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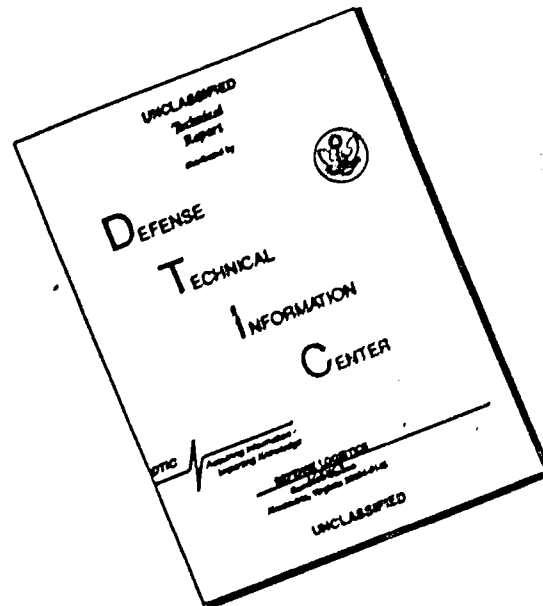
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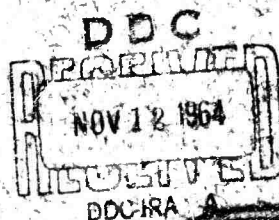


TECHNICAL REPORT

ES-13

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**A METHOD FOR PREDICTING THE PROBABLE FREQUENCY
OF OCCURRENCE OF DAILY MAXIMUM TEMPERATURES
FROM SUMMARIZED DATA**



EARTH SCIENCES DIVISION



AUGUST 1964

NATICK, MASSACHUSETTS

AD- DIV. 2:7 Accession No. U. S. Army Natick Laboratories, Natick, Mass. A METHOD FOR PREDICTING THE PROBABLE FREQUENCY OF OCCURRENCE OF DAILY MAXIMUM TEMPERATURES FROM SUMMARIZED DATA by Earl E. Lackey, August 1964, 41 pp., illus. (Technical Report ES-13). The frequency and distribution of daily maximum temperatures for any given "summer" month (May-September in northern hemisphere) may be predicted with a considerable degree of confidence when only summarized data are available by use of a multiple nomograph. The nomograph and associated table represent 45 converted mean daily maximum temperatures, having values from 36 to 80, each of which is associated with a unique numerical pattern of converted predictive temperature values. The converted mean daily maximum temperature may be computed from the following four items usually found in climatic summaries: (1) the absolute maximum (2) the mean daily maximum (3) the mean daily minimum (4) the length of record Values on the nomograph have been determined by a detailed study of the frequency occurrence of daily maxima through a 10-year period for May, July and September at twelve representative stations. The method readily lends itself to machine processing. At the end of the report is an extra copy of both the nomograph and the associated table, for easy withdrawal and use in doing prediction problems. AD- DIV. 2:7 Accession No.	UNCLASSIFIED 1. Atmospheric temperature 2. Meteorological parameters 3. Nomographs 4. Diurnal variation 5. Probability 6. Periodic variations I. Lackey, Earl E. II. Title III. Series	AD- DIV. 2:7 Accession No. U. S. Army Natick Laboratories, Natick, Mass. A METHOD FOR PREDICTING THE PROBABLE FREQUENCY OF OCCURRENCE OF DAILY MAXIMUM TEMPERATURES FROM SUMMARIZED DATA by Earl E. Lackey, August 1964, 41 pp., illus. (Technical Report ES-13). The frequency and distribution of daily maximum temperatures for any given "summer" month (May-September in northern hemisphere) may be predicted with a considerable degree of confidence when only summarized data are available by use of a multiple nomograph. The nomograph and associated table represent 45 converted mean daily maximum temperatures, having values from 36 to 80, each of which is associated with a unique numerical pattern of converted predictive temperature values. The converted mean daily maximum temperature may be computed from the following four items usually found in climatic summaries: (1) the absolute maximum (2) the mean daily maximum (3) the mean daily minimum (4) the length of record Values on the nomograph have been determined by a detailed study of the frequency occurrence of daily maxima through a 10-year period for May, July and September at twelve representative stations. The method readily lends itself to machine processing. At the end of the report is an extra copy of both the nomograph and the associated table, for easy withdrawal and use in doing prediction problems. AD- DIV. 2:7 Accession No.	UNCLASSIFIED 1. Atmospheric temperature 2. Meteorological parameters 3. Nomographs 4. Diurnal variation 5. Probability 6. Periodic variations I. Lackey, Earl E. II. Title III. Series
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⑤ ARMY NATICK LABORATORIES,
Massachusetts

EARTH SCIENCES DIVISION

Technical Report
ES-13

⑥

A METHOD FOR PREDICTING THE PROBABLE FREQUENCY OF
OCCURRENCE OF DAILY MAXIMUM TEMPERATURES
FROM SUMMARIZED DATA,

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⑩
Phy Earl E. Lackey,
General Environments Laboratory

Project Reference:
1K025001A129

August 1964

FOREWORD

Activities and efficiency of Army personnel and the adequacy of Army materiel are often conditioned by the maximum ambient temperatures that may be encountered. In general, it is not enough to know the absolute maximum that has occurred through a series of years. It is more significant to know how frequently given critically high temperatures may be expected. Since daily high temperature frequency tabulations are not as a rule available, it is desirable to devise a method for predicting these high temperature frequencies from available temperature summaries. The following study presents a method whereby the frequency of specified high temperatures may be predicted with considerable confidence when the only temperature items available are: (1) the absolute maximum temperature, (2) the mean daily maximum, (3) the mean daily minimum, and (4) the length of record.

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ABSTRACT

The frequency and distribution of daily maximum temperatures for any given "summer" month (May-September in northern hemisphere) may be predicted with a considerable degree of confidence when only summarized data are available by use of a multiple nomograph. The nomograph and associated table represent 45 converted mean daily maximum temperatures, having values from 36 to 80, each of which is associated with a unique numerical pattern of converted predictive temperature values. The converted mean daily maximum temperature may be computed from the following four items usually found in climatic summaries:

- (1) the absolute maximum,
- (2) the mean daily maximum,
- (3) the mean daily minimum,
- (4) the length of record.

Values on the nomograph have been determined by a detailed study of the frequency occurrence of daily maxima through a 10-year period for May, July and September at twelve representative stations. The method readily lends itself to machine processing.

At the end of the report is an extra copy of both the nomograph and the associated table, for easy withdrawal and use in doing prediction problems.

A METHOD FOR PREDICTING THE PROBABLE FREQUENCY OF OCCURRENCE
OF DAILY MAXIMUM TEMPERATURES FROM SUMMARIZED DATA

Introduction

A method is presented here for predicting daily maximum temperature and frequencies for any given summer month from four items of summarized data, namely:

the absolute maximum (AbMx)* for the month
the mean daily maximum (NDMx)
the mean daily minimum (NDMI)
the length of the record.

The uniqueness of the method is the way in which four items in a summary record may be used to reveal the pattern of asymmetry of the frequency and distribution of daily maximum temperatures for any given warm-season month (Fig. 2 and Table III). The method does not require the use of mathematical models, but depends upon forty-five frequency patterns, determined empirically, each of which is identified by the asymmetrical position of the mean daily maximum (NDMx) between the absolute maximum (AbMx), and the mean daily minimum (NDMI) when the temperatures are all converted to a 100-unit scale.**

PART I - COVERAGE AND PROCESSING

1. Records used - area and time coverage

For purposes of this study, the daily maximum temperatures (DMx) for three "summer"*** months (May, July and September, 1946-1955) from twelve representative weather stations in the United States underscored in Figure 1 were used -- 36 records in all. Temperature data from the underscored stations were frequency tabulated by the U.S. Air Weather Service, Data Control Unit. The records from the other stations marked in Figure 1 were used to test the reliability of the method.

*See Abbreviations and Glossary, Appendix A.

**Conversion to the 100-unit scale is explained in connection with Table I. Also see references 4 and 5.

***In this report a "summer month" is considered one of the 5 or 6 warm months of the year. Also, all temperatures are in Fahrenheit.

