C_d(\Delta\Delta T_{max})$ curves of Figures 1 and 3. One-year record periods are the minimum practicable because of the annual periodicity, but they are evidently far too short to yield equivalent or identical distributions.

Figures 4, 5, and 6 show C_d distributions with each line representing the accumulated values for a five-year period. It is evident that lengthening the period has brought the lines closer together. The distributions of the different five-year periods are not yet identical, but the fact that they are grouped more closely shows that there is a definite tendency for convergence as the length of period is increased. The lines representing the five-year Δy and $\Delta\Delta y$ distributions for Taipei can be shown on the same chart as those for Storrs, without too much overlap. Figures 7, 8, and 9 show curves for the distributions for longer periods at Storrs. Further convergence is evident in each case.

Since it was thought that the tendency toward convergence might have been due to the location of both of these stations near the ocean, a similar study was made of maximum daily temperature records from Burlington, Colorado, Elev. 4250, located on the plains some 150 miles east of the foothills of the Rocky Mountains, and Hayden, Colorado, Elev. 6300, in the Colorado mountains across the Continental Divide some 100 miles from the plains. The curves, covering periods of 4 and 14 years, are shown in Figs. 10-15. For both locations the distributions of T_{max} , ΔT_{max} , and $\Delta\Delta T_{max}$ converge as the length of period is increased. To provide most convincing evidence of the tendency toward convergence, it would be necessary to compare 36 single-year records, 36 five-year records, 36 ten-year records, etc. Data continuous over periods long enough to carry this comparison very far may not exist, since the temperature measuring stations are affected by man's alterations of the environment.