LOCATION OF STATIONS USED IN CONSTRUCTING AND TESTING THE MULTIPLE NOMOGRAPH

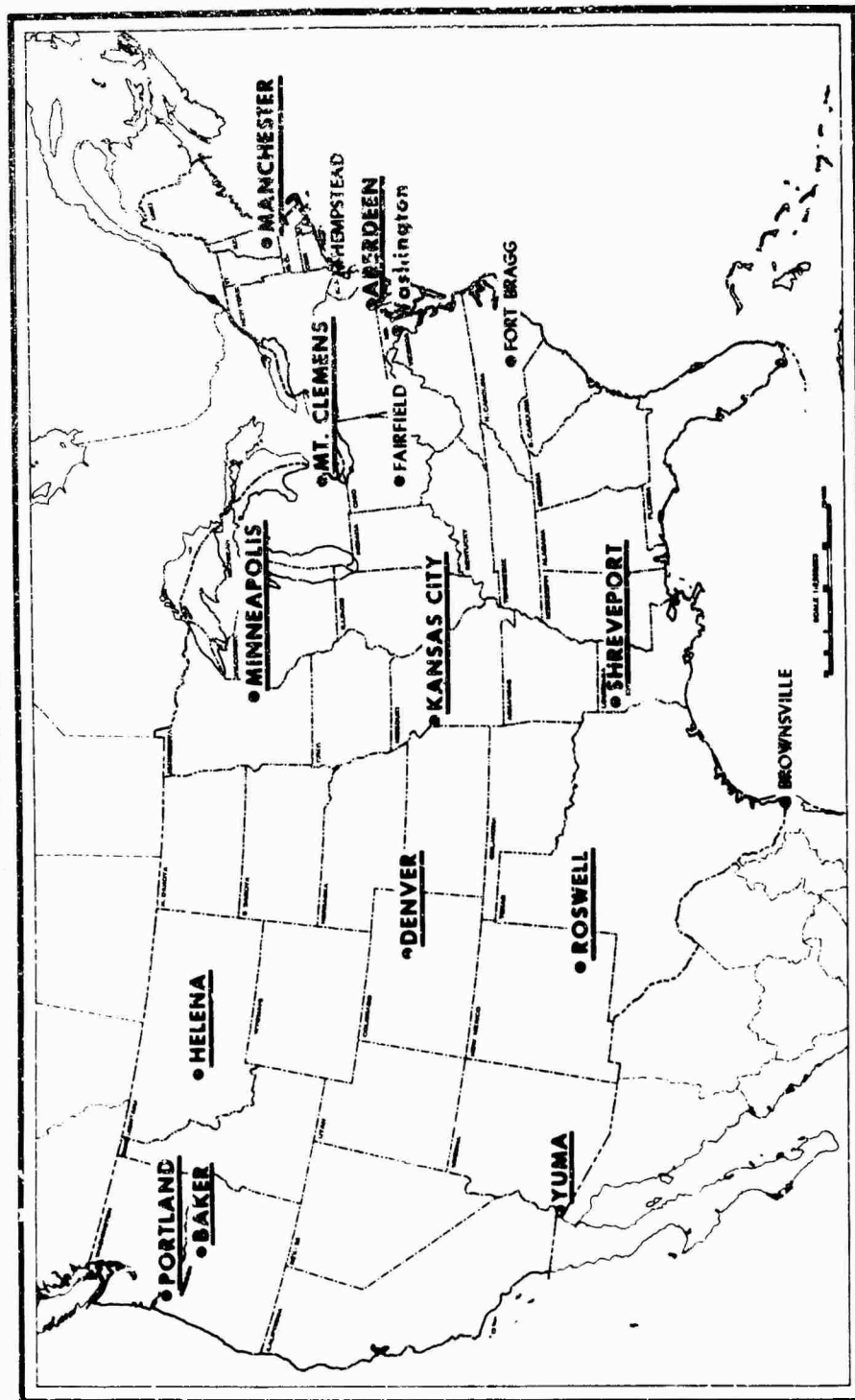


Figure 1

2. Compiling and tabulating the data

The tabulated data for the 36 months were assembled into tables similar to the one for May at Aberdeen, Maryland, Table I. It should be noted that the Essential Temperature Data in columns 1, 2, and 3, line c (95°F, 74°F and 53°F) are the only temperatures needed to assess the probable temperature that will be equalled or exceeded through the indicated number of years up to 100.

However, the Frequency Data on the same line (83 F, 85 F, etc., to 95 F) for 36 months at the other stations (3 different months, 12 stations) were needed to construct the nomographic device featured in this study. An understanding of Table I can greatly help in the discussion that follows.

3. Converting conventional data to the 100-unit scale

Conventional temperature values (Fahrenheit or centigrade)* cannot be used directly on the nomograph. It is adapted only to the use of "converted" values, that is, values that have been changed from conventional measures (Fahrenheit or centigrade) to a 100-unit scale. The predicting is done in converted scale values, which are then converted back to conventional (F. or C.) measures. For example, the Essential Data for Aberdeen, Maryland, were assembled as given in Table I, columns 1, 2, 3, line c. Essential Data are:

- (1) 10-year Absolute Maximum (AbMx) 95°F
10-year Mean Daily Maximum (MDMx) 74°F
10-year Mean Daily Minimum (MDMI) 53°F

(2) Under Frequency Data (line c, columns 5 - 10) are given the 10-year frequency occurrence of daily maxima (°F) for six different time intervals, e.g.,

83°F	daily maxima	occurred	an	average	of	5	days	in	every	May	(5/31)
85°F	"	"	"	"	"	3	"	"	"	"	(3/31)
89°F	"	"	"	"	"	1	day	"	"	"	(1/31)
93°F	"	"	"	"	"	1	"	"	3	Mays	(1/93)
94°F	"	"	"	"	"	1	"	"	5	Mays	(1/155)
95°F	"	"	"	"	"	1	"	"	10	Mays	(1/310)

*Note: Fahrenheit values are used exclusively in the problems in this report.

TABLE I. ABERDEEN, MARYLAND, MAY: SAMPLE OF THE PROCEDURE IN CONSTRUCTING A MULTIPLE MONOGRAPH FOR PREDICTING THE FREQUENCY AND LEVELS OF DAILY MAXIMUM TEMPERATURES. (See Appendix A for glossary and abbreviations)

Nature of Items	Essential Data (10-Yr Record)		Frequency Data (10-Yr Record)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Records: Temps °F	95 AbMx	74 MDMx	53 MMH	a	5/31 16.1%	3/31 9.7%	1/31 3.2%	1/93 1.1%	1/155 .64%	1/310 .32%
Subtract MDM (53°F)	53	53	53	b						
Reduced Temps (RFT)	42	21	0	c	83	85	89	93	94	95
Line c minus MDM (53)	RABMx	RMDMx	RMDM	d	53	53	53	53	53	53
Converted Temps (CFT)	100	50*	0	e	30	32	36	40	41	42
100-Unit Scale	CABMx	CMOMx	CMOM	f	71	76	86*	95	98	100
Predicted Temps Using Table III or Monograph				g	83	86	90	92	93	95
(Columns)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Explanation

- Line a. Ratio of temperature of given number of days to total days involved, e.g., 5/31, or 5 May days in 31 (1 month)
- b. Temperature of given number of days as a percentage of total days involved, e.g., 5/31 = 16.1% of the total
- c. Actual maximum temperature converted to 100-unit scale. Values in a multiplied by 100; divided by RABMx (42).
- d. Subtract MDM (53°F) for purposes of conversion.
- e. Reduced temperatures (c - d).
- f. Reduced temperatures converted to 100-unit scale. Values in a multiplied by 100; divided by RABMx (42).
- g. Temperatures in line f were predicted later by use of the Monograph, Basic Section.

Comment: 35 other records (12 stations, 3 different months) were processed in like manner. The ratios in line a above are averages reduced from the 10-year record, e.g., 50/310-5/31, 30/310-3/31, 10/310-1/31, etc. *CMOMx 50 and CFT 86 are listed in Table II (Aberdeen, May) along with 35 other paired values, and plotted on Fig. 2 (see stars) to construct the 1/31 predictive curve. Values in line f are Converted Frequency Temperatures (CFT) and become CFT values when generalized on the monograph.

The Aberdeen record (in line c Table I.) was converted to a 100-unit scale as follows:

(1) Reduce each value in line c by subtracting from it the MDM, 53°F (line d). Thus in line e -

the Reduced AbMx becomes	42°F
" " MDM	21°F
" " MDM	0°F

(2) In order to convert to the 100-unit scale (line f), the reduced AbMx (42°F) or temperature range between the MDM and AbMx, is changed to 100 and the MDM (col. 3) becomes zero (0).

Now where do each of the other items (columns 5 through 10) in line e fit into the 100-unit scale? Multiply each by 100 and divide by 42. (Conversion formula: multiply by 100 and divide by the reduced AbMx.) Thus each Fahrenheit temperature in line e is proportional to its corresponding converted value (CFT) in the 100-unit scale in line f.

It should be noted here that CMDMx 50 (Column 2) is the key to the frequency distribution (converted scale) of daily maximum temperatures in May at Aberdeen, Maryland. However, it was found that from station to station and month to month the asymmetrical (skewed) position of the CMDMx ranges widely, in fact from 38 (Minneapolis in May) to 75 (Yuma in September) on the 100-unit scale (Table II, the two underscored CMDMx's).^{*} In other words, the position of the CMDMx's between 0 and 100 on the converted scale is the measure of the asymmetry and furnishes the pattern of the distribution of daily maximum temperatures between the CABMx (100) and the CMDM (0).

4. Some assumptions basic to the method

a. The frequency distribution of Daily Maximum temperatures for the present and future are reliably related to temperature distribution of the past.

b. The asymmetrical position of the Mean Daily Maximum temperature between the Absolute Maximum and Mean Daily Minimum furnishes nearly 50 patterns of distribution, one of which may be found to be satisfactory for any station for any of 5 warm months.

c. The Mean Daily Maximum temperature for any station through 10 or more years is a near constant.

^{*}By extrapolation, the range of CMDMx was extended downward to 36 and upward to 80. (See Fig. 2 and Table III)

TABLE II: PAIRED CONVERTED TEMPERATURE VALUES USED FOR
THE CONSTRUCTION OF THE ONE DAY PER MONTH
PREDICTION LINE (10 DAYS IN 310)

	<u>CMDMx</u>	<u>CFT</u>		<u>CMDMx</u>	<u>CFT</u>
Aberdeen, Md.			Kansas City, Mo.		
May	50*	86*	May	43	74
July	57	89	July	53	90
Sept	51	85	Sept	45	83
Shreveport, La.			Portland, Ore.		
May	66	93	May	43	80
July	61	91	July	48	85
Sept	58	88	Sept	47	88
Manchester, N.H.			Helena, Mont.		
May	48	70	May	49	86
July	60	87	July	64	93
Sept	53	91	Sept	50	90
Minneapolis, Minn.			Baker, Ore.		
May	<u>38**</u>	74	May	51	86
July	49	91	July	67	94
Sept	45	89	Sept	58	91
Roswell, N. Mex.			Denver, Col.		
May	66	88	May	53	87
July	73	90	July	66	86
Sept	60	87	Sept	67	94
Mt. Clemens, Mich.			Yuma, Ariz.		
May	43	89	May	62	88
July	52	85	July	71	89
Sept	43	80	Sept	<u>75**</u>	95

* According to a 10-May record (310 days, Table I), Aberdeen had a CMDMx temperature of 50, and 1 day in 31 (1/31) a Converted Frequency Temperature (CFT) of 86 or above, but below 95 (base of adjacent time interval, (1/93).

** Underlined numbers 38 and 75 represent the lowest and highest CMDMx for the 36 records (3 months at each of 12 stations).

Note: The CFT's became CPT's when generalized in the Nomograph and Table III.

Note: It must be pointed out here that 12 of these months have 30 days each, and 24 months have 31 days each. The Nomograph and Table III integrated the 36 records and proceed as if each month has 31 days. Of course this does not coincide with the facts. However, the error is assumed to be negligible.

d. The Mean Daily Minimum temperature for any station through 10 or more years is a near constant.

e. The Daily Maximum temperatures (DMx) through 10 or more years (e.g., 310 May days rearranged in numerical sequence) is an increasing variable, but with a decelerated trend corresponding to the trend of a series of daily maxima arranged in an ascending numerical sequence.

f. This trend may be discovered by plotting the ascending decelerated series on a skew-log probability scale, using data from 10-year records.

g. The Mean Daily Minimum is a near stable anchor from which to measure the oscillating extreme maxima.

h. Usually, summary temperature records provide the essential data for computing the CMDMx and for predicting daily maximum temperature frequencies through any required span of years.

i. Tests for the spread of CMDMx from the latitude of Singapore, Malaya, to Tanana, Alaska, gave results well within the 36 to 80 of CMDMx on the Nomograph.

PART II - NOMOGRAPH, BASIC SECTION

5. Constructing the Basic Section

As stated before, conventional temperature values (Fahrenheit or centigrade) cannot be used directly on the nomograph (Fig. 2) but must be converted to a 100-unit scale. (See Table I.) The July and September daily maximum temperature records at Aberdeen, Maryland, were processed in the same way as those for May (shown in Table I). Corresponding records (1946-1955) for the same months at eleven other stations in the United States (Fig. 1 underscored) were processed in the same manner - 36 records in all. The CMDMx's ranged from 38 to 75, each associated with a family of converted frequency temperatures (CFT). (For example, CMDMx 50 in Table I, line f is associated with the converted values in the same line.) These CFT's are converted values of DMx's which actually occurred within the given frequencies (line c, Table I).

The sloping 1/31 line of the nomograph was plotted as follows: The CMDMx 50 (Table I, line f) and the CFT 86 (Table I, line f, column 7) are the paired converted temperature values for Aberdeen, Maryland, for 1 day in each May (year), or 1/31. (These paired values are shown at the beginning of Table II.) There is a corresponding pair (CMDMx and CFT values) for each of the other 35 records, ranging from a low CMDMx of 38 (May at Minneapolis) to a high CMDMx of 75 (September at Yuma). Each of these 36 pairs (Table II) is plotted (stars) on the Nomograph Basic Section (Figure 2). The (curved) line on the nomograph for the frequency 10 days in 310 or an average of 1 day in 1 month, 1/31, is the visual "best fit" through

and among the 36 plotted stars. The shape and position of this curved line is influenced somewhat by that of the nine associated curved predictive lines in the Basic Section, all of which are similarly derived and mutually adjusted. The generalized predictive curves are for frequencies ranging from 25 days in a given month (25/31) to 1 day in 310 days (1/310, straight line) of the same month (i.e., 1 day in 310 May days, or 10 years) -- 10 predictive lines in all in the Basic Section.

6. Predicting maximum temperature frequencies by use of the Nomograph, Basic Section

Let us now go back to Table I and find out how near the predicted maxima for May at Aberdeen, Maryland, come to actual occurrences. There are three steps in finding the predicted maxima from 10-year records (Basic or Extrapolated Section of the nomograph): 1) Find the CMDMx, 2) Find the CPT* for the required frequency, 3) Using the Reconversion Formula, reconvert the values to degrees Fahrenheit.

The CMDMx for May at Aberdeen is CMDMx 50 (see Table I).

CPT values are found as follows: If on the nomograph we follow the horizontal line corresponding to CMDMx 50 to its intersection with predictive line 5/31 (5 days in 1 May, or 1 year) and then follow this point of intersection to the top - the CPT scale - we get the CPT value of 72. Corresponding converted predictive temperatures for from 5 days in 1 year to 1 day in 10 years are found by the same method to be:

5/31, 72; 3/31, 79; 1/31, 87; 1/93, 93; 1/155, 96, and 1/310, 100.

The formula for reconversion for maximum 1-day temperature (°F) associated with given frequencies is:

$$\text{Predicted DMx (°F): } \frac{\text{CPT (AbMx - MDMi)}}{100} + \text{MDMi} \quad \begin{array}{l} \text{Formula} \\ \text{(Reconversion)} \end{array}$$

$$\begin{array}{l} \text{(Substituting;)} \\ \text{Probable DMx, 5/31: } \frac{72 (95\text{F} - 53\text{F})}{100} + 53\text{F} = 83\text{F}^{**} \end{array}$$

$$\text{Probable DMx 3/31: } \frac{79 (95 - 53)}{100} + 53 = 86\text{F}$$

$$\text{Probable DMx 1/31: } \frac{87 (95 - 53)}{100} + 53 = 90\text{F}$$

*Note that the CPT values were taken from the actual maximum temperature frequencies at 12 stations, whereas the CPT's are generalized values taken from the nomograph.