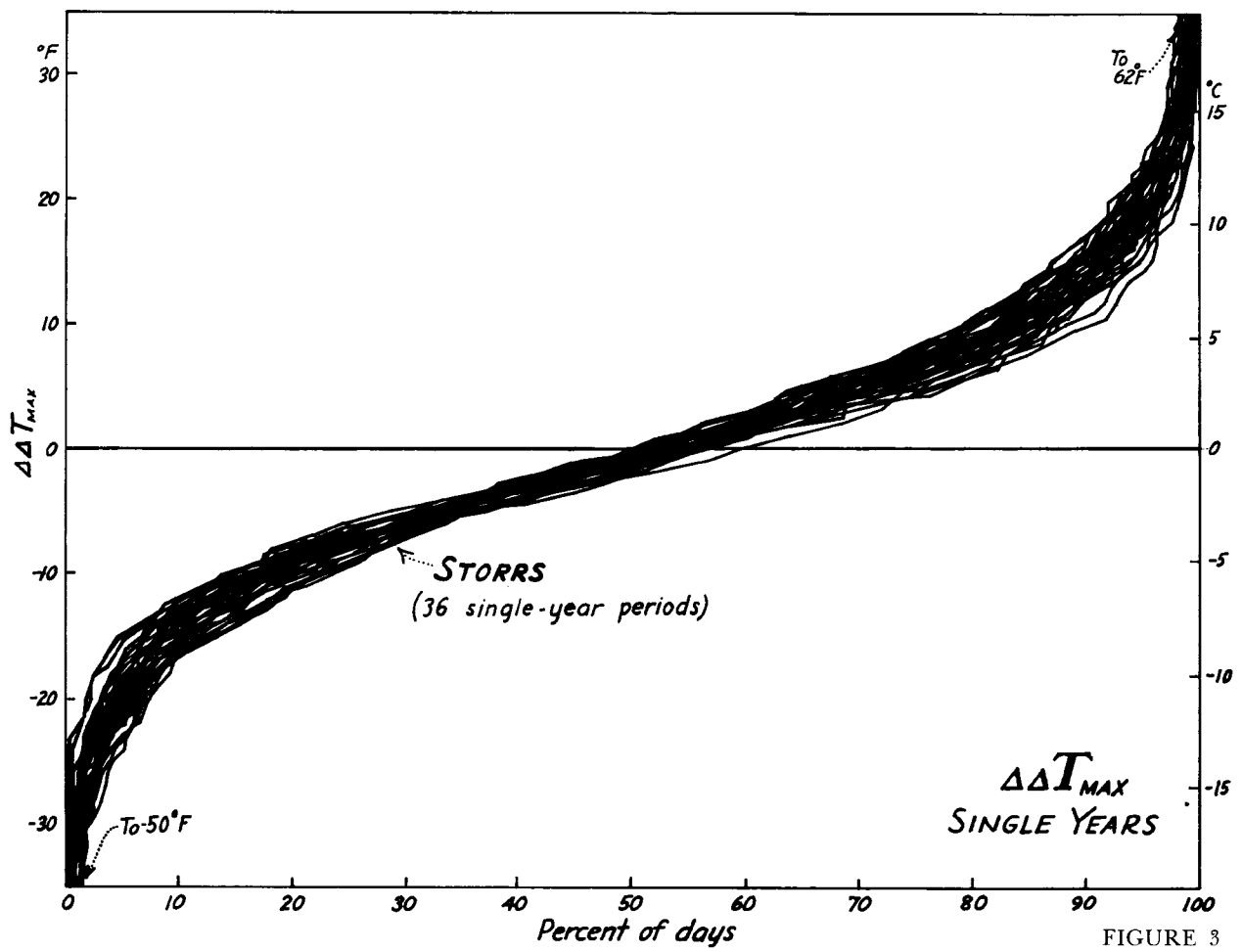


FIGURE 3

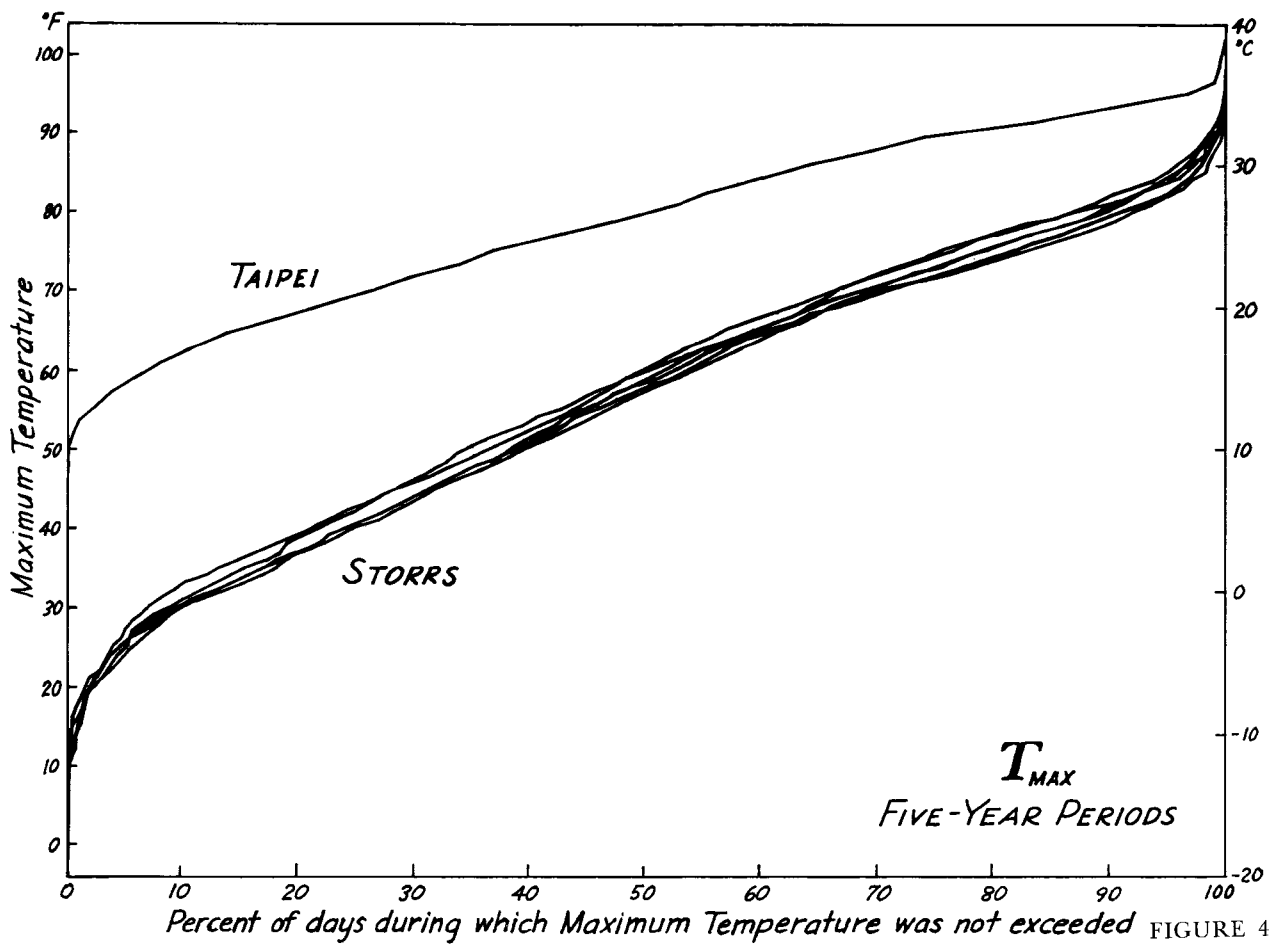


FIGURE 4

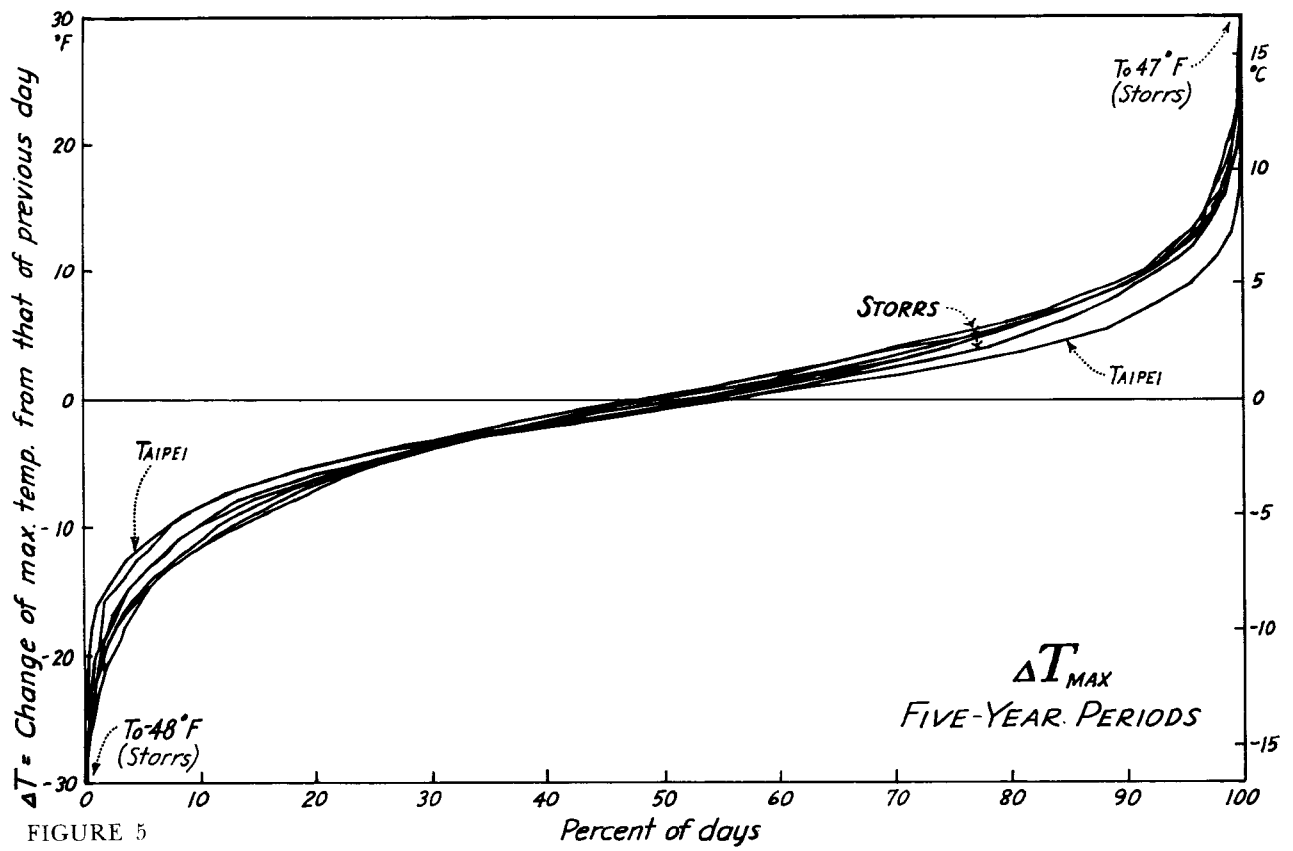


FIGURE 5

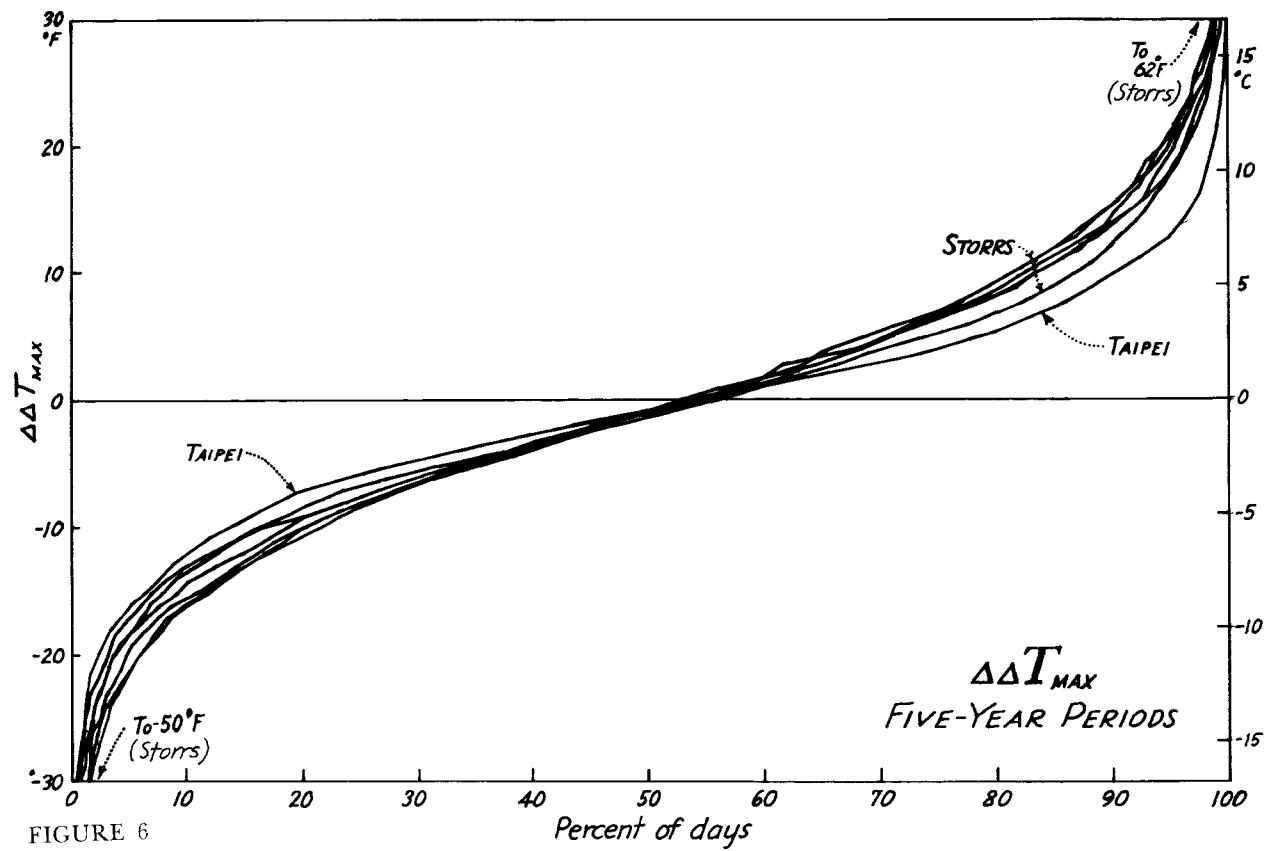


FIGURE 6

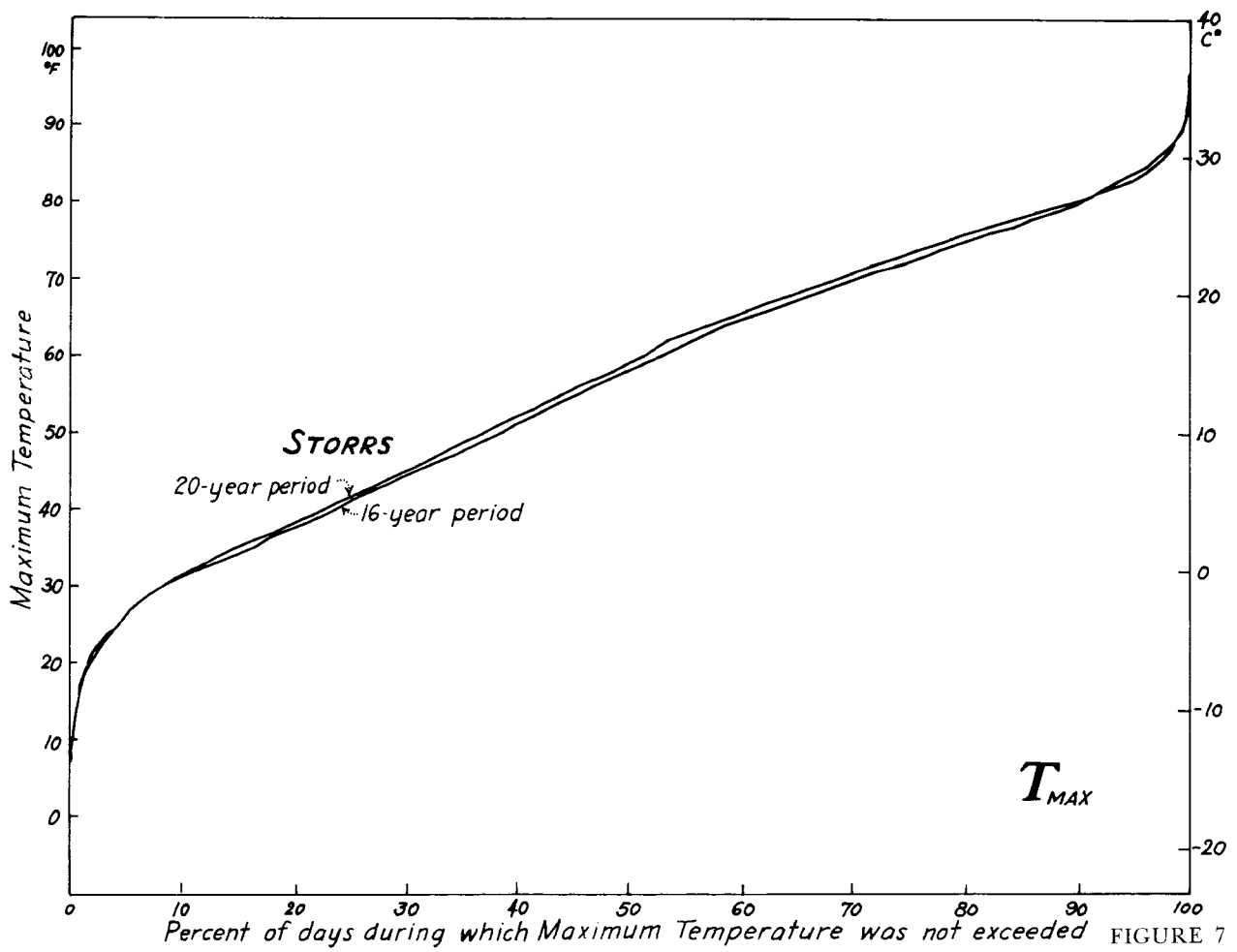


FIGURE 7

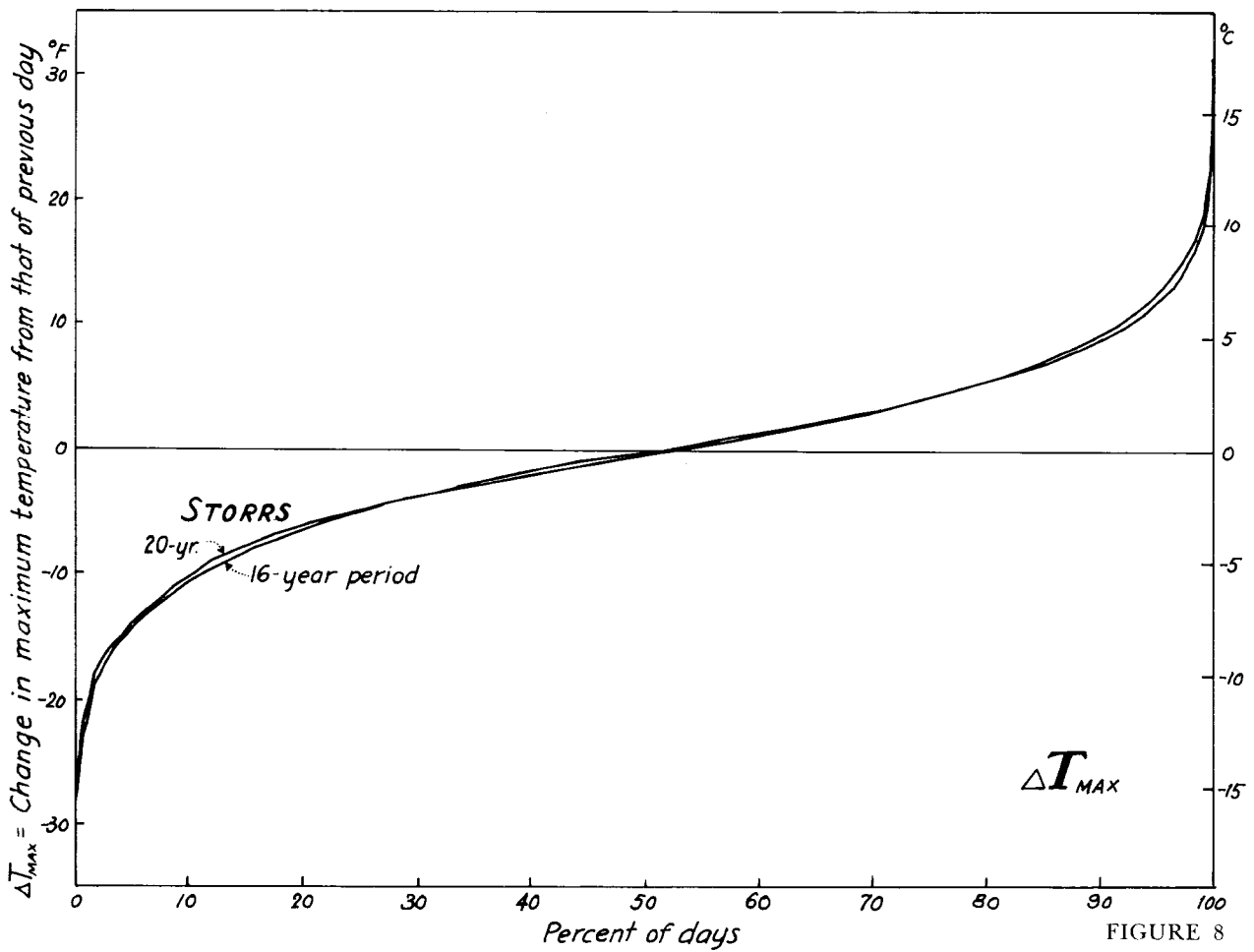


FIGURE 8

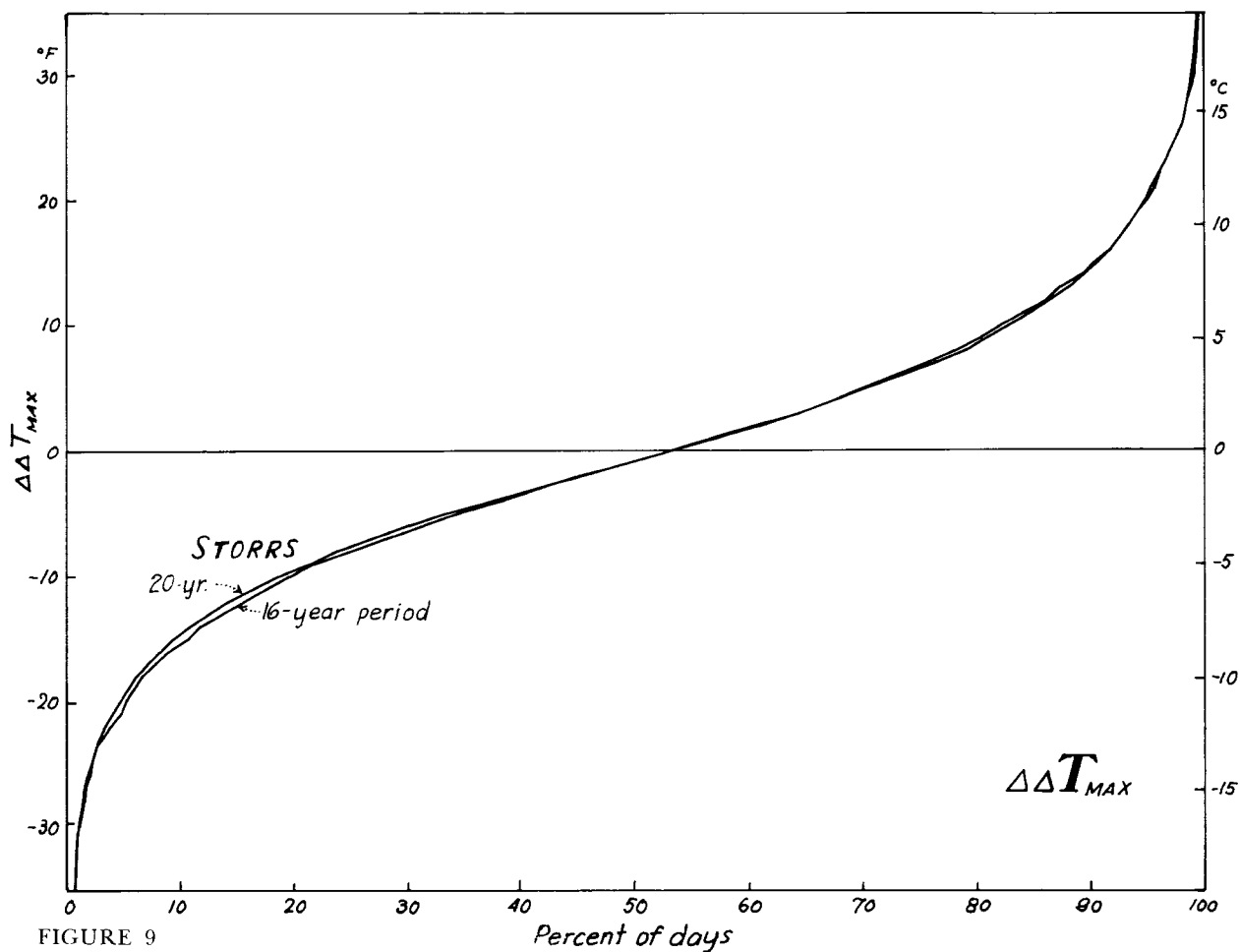


FIGURE 9

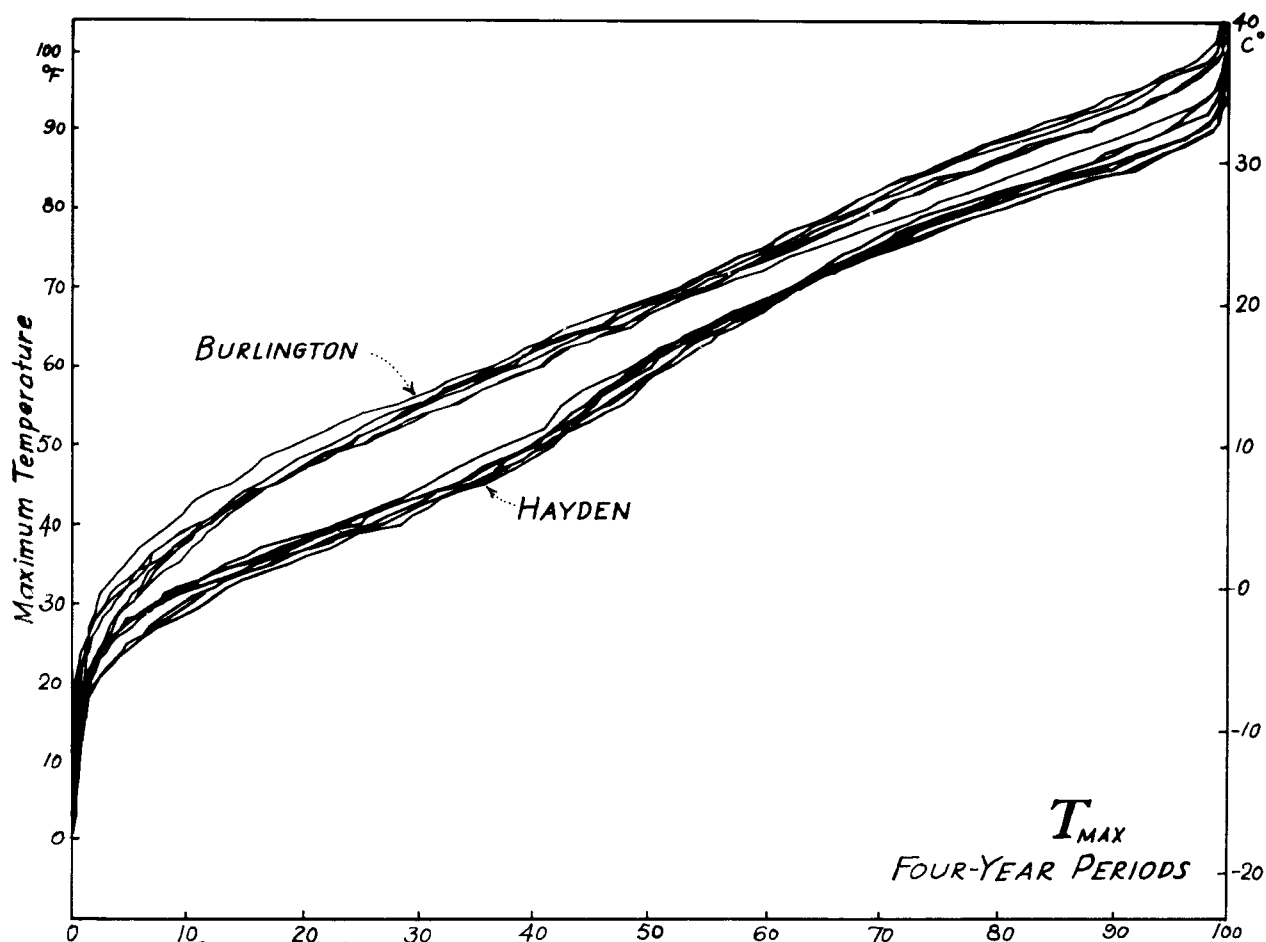


FIGURE 10 Percent of days during which Maximum Temperature was not exceeded

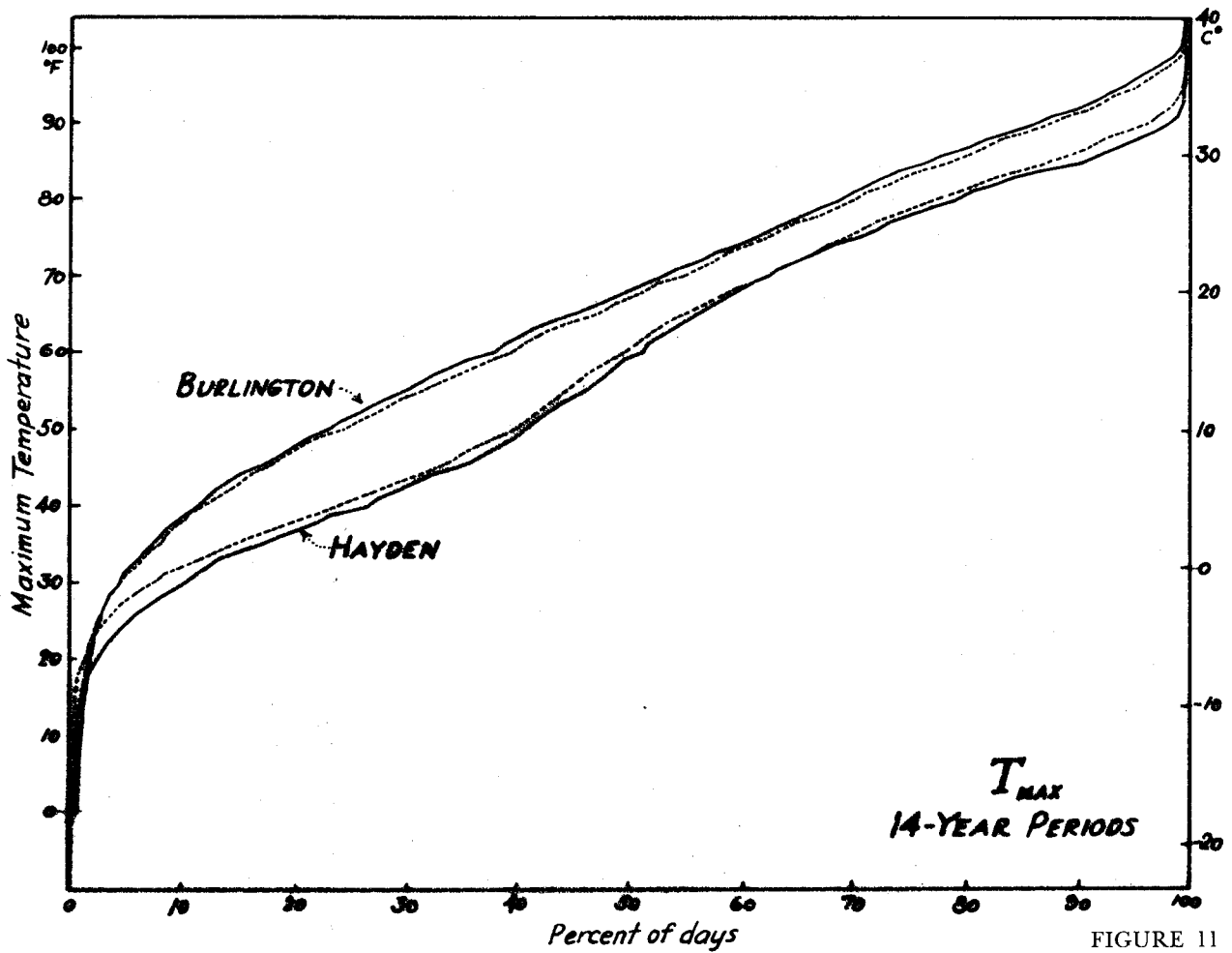


FIGURE 11

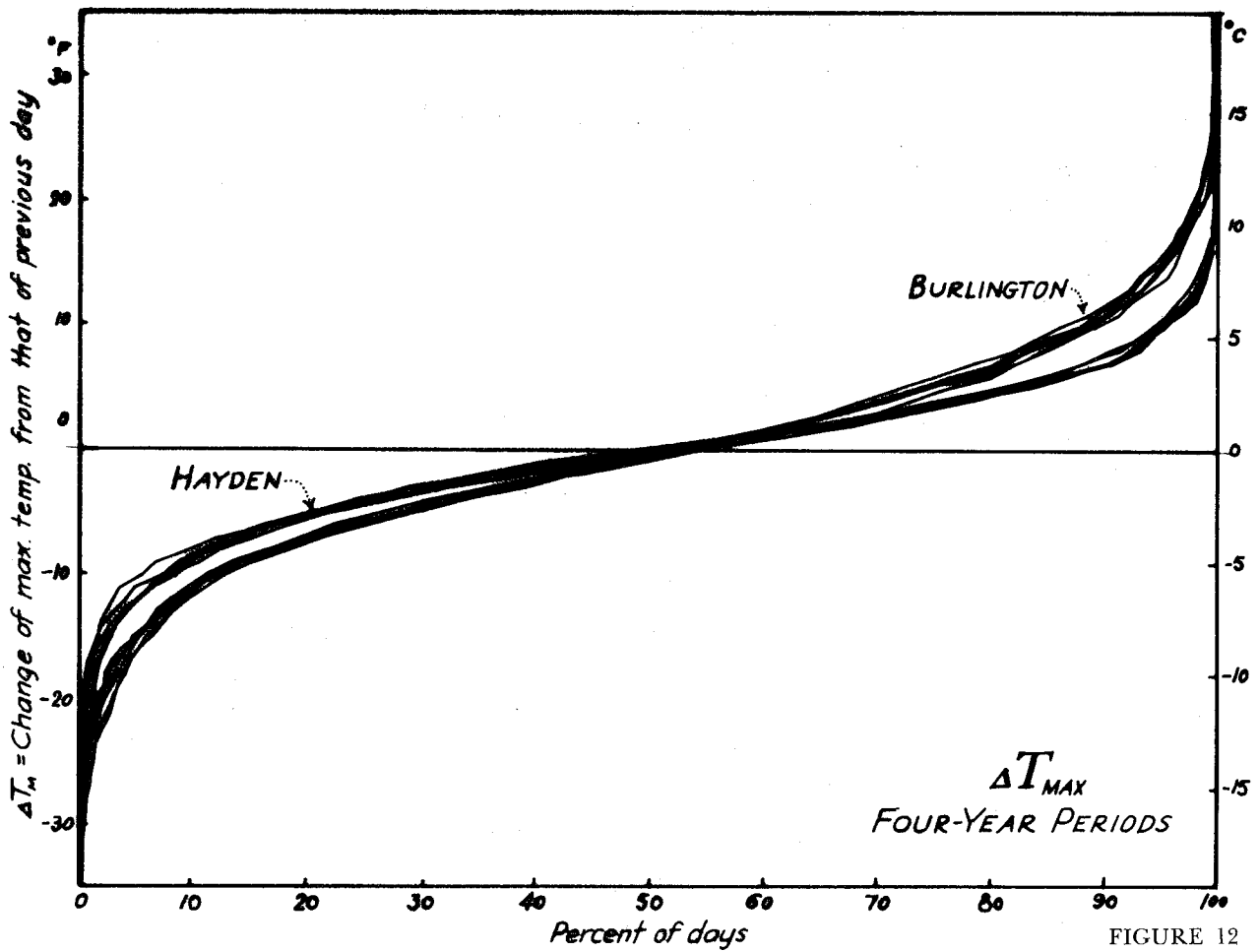


FIGURE 12

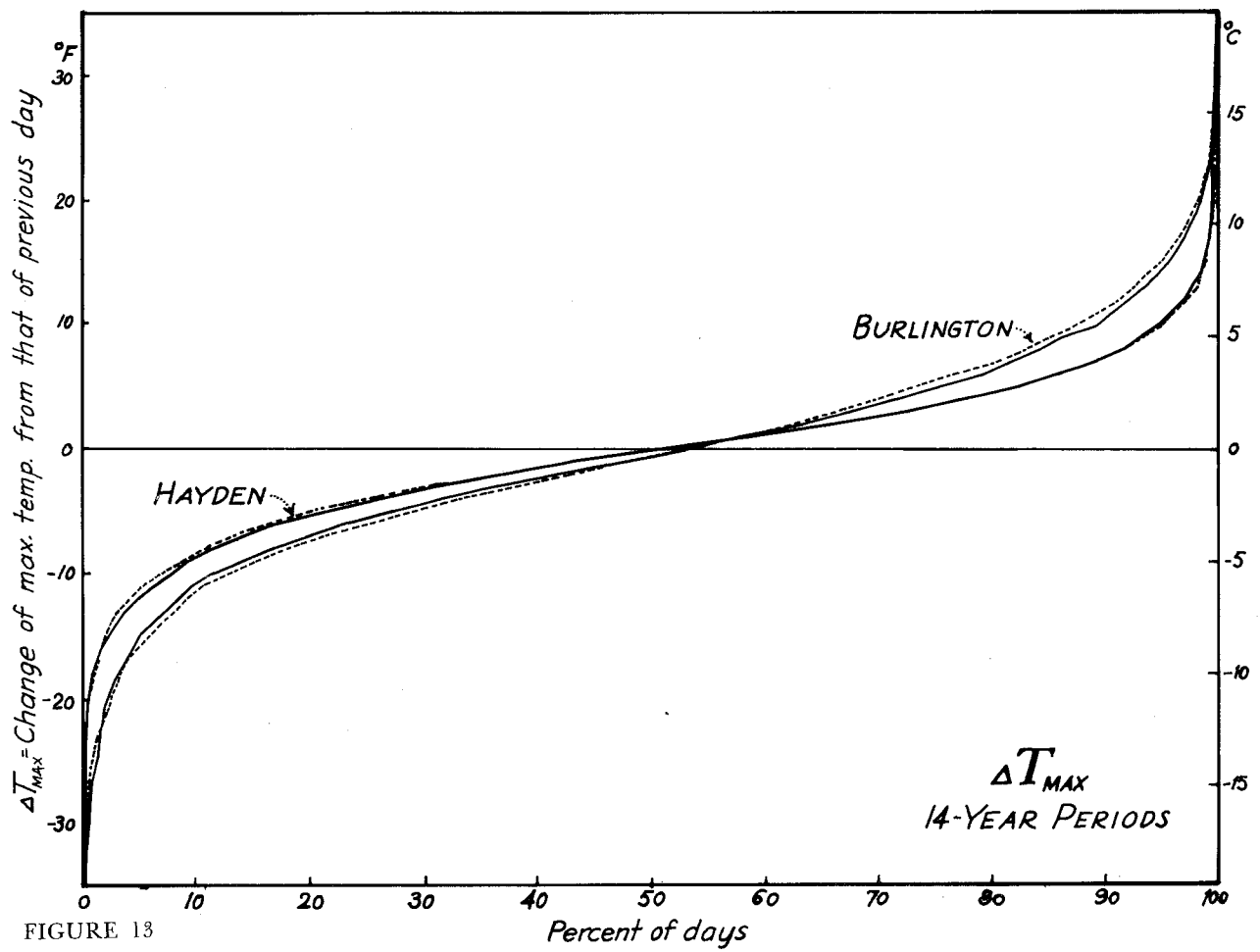


FIGURE 13

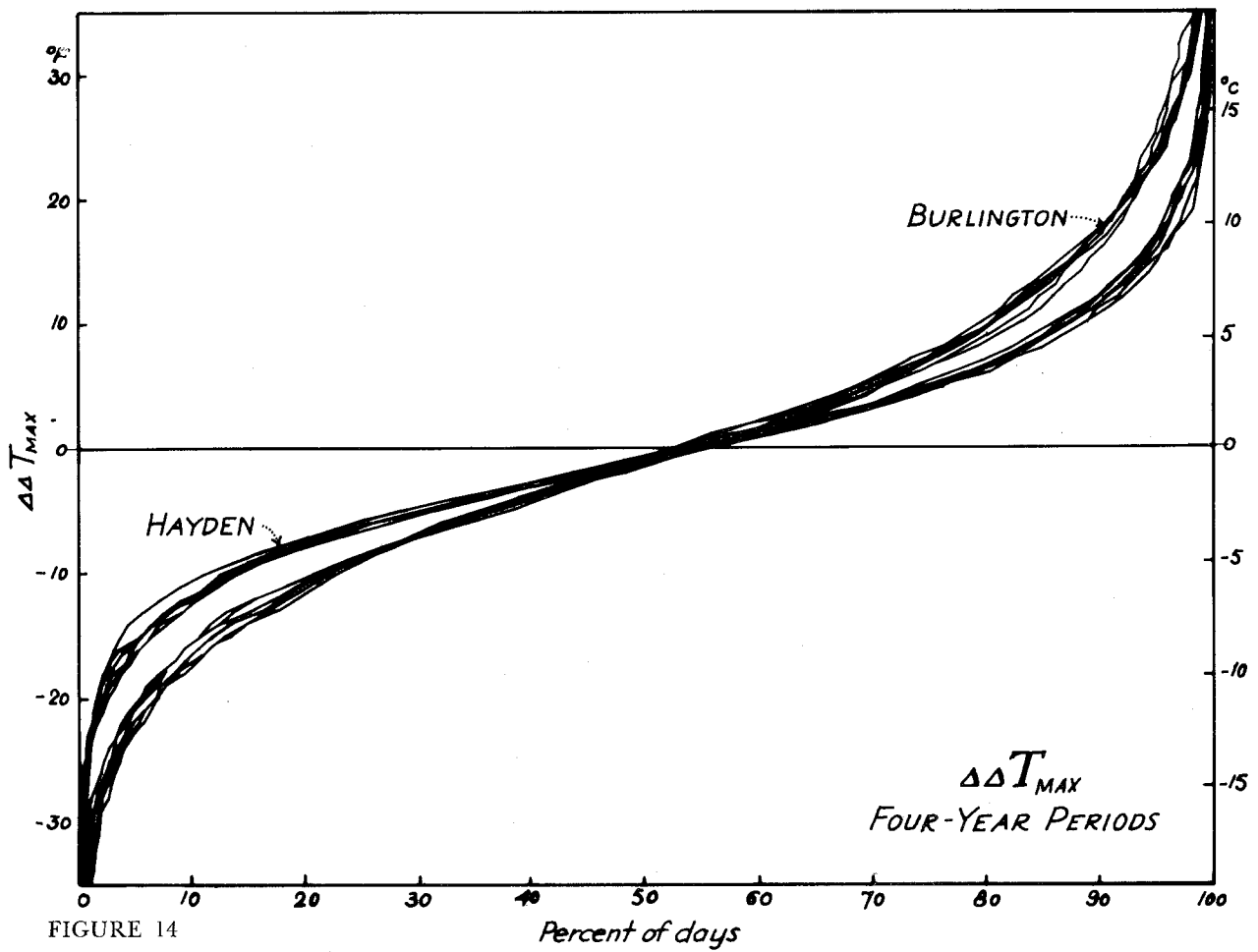


FIGURE 14

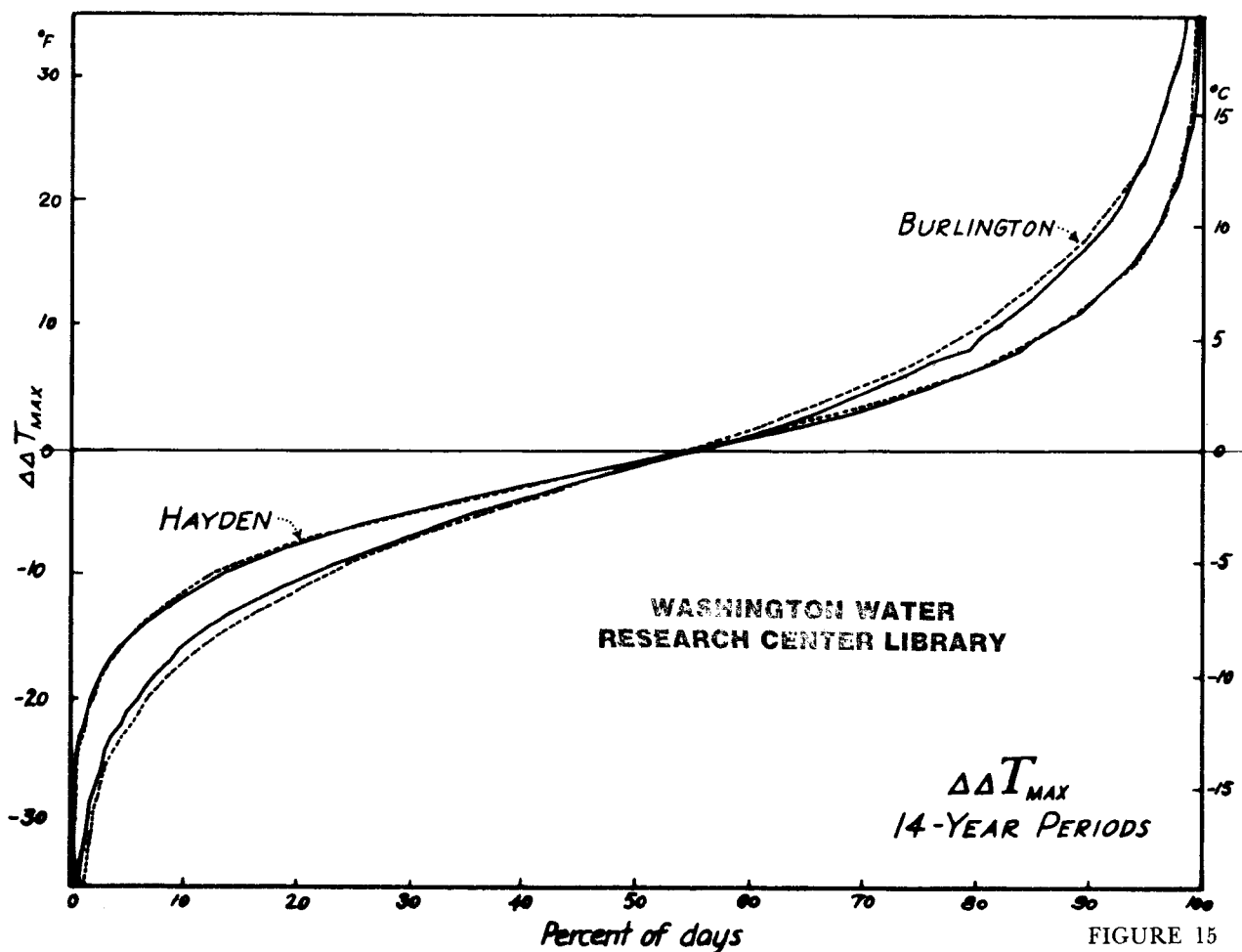


FIGURE 15

COMPARISON OF LONG-PERIOD RECORDS