**See footnote c to Table I.

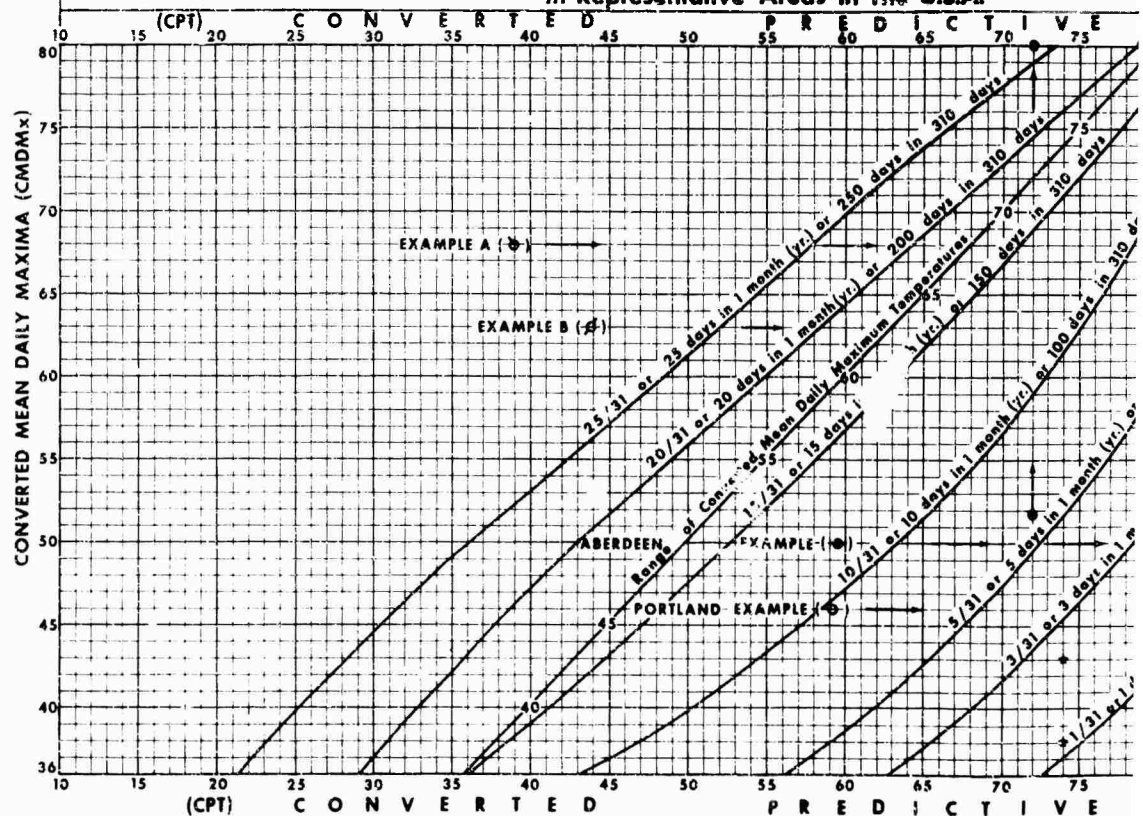
MULTIPLE NOMOGRAPH FOR PREDICTION

MAXIMUM TEMPERATURE

TO PREDICT FROM 10-YEAR

Basic Section From 25 Days In a Given Month U

Constructed From Actual Frequency Distribution Of Daily Maxima At
In Representative Areas In The U.S.A.



Explanation of General Symbols:

- ☆ Stars in the Basic Section represent paired converted temperature values (CMDMx)
 - ▲ Triangles in the Extrapolated Section represent CPT values extrapolated from 10-year records and used to construct the 1/620 prediction curved line.
 - Dots in the "Duration" Section for line "xy", identifying the CMDMx 60 (on values to use in place of 12 different patterns of longer or shorter records)
- Examples A and B are discussed in Appendix C.
- Examples Aberdeen and Portland are discussed in the text, Sections 6 and

Figure 1

GRAPH FOR PREDICTING FREQUENCIES OF DAILY MAXIMUM TEMPERATURES

FROM 10-YEAR RECORD ONLY

Predicting From
Long Records:
Up to 100 Years

In a Given Month Up To 10 Years

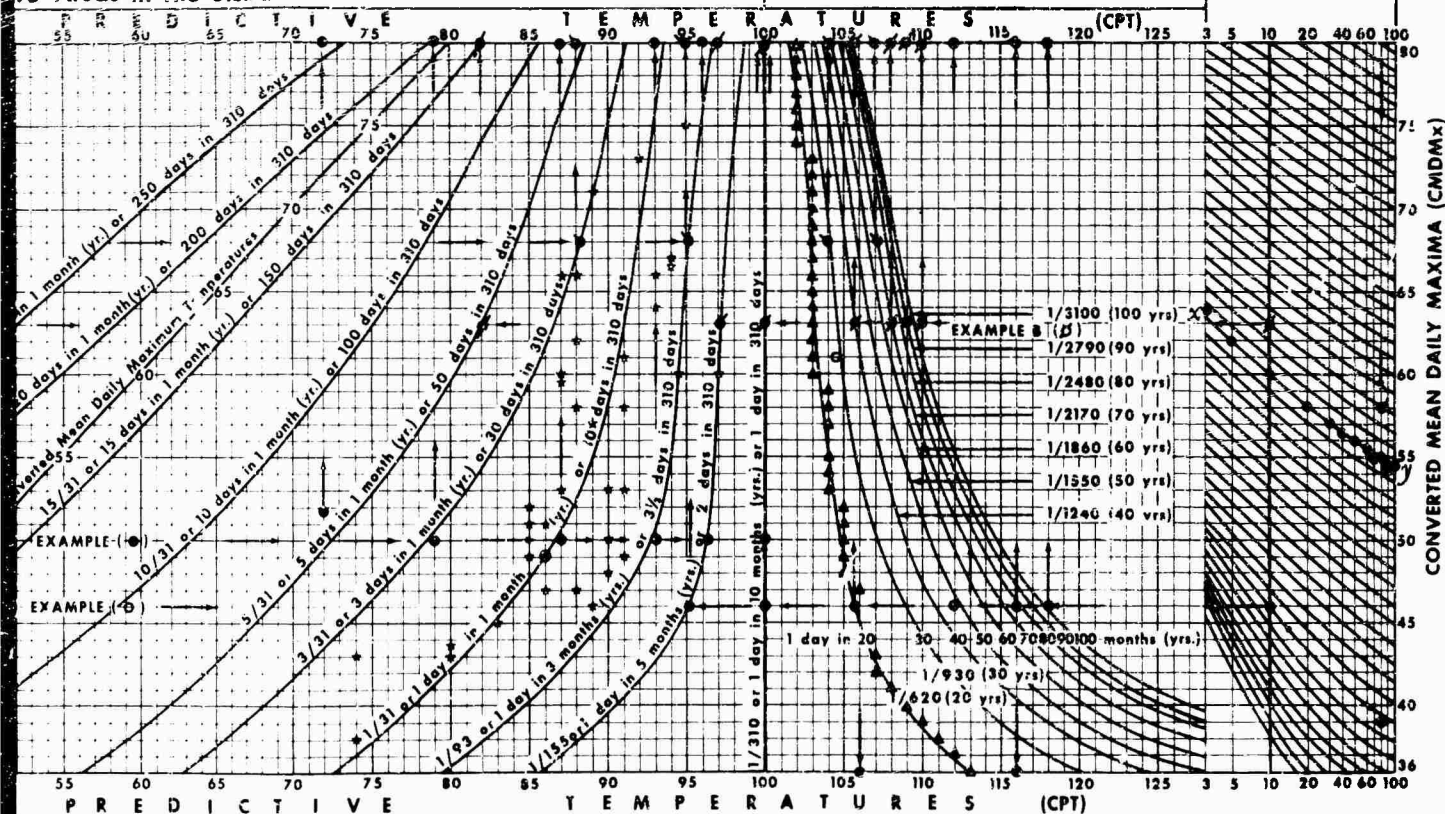
Extrapolated Section
Increments, 20 to 100 years

Duration Section

Frequency Distribution Of Daily Maxima At 12 Stations
in the U.S.A.

Extrapolated From
Basic Section

TO FIND THE 10 YEAR
CMDMx EQUIVALENTS



Converted temperature values (CMDMx and associated CPT values, Table II) for the 1/31 curved prediction line.
CPT values extrapolated from the CPT trends in the 45 CMDMx predictive patterns in the Basic Section,
curved line.

Identifying the CMDMx 60 (on the 10-year vertical accentuated line) represent predictive pattern of CPT
values of longer or shorter records (1/93 to 1/3100). See text, Section 12.

See text, Sections 6 and 14, respectively.

Figure 2

$$\text{Probable DMx 1/93: } \frac{93 (95 - 53)}{100} + 53 = 92F$$

$$\text{Probable DMx 1/155: } \frac{96 (95 - 53)}{100} + 53 = 93F$$

$$\text{Probable DMx 1/310: } \frac{100 (95 - 53)}{100} + 53 = 95F$$

It may be seen that the values predicted from the nomograph (line 9, Table I) for May at Aberdeen do not depart from the recorded (line c Table I) at any predictive level by more than 1F°. However, it should be expected that the CMDMx 50 pattern would always do as well on other summary 10-year (7 years to 14 years) records.

7. Constructing Table III Basic Section from Basic Section of the Nomograph (Fig. 2) and its use

Each of the 10 predictive lines 25/31, 20/31, 15/31, etc., in the nomograph, Fig 2, Basic Section, crosses 45 horizontal CMDMx lines (36 to 80) making in all 450 fixed converted predictive temperature (CPT) values. (For example, note the six CPT values associated with CMDMx 50 in the preceding problem.) These 450 constant values (CPT's) are entered in Table III. They are the underlined, or principal, numbers in each cell. They are CPT's for predicting from 10-year records. (The other numbers in the cells are CMDMx identification factors, to be used if the record is longer or shorter than 10 years, and will be explained later.)

This table may be used instead of the Nomograph for predicting the probable daily maxima. For example: The CPT values associated with CMDMx 50 in the problem discussed above (72, 79, 87, etc.) are to be found on the table. Follow the numbers (underscored) on the horizontal CMDMx 50 line to the required time interval in the column heading at the top. Once you have the required CPT value, the procedure is the same; that is, you substitute the CPT values in the Reconversion Formula. See Appendix D, Example A, for the use of the table in predictions.

PART III - NOMOGRAPH, EXTRAPOLATED SECTION

Often it is desirable to know the daily maximum temperature probabilities for periods of time longer than 10 years. Thus, it became necessary to construct the Extrapolated Section of the Nomograph.

8. Theory and Use of a Skew-Log Probability Scale

It may be noted (Basic Section, Table III) that the converted predictive temperature values increase as the length of the record increases.

For example, for CMDMx 60 the converted values for 1, 3, 5 and 10 years are respectively, 90, 94, 97 and 100.* When these four values are plotted on a skew-log adjustable probability scale** (Fig. 3) and the straight line connecting them is prolonged to 1 day in 3100 (1/3100 or 0.032%) (100 Mays or 100 years) the decile-interval converted predictive temperature values (CPT) become:

<u>103</u> for 20 Mays (1/620)	<u>107</u> for 50 Mays (1/1550)
<u>105</u> for 30 Mays (1/930)	<u>108</u> for 60 Mays (1/1860)
<u>106</u> for 40 Mays (1/1240)	<u>110</u> for 100 Mays (1/3100)

9. Construction of Nomograph, Extrapolated Section

The process described in the preceding paragraphs of extrapolating the values of a 10-year record (specifically the associated CPT's of CMDMx 60) into a period longer or shorter than 10 years was repeated for each of the other 44 CMDMx patterns (36 to 80). The 44 triangles on the Extrapolated Section of the Nomograph furnished the "visual" pattern for the predictive line, 1 day in 20 Mays or years (620 May days, 1/620). The other predictive curved lines in the Extrapolated Section (1/930, 1/1240, 1/1550, etc., to 1/3100) were constructed in a similar manner (see curved lines on Nomograph, Extrapolated Section). As in the Basic Section, the shape and position of the curved predictive lines in the Extrapolated Section were influenced somewhat by the shape and position of the associated predictive lines, all of which were similarly derived and mutually adjusted. Thus was constructed from 36 monthly records at 12 stations a nomograph based on 10 years of tabulated monthly maximum temperature frequencies from which it is now possible from abbreviated records to predict the frequency of expected maximum temperatures for any summer month for 1, 3, 5, and 10 years, and also (Extrapolated Section) for decile yearly increments from 20 up to 100 years.***

10. Using the Nomograph: Predicting from a 10-Year Record, the Probable Maximum Temperatures for a Given Month from 1 to 100 Years

By use of the Nomograph (Fig. 2, Basic Section) maximum temperature predictions for Aberdeen were made for periods of 10 years or less (see

*See underscored values on CMDMx 60 line, Table III.

**The skew-log probability scale is a Gumbel Extreme probability scale superimposed on two-cycle logarithmic paper. Because of its flexibility, a curved line of distribution may be converted to a near straight line. See reference 4.

***The nomograph and Table III may be used also to predict the maximum temperatures to be expected for as many as 25 days per month (25/31).

1

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CMDMX 60 (10-YEAR RECORD) EXTRAPOLATED TO 100 YEARS (3100 JULY DAYS)

BY USE OF A SKEW - LOG PROBABILITY SCALE

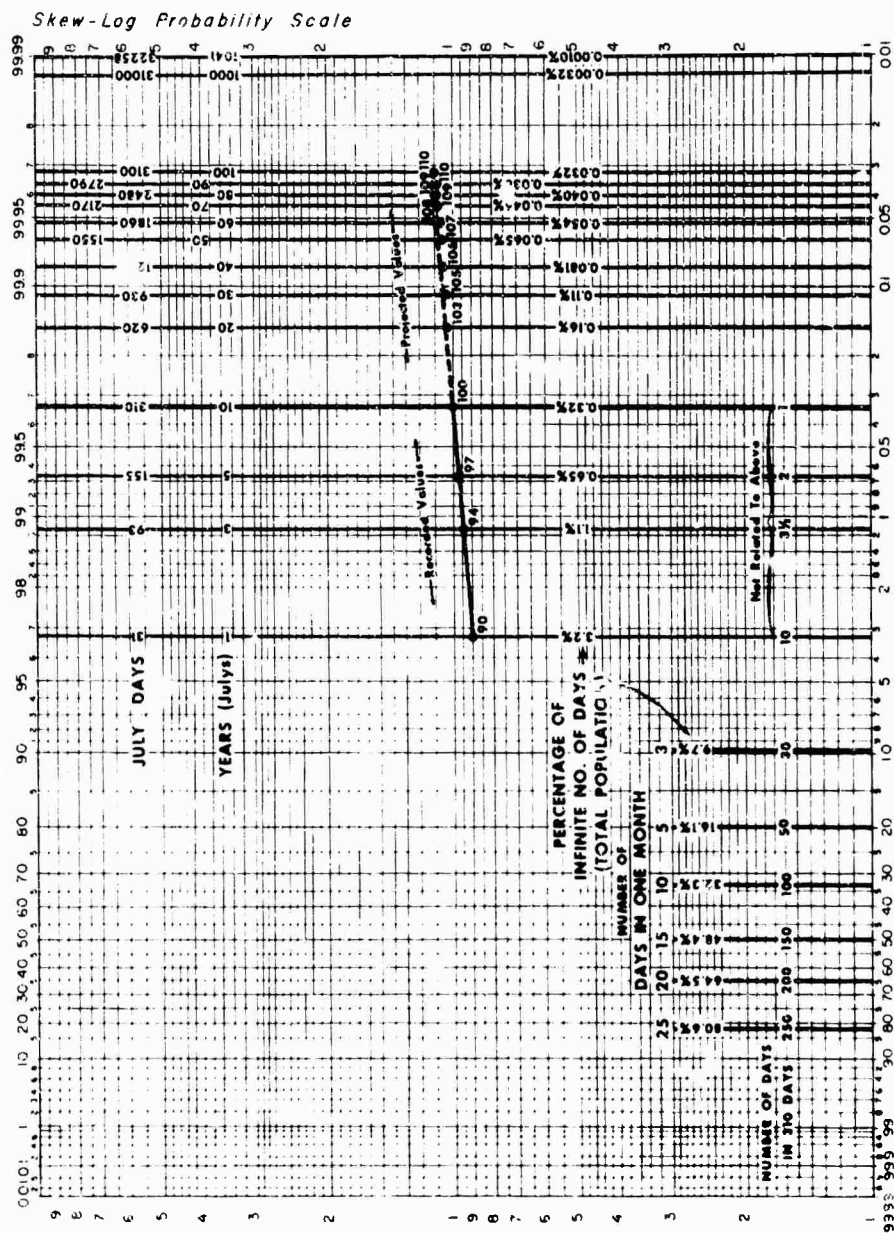


Figure 3

section 6 above). Now by use of the Extrapolated Section of the Nomograph, predictions up to 100 years may be made from the 10-year record.