Figs. 16, 17, and 18 permit comparison of the distributions of T_{max} , ΔT_{max} , and $\Delta\Delta T_{max}$ for three stations; Storrs, Connecticut, and Burlington and Hayden, Colorado. The curves for Storrs represent a total period of 36 years, while those for the two Colorado stations summarize the daily temperature maximums for 28 years. The curve for the 5-year period at Taipei has been included on Fig. 10, but the corresponding curves for Taipei are not shown on Figs. 17 and 18 since the 5-year record is too short to warrant its being placed in comparison with the other curves when the differences between curves are so small.

It seems evident from comparison of Figs. 16, 17, and 18 that the T_{max} distribution alone is sufficient to distinguish between these different maximum daily temperature records. This is to be expected because the periodic annual variation is strongly affected by location, and has the greatest influence on the T_{max} distribution. The differences between the different locations on Fig. 16 are greater than the

differences on Figs. 17 and 18. For this particular quasi-periodic time series, then, the $C_d(\gamma)$ distribution alone may be sufficient to establish identification. The T_{max} distribution is of incidental interest with regard to whether one would enjoy living in the particular locality. Most of us, however, would also like to see the T_{min} distribution, and for a really complete investigation, the distribution of hourly temperatures.

Fig. 16 reflects the seasonal variation well, but says little about how equable the day-by-day climate is. What are the chances that tomorrow's maximum will differ from today's by 5, 10 or more degrees? Fig. 17 gives us this information. It shows that as far as daily maximums go, Hayden has a more equable climate than Storrs, which in turn is more equable than Burlington. This is surprising, since it was originally thought that nearness to the ocean would be the