For example, let us consider the above-mentioned Aberdeen-May pattern:

We have CMDMx 50 (Table I).

To find the CPT values: We follow CMDMx 50 on the Nomograph from the Basic Section, beyond the 100 CPT limit and into the Extrapolated Section. CMDMx 50 intersects the 20-year predictive curve (1 day in 620 May days) at a point which would indicate (according to the scale at the top of the graph) a CPT of 105. This and other CPT values of CMDMx 50 pattern, similarly found, are as follows:

20 yrs, <u>105</u>	30 yrs, <u>107</u>	40 yrs, <u>109</u>	50 yrs, <u>111</u>	60 yrs, <u>112</u>
70 yrs, <u>113</u>	80 yrs, <u>114</u>	90 yrs, <u>114</u>	100 yrs, <u>115</u>	

These values are reconverted to Fahrenheit by using the Reconversion Formula (Section 6 above). In this Formula, the maximum 1-day temperature associated with the required frequency is:

$$\frac{\text{CPT (AbMx - MDM1)}}{100} + \text{MDM1}$$

$$\text{Substituting, for 1/620} \quad \frac{105 (95 - 53)}{100} + 53 = 97\text{F}$$

$$\text{Substituting, for 1/930} \quad \frac{107 (95 - 53)}{100} + 53 = 98\text{F}$$

Thus the maximum temperature frequency probabilities for Aberdeen in May are:

1 May day in 20 years	(1/620 May days):	97F*
1 " " " 30 "	(1/930 May days):	98F
1 " " " 40 "	(1/1240 May days):	99F
1 " " " 50 "	(1/1550 May days):	100F
1 " " " 80 "	(1/2480 May days):	101F
1 " " " 100 "	(1/3100 May days):	101F

The 10-year summary record (AbMx, MDMx, MDM1) for any station for any summer month may be used for predictive purposes after the CMDMx pattern has been computed as in the Aberdeen example. For another illustration of the predictive techniques, see Appendix C, Example A.

*See footnote to Table I, line c.

11. Construction and Use of Table III, Extrapolated Section

There are about 400 constant values at the intersections of the horizontal CMDMx lines (36 to 80) and the nine sloping prediction lines in the Extrapolated Section of the nomograph. These CPT values are entered in Table III, Extrapolated Section, underscored numbers. Table III may be used instead of the Nomograph for predicting probable maximum temperatures and frequencies for any given summer month for periods of 15 to 100 years. The steps are the same as for predicting from the Basic Section (see Section 7 above), or for predicting from the nomograph: 1) Find the CMDMx 2) Find on the table (or Nomograph) the CPT for the required frequency 3) Use the Reconversion Formula to convert to °F. A complete example of this type problem is given in Appendix D, Example A.

PART IV - CONSTRUCTION OF THE NOMOGRAPH, "DURATION" SECTION

12. Derivation of Data for Constructing "Duration" Section of the Nomograph

It must be remembered that the CPT values (underscored numbers) of both the Basic and Extrapolated Sections of Table III are keyed exclusively to 10-year records and, therefore, Table III may be used for prediction of Daily Maximum Temperatures and Frequencies when the essential data (AbMx, MDMx and MDMi) are for approximately 10 years (8 to 14).

When the summarized data for processing come from records longer or shorter than 10 years, the "Duration" Section of the nomograph must be used to identify the 10-year equivalent pattern to substitute for the CMDMx for the longer or shorter period of record.

Every line in the "Duration" Section of the nomograph (vertical, horizontal and sloping) is keyed to the accentuated 10-year vertical line. The essential data for drawing the sloping lines in the "Duration" Section are the numbers (not underscored) in Table III. These values are computed as follows: It may be seen that daily maximum temperatures when arranged in a numerical sequence, become progressively higher with increased length of record, but at a decelerated rate. This is illustrated, for example, in Table VII, where the CPT values (underscored numbers) associated with CMDMx 60 run as follows: 73, 80, 85, 90, 94, 97, 100, etc., to 110, respectively. Each of these values is keyed to the 100-unit scale with the CMDMx 60 and the 10-year basic record. However, this whole 10-year sequence of CPT's associated with CMDMx 60 may be converted into an equivalent 100-scale sequence corresponding proportionally to, for example, a 70-year record.

In this case, the CPT 109 (extrapolated 70-year prediction, based on 10-year records) becomes CPT 100 for an equivalent 70-year (record) CPT scale and the 10-year (record) CMDMx 60 becomes the 70-year (record) CMDMx 55.

$$\left[(60 \text{ times } \frac{100}{109}) = 55.046 \text{ or } 55 \text{ (rounded)} \right]$$

See "55", (not underlined) CMDMx 60, 70-year column, Table III)]

In other words, the 70-year (record) CMDMx 55 becomes identified with the 10-year record CMDMx 60 pattern of converted prediction values. Other identification values in the same line associated with CMDMx 60 are (all not underlined numbers in Table III):*

for 3 years:	63.8	or	64**	for 50 years:	56.1	or	56
" 5 "	61.9		62	" 60 "	55.6	"	56
" 10 "	60.0		60	" 70 "	55.0	"	55
" 20 "	58.3		58	" 90 "	54.5	"	55
" 30 "	57.1		57	" 100 "	54.5	"	55
" 40 "	56.6		57				

There are 16 identification values for each CMDMx (36 to 80) - more than 700 such entries in Table III.

When the above-mentioned CMDMx 60 identification values are entered on the nomographic grid in the "Duration" Section of the Nomograph, they determine the smooth identification curve "x y". Similar curves were constructed for each of the other CMDMx's (36 to 80) from the associated values in Table III, i.e., the numbers not underlined. The CMDMx identification values for the numbers not underlined in Table III are each associated with a counterpart in the "Duration" Section of the Nomograph, and some one of these more than 700 CMDMx's is assumed to represent the pattern of summary temperature record (AbMx, MDM1 and MDMx) of 3 years to 100 years for any summer month.

Since the "x y" line, ("Duration" section) representing the CMDMx for any length record from 3 years to 100 years, crosses the 10-year line (vertical, accentuated) at 60, it follows that the CPT values on CMDMx 60 may be used for predictive purposes for records running from CMDMx 55 to CMDMx 64 for any summer month from 3 years to 100 years.

For another example, it is evident that a 90-year record with a CMDMx 44 would use the 10-year (record) CMDMx 50 pattern of converted temperatures (CPT) for predictive purposes. (In the "Duration" Section of the nomograph, at the point where horizontal line CMDMx 44 crosses the 90-year vertical line, follow the nearest sloping line to where it crosses the 10-year vertical line: CMDMx: 50.) Each of the sloping lines in the "Duration" Section is designed to serve purposes similar to the marked "x y" line.

*The identification values for the numbers not underlined were computed in the same manner as the present CMDMx 55, Table III.

**Rounded.

To recapitulate: In order to make Table III more useful, the numerical CMDMx value at each intersection (sloping and horizontal lines) in the "Duration" section of the Nomograph is entered with its 10-year (record) associated CPT value (computed as shown earlier) in the 10-year prediction Table III (numbers not underlined). There are more than 700 such entries in Table III. Thus, the CMDMx 44 mentioned in the above paragraph may be found in the 90-year column (number, not underlined) associated with the 10-year-record CMDMx 50 and 10-year-record CPT 114 (the underlined number in the same cell). That is to say, the 90-year-record CPT is at least 1.14 times the 10-year-record CPT. Let us solve a specific problem.