biggest factor. Apparently the high elevation of Hayden, the surrounding high mountains, and frequent clear skies produce more uniformity than does proximity to the sea.

The ΔT_{max} distributions shown in Fig. 17 do not differ nearly as much, in comparison, as the T_{max} distributions. This is probably due to the fact that they are mostly the product of the great macro-turbulence of the atmosphere's cyclonic storms, which may be remarkably regular in their pattern of non-uniformity over much of the earth's surface. The comparison should be extended to include stations near the poles and nearer the equator.

The distributions of $\Delta\Delta T_{max}$, shown in Fig. 18, pertain to the changeability of the climate in a different way. How quickly do temperature trends reverse themselves? The three stations shown rank in the same relative order as before. One can sympathize with the residents of Burlington, in the middle of the bare plains, subject to easy attack by winds from every direction. Again, the distributions are surprisingly similar for the different locations, probably for the same reason.

FUTURE APPLICATIONS

Now that the computations necessary for the analysis of long time series by this method can be quickly made by the digital computer, the way is open to investigate many types of phenomena, such as the hourly temperatures previously mentioned, stream flows, etc. Perhaps the biggest difficulty is in obtaining reliable continuous records of sufficient length. The data must be on punched cards or tape, ready for the machine, and must not have any gaps.

GENERAL CONCLUSIONS

(1) Evidence is presented that the cumulative frequency distributions of daily maximum temperatures and of their first and second successive differences each tend to converge toward a fixed curve as the length of period is increased.

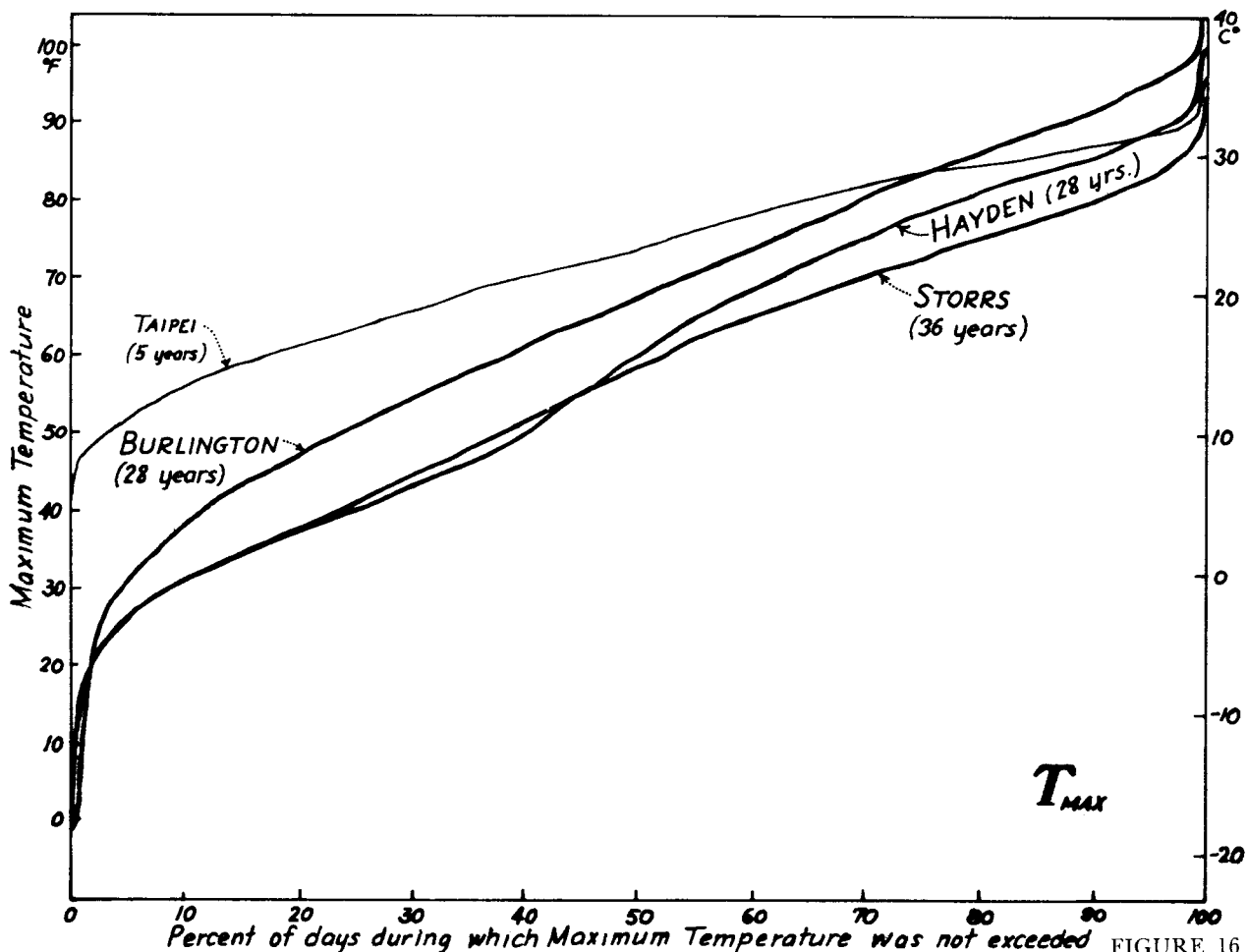


FIGURE 16

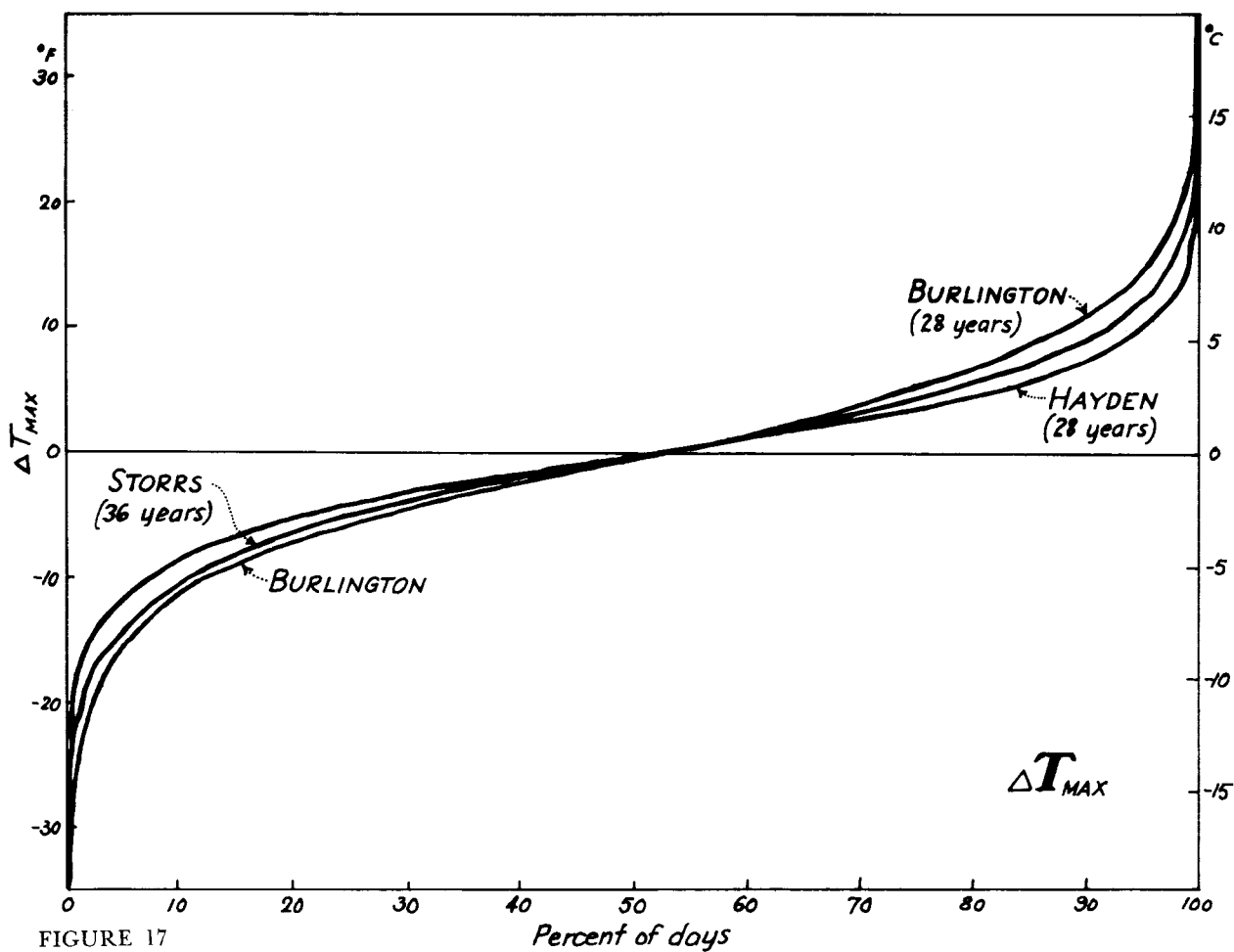


FIGURE 17

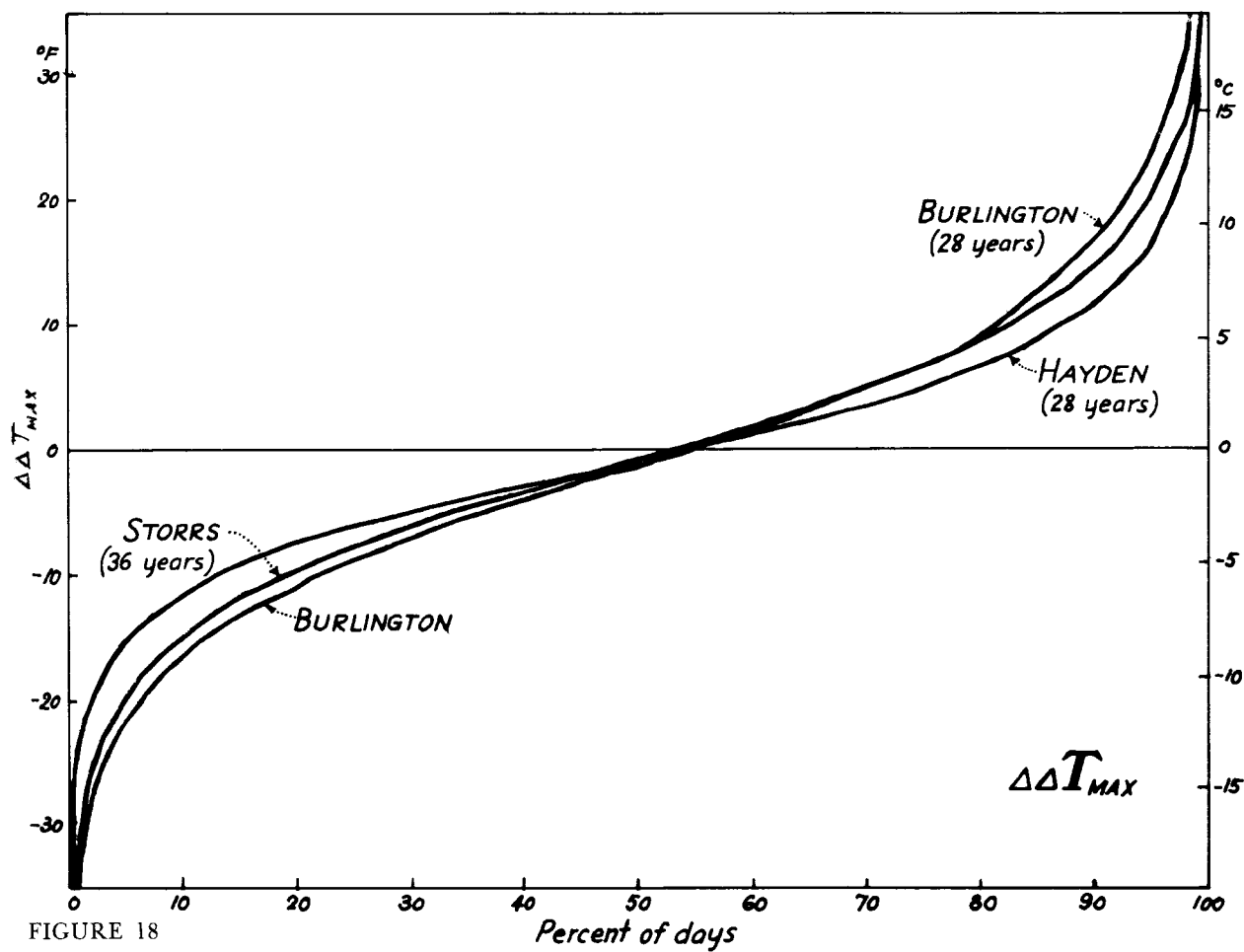


FIGURE 18

(2) The three cumulative frequency distributions obtained from daily maximum temperatures converged rapidly enough that curves from the different locations studied could be definitely distinguished, even though the length of period was as short as five years.

(3) The distributions of the first and second successive differences provide insight into the pattern of variability of the daily maximum temperature.

(4) The fact that the distributions of the first and second successive differences of daily maximum temperatures for the widely separated locations studied show more uniformity than the temperature distributions themselves suggests the possibility of a world-wide similarity in the atmospheric macro-turbulence that causes the quasi-random quasi-periodic fluctuations. This should be tested by including a comparison of records from oceanic equatorial and near-polar stations.

ACKNOWLEDGEMENTS

Initially, this study was supported by the Department of Civil Engineering of the University of Connecticut, with computer time provided by the University's Computer Center. The Water Resources Commission of the Republic of China assisted by analyzing the records from Taipei. A brief report was presented at the spring 1964 meeting of the American Geophysical Union. One of the anonymous reviewers of that report suggested that much more data were necessary to support the conclusions reached, and raised questions which showed the need of a more thorough explanation. Study was recommenced in 1965 as a project of the Connecticut Institute of Water Resources. The writer is indebted to many individuals, particularly to W. C. Kennard, J. J. Brumbach, Byron Janes, Joseph Breen, Bijoy Bhattacharya, W. B. Moeller, and Gerald Gromko, for assistance in various stages of the work.

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APPENDIX

Computer Program

by

Bijoy K. Bhattacharya

The program described here is for the purpose of obtaining cumulative frequency distributions of a large number of successive values of a quasi-periodic variable, and their first and second differences. As given, it is for the use in the IBM 7040 (FORTRAN IV). It could be modified for IBM 1620 (FORTRAN II). The latter, however, will take much more computing time.

In the present example the successive values are daily maximum temperatures, covering a period of 14 calendar years.

Let

N = Daily maximum temperature

L = Total number of days

$N(I)$ = Maximum temperature of the "I"th day (I varies from 1 to L according to the sequence of the dates.)

The first difference of the daily maximum temperature is

$$\text{NDEL}(I) = N(I+1) - N(I).$$

In the above equation I varies from 1 to $(L-1)$. In the program $(L-1)$ has been replaced by another variable "LP".

The second difference of the daily maximum temperature is

$$\text{NNDEL}(I) = N(I+2) - 2N(I+1) + N(I).$$

In this equation I varies from 1 to $(LP-1)$.

INPUT DATA FOR THE PROGRAM

First the machine will read the values of L , $M1$ and $M2$ where, L = total number of data (or days). ($M1$ and $M2$ will be discussed later.)