13. Using Table III, including identification numbers CMDMx's (not under-scored) for indicated lengths of record

Solution of problems involving record of more than 10 years can be done more easily by use of Table III than by the nomograph.*

Given: In May at Portland, Oregon, during a 78-year record:
 AbMx: 99F MDMx: 68F MDM1: 48F

Required: What May day maximum temperature should be expected 1 day
 in -
 20 yrs (1/620)? 50 yrs (1/1550)? 100 yrs (1/3100)? 5 yrs (1/155)?

Solution:

a. Find the 80-year (record) CMDMx

$$\text{Formula: CMDMx} = \frac{100 (\text{MDMx} - \text{MDM1})}{\text{AbMx} - \text{MDM1}}$$

$$(\text{Substituting:}) \quad \frac{100 (68 - 48)}{99 - 48} = 39.2$$

b. Find the 10-yr (record) equivalent to CMDMx 39 in 80-yr column (Table III)

Method: Follow down the 80-year column of numbers not underlined to number 39, that is, the CMDMx for 80-year record. This is found on the CMDMx 45 line. Therefore CMDMx 45 10-yr pattern will be used for prediction. (Increasing the length of the record increased the AbMx but at a decelerated rate, thus changing the CMDMx pattern, 39 in one instance, 45 in the other.

*For another illustration, see Appendix D, Example B: Kansas City

c. Find the required CPT's, using the CMDMx 45 pattern

Method: Follow CMDMx 45 from left margin to each required time interval, as indicated in column heading at top. These CPT's are:

For 20 years, 106; For 50 years, 113; 100 years, 119; 5 years, 95

d. Find the 10-year (record) predicted Absolute Maximum

$$\text{Formula: } \frac{100 (80 \text{ yr AbMx} - 80 \text{ yr MDM})}{80 \text{ yr CPT on CMDMx 45}} + \text{MDM}$$

(Note: Value in denominator above is in the 80-yr column, CMDMx 45 line of table. That is, the 80-yr AbMx is CPT 117 on the 10-yr table.)

$$\text{Substituting: } \frac{100 (99F - 48F)}{117} + 48F = 92F$$

e. Reconvert CPT's in (c) to °F (using 92F as AbMx)

Formula (IMx associated with given frequencies:)

$$\frac{\text{CPT (10-yr AbMx} - 80\text{-yr MDM)}}{100} + \text{MDM}$$

(Substituting CPT's from c above:)

$$\text{Predicted 20-yr Mx } \frac{106 (92 - 48)}{100} + 48 = 95F$$

$$\text{Predicted 50-yr Mx } \frac{113 (92 - 48)}{100} + 48 = 98F$$

$$\text{Predicted 100-yr Mx } \frac{119 (92 - 48)}{100} + 48 = 100F$$

$$\text{Predicted 5-yr Mx } \frac{95 (92 - 48)}{100} + 48 = 90F$$

When the constant values listed in Table III are entered on punch cards and directions according to the preceding formulas are given to a computing machine, processing of the data for the frequencies of expected daily maximum temperatures can be done quickly and accurately.

14. Using the "Duration" Section of the Nomograph for prediction

This example shows how to use the nomograph constructed from 10-year daily records to predict daily maximum probabilities from summary records of more than 10 years - in fact, from 3 years to 100. The problem is the same as the one for Portland using Table III, Section 13.

Given: In May at Portland, Oregon, during a 78-year record:

AbMx: 99F MDNx: 68F MDM: 48F

Required: What May day maximum temperature should be expected 1 day in -

20 yrs (1/620)? 50 yrs (1/1550)? 80 yrs (1/2480)?
100 yrs (1/3100)? 5 yrs (1/155)?

Solution:

- a. Find the 80-year CMDNx (for 78-year record).
This is 39.2 (see Section 13 above, part a of solution).
- b. Find the 10-year equivalent CMDNx pattern.

Method: On the "Duration" section of nomograph, follow down the 80-year vertical line to CMDNx 39. Then follow the nearest sloping line left and upward to vertical line 10 years (accentuated). This is on horizontal line CMDNx 46.*

- c. Find the required CPT values in the CMDNx 46 pattern.
(See "Portland Example")

Method: Follow CMDNx 46 left to predicting sloping lines, 1/620, 1/1550, 1/2480, 1/3100, 1/155 (see arrows and circles). Thence, go upward to corresponding CPT values 106, 112, 116, 116, and 95, respectively.

- d. Find the 10-year (1/310) expected May Maximum

Formula: $\frac{100 (80\text{-yr AbMx} - 80\text{-yr MDM})}{80\text{-yr CPT on CMDNx 46}} + \text{MDM}$

Substituting: $\frac{100 (99F - 48F)}{116} + 48F = 92F$

*The Table value is CMDNx 45. The slight difference here is negligible and is to be expected. If the values in the Table and on the Nomograph were expressed with fractional exactness, the predictions would agree even more closely. In order to make serious differences in predictions the CMDNx's would need to differ by several units.

- e. Reconverting CPT's in (c) using 92F as AbMx

Formula: Required Predictions:

$$\frac{\text{CPT (10-yr. AbMx - 80 yr. MDM)} + \text{MDM}}{100}$$

Substituting:

$$\text{Prediction for 20-yr Mx} \quad \frac{106 (92-48)}{100} + 48 = 95\text{F}$$

$$\text{Prediction for 50-yr Mx} \quad \frac{112 (92-48)}{100} + 48 = 97\text{F}$$

$$\text{Prediction for 80-yr Mx} \quad \frac{116 (92-48)}{100} + 48 = 99\text{F}$$

$$\text{Prediction for 100-yr Mx} \quad \frac{118 (92-48)}{100} + 48 = 100\text{F}$$

$$\text{Prediction for 5-yr Mx} \quad \frac{95 (92-48)}{100} + 48 = 90\text{F}$$

PART V - TESTING THE RELIABILITY OF THE METHOD

15. Internal consistency

Tabulated actual temperature frequencies for a 10-year (10 May) record at Aberdeen are given in Table I, Frequency Data, line c. In line g are listed the corresponding temperatures and frequencies as predicted by use of the nomograph from the Essential Data in line c. This may be termed the internal consistency of the method. Predicted temperatures at each of the six frequency levels are within 1F° of the recorded. This test could be repeated for the 3 months (May, July and September) for each of the twelve stations.

16. Testing the method for a different month (August)

Tests similar to that for Aberdeen (May, July and September) were made for the month of August for four widely separated stations (Hamstead, N.Y., Fairfield, Ohio, Fort Bragg, N.C., and Brownsville, Tex., Fig 1). The results are shown in Table IV. It may be seen that the recorded temperature frequencies for August did not differ from the predicted at any of the seven frequency levels by more than 2F° (28 comparisons in all).

TABLE IV: RELIABILITY OF THE MONOGRAPH
RECORDED AND PREDICTED FREQUENCIES FOR AUGUST COMPARED

Station	Essential Data				Frequency Data									
	Ab	MD	MD	MD	10/31	5/31	3/31	1/31	1/93	1/155	1/310			
Hempstead N.Y.	97	81	64		84* 85	87 88	89 91	92* 93	96 95	97 96	97			
Fairfield Ohio	97	85	62		89 89	92 91	94 92	96 94	97 95	97 96	97			
Fort Bragg N.C.	101	83	68		91 93	94 95	95 96	97 98	98 99	100 100	101 101			
Brownsville Texas	101	92	76		94 92	95 94	96 96	97 98	99 99	100 100	101 101			

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That is, the recorded temperature in August at Hempstead reached 84°F or above, but below 87°F (the next time interval) 100 August days in 10 years (310 days in all), or 32.3% of the time; 92°F, 10 August days in 310 days, or an average of 1 August day per month (1/31) for 3.23% of the time.

The temperatures at Hempstead, predicted from the Essential Data (97°, 81° and 64°), ran 1 or 2 degrees higher at the designated temperature levels, than the recorded.

See Formulas, Sections 3, 6 and 13 of this report.

17. Testing the method by use of extended records

Summarized records for longer than 10 years duration were found for five of the component stations shown in Figure 1. These were tabulated for May, July and September. Associated with the summarized data for each are the predictions at various time intervals from 1 to 100 years (Table V).