Then the machine will read the data N as $N(1)$, $N(2)$, $N(3)$ $N(L)$, according to the "FORMAT" specified. In this program the FORMAT used for the daily maximum temperature is (20I3).

A schematic view of the deck of input cards is shown in Figure 19.

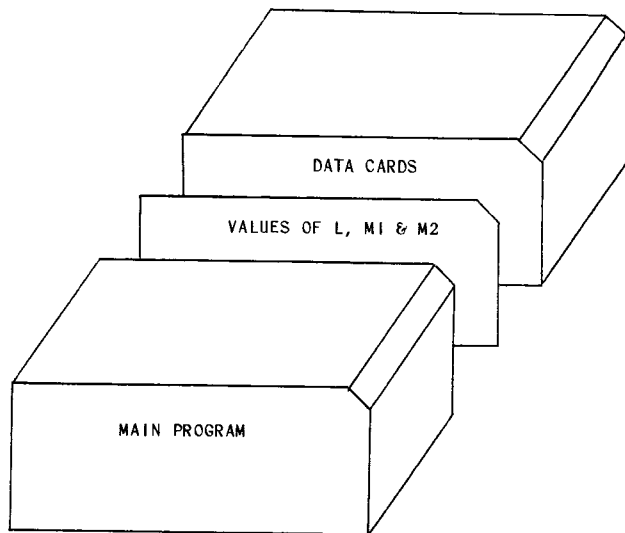


FIGURE 19 SCHEMATIC VIEW OF THE DECK OF INPUT CARDS

EXPLANATION OF THE STEPS OF COMPUTATIONS

1. The machine will first compute the first difference (Δ) as "NDEL" and the second difference ($\Delta\Delta$) as "NNDEL".
2. The machine will count the number of times each particular value occurs in the given set of data and it will also count the number of times each

particular value of the first and second difference occurs in the set of "NDEL" and "NNDEL", respectively.

3. Here the machine will compute the percentage of occurrence of:

- (a) each and every value in the set of "N"
- (b) each and every value of first difference in the set of "NDEL" already computed
- (c) each and every value of second difference in the set of "NNDEL" already computed.

VALUES OF "M1" AND "M2"

The values of $M1$ and $M2$ will depend upon the type of problem. The values of $M1$ and $M2$ indicate the range of numbers in which all the values of N , $NDEL$ and $NNDEL$ will lie.

For example if all the numbers lie between (-80) and (150) then

$$M1 = 150 + 81 = 231$$

$$M2 = 81$$

From the following two statements

$$\text{DO } 60 \text{ } K=1, M1$$

$$J(K) = K - M2$$

With the above values of $M1$ and $M2$ we find that:

$$J(K) = 1 - 81 = -80 \quad \text{when } K=1$$

$$J(K) = 231 - 81 = 150 \quad \text{when } K=231$$

That is the machine will compute the percentage of occurrence of N , $NDEL$ and $NNDEL$ in which all the values of N , $NDEL$ and $NNDEL$ lie between -80 and 150 .

Hence, the values of $M1$ and $M2$ are to be considered according to the type of problem.

The daily maximum temperatures of the following two stations will serve as an example:

1. Burlington — Daily maximum temperatures from 1932 to 1959
2. Hayden — Daily maximum temperatures from 1934 to 1961

In the case of Burlington the minimum temperature throughout the period as mentioned was -8°F and maximum temperature was 106°F . The values of $M1$ and $M2$ were taken as 251 and 81, respectively, to have a range of -80° to 170°F . The increased range is necessary to avoid the danger of getting a total of less than 100%. It has to go

far beyond the T_{max} range to take care of the $\Delta\Delta T_{max}$ range.

In the case of Hayden the minimum temperature throughout the period was -3°F and the maximum was 100°F . The values of M1 and M2 were taken as 231 and 81, respectively, to have a range of -80 to 150 .

So far, it has been found that the following relation avoids the danger of getting a total of less than 100% in any of the three distributions:

$$M1-M2 = \text{maximum value of the set of data}$$

Note that the "DIMENSION" statement in the program depends upon the type of the problem.

The dimensions of all subscripted variables are set according to the values of L, M1 and M2. There are four subscripted variables and the dimensions of them will be as follows:

N (value of L)

J (value of M1)

NDEL (value of L)

NNDEL (value of L)

For example, if $L = 1500$ and $M1 = 201$ then the dimension statement will be DIMENSION N(1500), J(201), NDEL(1500), NNDEL(1500).

Hence, we have the following input data cards after the "END" card of the main program.

1st DATA CARD — containing the values of L, M1 and M2 according to the FORMAT (316).

After the 1st card the rest of the cards will contain the data (e.g. Maximum temperatures, etc.) according to the FORMAT (2013) (or as required).

Note that this program is applicable only for data which are all integral values.

The main program with a sample output for the years 1948 — 1961 at Hayden is given in the following pages.

```

        DIMENSION N(5500),J(250),NDEL(5500),NNDEL(5500)
        READ (5,7) L,M1,M2
    7  FORMAT (3I6)
        READ (5,2) (N(I),I=1,L)
    2  FORMAT (20I3)
C     CALCULATION OF FIRST AND SECOND DIFFERENCES
        LP=L-1
        DO 8 I=1,LP
            NDEL (I)=N(I+1)-N(I)
            IF (I-LP) 9,8,8
    9  NNDEL(I)= N(I+2)-2*N(I+1)+N(I)
    8  CONTINUE
C     CALCULATIONS OF NUMBER OF OCCURRENCES
        KOUNT=0
        KNT=0
        KT=0
        WRITE (6,100)
    100 FORMAT (1X,51HTEMPERATURE PERCENTAGE PERCENTAGE PERCENTAGE)
        WRITE (6,101)
    101 FORMAT (4X,51HT(MAX) OF DAYS DURING OF DAYS WITH OF DAYS WITH)
        WRITE (6,102)
    102 FORMAT (12X,49HWHICH T(MAX) DELTA T(MAX) DELTA DELTA T(MAX))
        WRITE (6,103)
    103 FORMAT (12X,40HWAS NOT XEDED NOT XEDING NOT XEDING)
        WRITE (6,104)
    104 FORMAT (29X,25HGIVEN VALUE GIVEN VALUE)
        DO 60 K=1,M1
            J(K)=K-M2
            DO 55 I=1,L
                IF (J(K)-N(I)) 55,54,55
    54  KOUNT=KOUNT+1
    55  CONTINUE
            DO 5 I=1,LP
                IF (J(K)-NDEL(I)) 5,6,5
    6  KT=KT+1
    5  CONTINUE
            LPP=LP-1
            DO 12 I=1,LPP
                IF (J(K)-NNDEL(I)) 12,13,12
    13  KNT=KNT+1
    12  CONTINUE
C     CALCULATION OF PERCENTAGE OF OCCURRENCES
        A=KOUNT
        B=KT
        C=KNT
        D=L
        E=LP
        F=LPP
        X=(A/D)*100.
        Y=(B/E)*100.
        Z=(C/F)*100.
        WRITE (6,120) J(K),X,Y,Z
    120 FORMAT (1X,I10,5X,F10.5,5X,F10.5,5X,F10.5)
    60  CONTINUE
        STOP
        END

```

FIGURE 20 MAIN PROGRAM

TEMPERATURE T(MAX)	PERCENTAGE OF DAYS DURING WHICH T(MAX) WAS NOT XEDED	PERCENTAGE OF DAYS WITH DELTA T(MAX) NOT XEDING GIVEN VALUE	PERCENTAGE OF DAYS WITH DELTA DELTA T(MAX) NOT XEDING GIVEN VALUE
-80	0.000000	0.000000	0.000000
-79	0.000000	0.000000	0.000000
-78	0.000000	0.000000	0.000000
-77	0.000000	0.000000	0.000000
-76	0.000000	0.000000	0.000000
-63	0.000000	0.000000	0.000000
-62	0.000000	0.000000	0.000000
-61	0.000000	0.000000	0.01956
-60	0.000000	0.000000	0.01956
-59	0.000000	0.000000	0.01956
-58	0.000000	0.000000	0.01956
-57	0.000000	0.000000	0.01956
-56	0.000000	0.000000	0.01956
-43	0.000000	0.000000	0.01956
-42	0.000000	0.01956	0.01956
-41	0.000000	0.01956	0.01956
-40	0.000000	0.01956	0.01956
-39	0.000000	0.01956	0.01956
-38	0.000000	0.03912	0.01956
-37	0.000000	0.03912	0.03912
-36	0.000000	0.03912	0.03912
-5	0.000000	21.31821	29.55790
-4	0.000000	25.93389	34.13537
-3	0.01955	30.80383	39.06494
-2	0.01955	36.88637	44.54225
-1	0.01955	43.61432	49.68701
0	0.05866	51.33972	54.83177
1	0.05866	59.12380	59.93740
2	0.09777	66.28203	64.78873
3	0.13688	73.02953	68.95540
4	0.15643	78.17328	72.84820
25	5.10364	99.94133	98.96322
26	5.80759	99.96088	99.11972
27	6.80485	99.98044	99.31534
28	7.93899	99.98044	99.45227
29	9.07313	100.00000	99.51095
30	10.26594	100.00000	99.66745
95	99.94134	100.00000	100.00000
96	99.94134	100.00000	100.00000
97	99.98044	100.00000	100.00000
98	99.98044	100.00000	100.00000
99	99.98044	100.00000	100.00000
100	100.00000	100.00000	100.00000
101	100.00000	100.00000	100.00000
102	100.00000	100.00000	100.00000

Fig. 21 Print-out. Record from Hayden, Colorado
(1948-1961, condensed to single page by omitting 166 lines)