The first line for each month gives summarized data and seven tabulated frequency values of recorded daily maximum temperatures for 10 years only. The remainder of line 1, of course, is blank. The 16 frequency temperatures in each of the second, third and fourth lines for each month are all maxima predicted from the independent summarized data in the same lines.

The starred temperature in each line is the recorded maximum for the time (decade) intervals, in years, shown in the first numeral column (40, 61, 15, 67, 56, etc.). The first line for each month gives recorded maximum temperature frequencies, based on a 10-year record. The second, third and fourth lines of frequencies are predictions for the corresponding months, made from the summarized records. See formulas in Appendix D.

The problem of sampling is critical. In general, the longer the continuous record, the higher the Absolute Maximum temperature (AbMx) will be. (Baker, Oregon in July with 101, 102, 103 and Kansas City in September with 107, 108 and 109). However, if the given records are not continuous, or the longer records do not include the shorter ones, then the comparative predictions may appear erratic (Baker, Oregon in May). In the case of Baker in July, the predictions from different length records (10-, 40-, and 61-years) do not differ at any decile level by more than 2° to 3° , even though neither the 40- or 61-year records included the 10-year daily maximum record. Therefore, the predicted maxima from a short record may run higher than in the predictions from a longer record, e.g., Shreveport, La., in July.

In general, the 10-year maximum temperature predictions from the longer records were somewhat lower than the recorded 10-year maxima.

The conclusion, evidently, is that the essential summarized data should come from relatively long records if the predicted temperature frequencies are to have satisfactory reliability.

TABLE V. - COMPLETENESS OF PREDICTIONS FROM THREE DIFFERENT LENGTHS OF RECORD FOR EACH OF THREE MONTHS AT EACH OF FIVE STATIONS

Station	Record		Summarized Data		CMRk		Predicted One-Day Maximum Temperature (°F) Frequency (1 day in Specified Years)																										
	Month	Years	At No.	ND No.	Full Time	15-Year Equiv.	From Different Periods of Record																										
							2.5 10/1	15.1 5/1	9.68 3/1	5.93 1/3	1.075 1/5	.743 1/10	.485 1/20	.305 1/30	.194 1/40	.125 1/50	.084 1/60	.054 1/70	.035 1/80	.025 1/90	.018 1/100												
Baker, Oregon	May	10	94	67	38			73	79	82	86	89	91	94											97	98	99	100	100	101	101	101	102
		10	94	67	38				74	79	83	87	90	93	94										98	99	100	100	101	101	101	101	102
		61	90	64	39				70	74	77	80	83	84	86										95	96	97	98	98	98	98	98	98
	July	10	101	85	46				89	93	94	98	99	101	101										103	103	104	104	105	105	105	105	106
		10	101	85	46				89	93	94	98	99	101	101										100	101	102	102	103	103	103	103	104
		61	104	82	49				83	91	93	95	97	98	100										102	102	103	103	104	104	104	104	105
	Sept.	10	99	71	36				81	87	89	91	94	95	97	99									102	103	103	105	105	105	106	106	107
		10	99	71	36				81	87	89	91	94	95	97	99									102	103	103	105	105	105	106	106	107
		61	94	71	41				77	81	83	86	88	90	92	94									96	97	97	98	99	99	99	100	100
Kansas City, Mo.	May	10	103	77	57				83	87	89	91	94	95	103										106	106	109	110	111	111	112	112	113
		10	103	77	57				83	87	89	91	94	95	103										106	106	109	110	111	111	112	112	113
		67	103	75	56				83	87	90	93	95	96	98										100	101	101	102	102	103	103	104	104
	July	10	111	93	72				97	102	103	107	109	110	111										113	113	114	115	115	116	116	116	116
		10	111	93	72				98	102	104	107	109	110	111										113	113	114	115	115	116	116	116	116
		67	109	90	63				93	97	99	102	104	105	106										110	110	111	111	111	111	111	111	112
	Sept.	10	107	81	60				86	91	94	99	102	104	107										110	110	111	112	112	113	113	113	114
		10	107	81	60				86	91	94	99	102	104	107										110	110	111	112	112	113	113	113	114
		67	109	81	60				89	91	94	97	100	101	103										105	106	107	106	108	109	109	109	109
Portland, Oregon	May	10	95	69	49				75	81	84	86	88	94	95										98	100	101	102	103	103	104	104	105
		10	95	69	49				76	81	84	86	88	94	95										98	100	101	102	103	103	104	104	105
		67	99	67	48				73	76	79	83	86	87	91										94	95	96	97	98	98	99	99	100
	July	10	103	79	57				85	86	89	95	100	102	103										107	109	110	110	111	112	112	112	113
		10	103	79	57				85	86	89	95	100	102	103										107	109	110	110	111	112	112	112	113
		67	104	79	56				87	90	93	96	97	99	100										104	108	108	103	103	104	104	104	105
	Sept.	10	97	72	54				78	81	86	92	94	95	97										100	101	101	102	103	103	103	104	104
		10	97	72	54				78	81	86	92	94	95	97										94	95	96	97	97	98	98	98	99
		67	102	72	52				77	81	84	88	91	93	95										96	95	100	110	101	101	102	102	103
Shreveport, Louisiana	May	10	93	83	62				87	89	90	91	92	93	95										94	94	95	95	95	95	95	95	96
		10	93	83	62				87	89	90	91	92	93	95										94	94	95	95	95	95	95	95	96
		61	101	83	64				86	89	93	95	96	97	98										99	100	100	101	101	101	101	101	102
	July	10	105	93	71				95	97	99	102	103	104	105										107	107	107	108	108	108	108	108	108
		10	105	93	71				95	97	99	102	103	104	105										107	107	107	108	108	108	108	108	108
		61	107	93	74				96	98	100	103	103	103	104										105	106	106	106	106	106	106	107	107
	Sept.	10	105	88	64				93	95	97	100	102	104	105										106	107	107	108	108	108	108	109	109
		10	105	88	64				94	97	98	101	103	104	105										103	104	104	105	105	105	105	105	106
		61	104	89	67				93	96	97	99	100	101	102										103	104	104	105	105	105	105	105	106
Tucson, Arizona	May	10	115	95	63				100	105	106	109	113	114	115										117	117	118	119	119	119	120	120	120
		10	115	95	63				101	105	106	110	114	115	116										117	117	118	119	119	119	120	120	120
		61	114	94	56				100	103	105	108	109	111	112										114	114	115	116	116	116	116	116	116
	July	10	119	106	81				110	112	113	115	117	118	119										120	121	121	121	121	121	121	121	121
		10	119	106	81				110	112	113	115	117	118	119										120	121	121	121	121	121	121	121	121
		61	116	105	73				107	110	112	114	117	118	119										115	116	117	117	118	118	118	118	118
	Sept.	10	115	103	73				106	110	112	114	117	118	119										117	117	118	118	118	118	118	118	118
		10	115	103	73				106	110	112	114	117	118	119										117	117	118	118	118	118	118	118	118
		61	114	101	66				104	106	107	109	110	111	112										113	113	114	114	114	114	114	114	114

NOTE: For each month, line 1 (underlined figures) gives the normal tabulated temperatures for the various frequencies for the 10-year record. But in line 2, 3 and 4 the temperatures for the various frequency intervals are predicted from the given summarized data for years of record indicated in the "Record" column (i.e., 40-year record, 61-year record).

10/1 means 10 days in 1 month (31 days); 1/50 means 1 day in 50 of the same month (1550 days, 50 years, or 1/1550).

For Formulas for computations, see Appendix D.

Summary and comments

- a. The 45 patterns of maximum temperature distribution cover adequately the range essential for satisfactory prediction for summer months.
- b. Four items of essential data are generally available for wide areal coverage.
- c. The method is satisfactory for manual computation and prediction, and also lends itself readily to machine processing.
- d. Visual impressions of areal distribution of maximum temperatures may be secured by mapping processed data.
- e. Variables that recur only at long time intervals may not be encompassed within the 10-year coverage. Therefore, predictions from long records are preferable.
- f. The validity of the method could probably be improved by integrating into the study more stations, more months, and longer records.

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APPENDIX A

ABBREVIATIONS AND GLOSSARY OF TEMPERATURE TERMS

1. AbMx = Absolute Maximum Temperature:

The highest temperature ever recorded in a given month at a given station.

2. DMx = Daily Maximum:

The highest temperature occurring day by day in a given month.

3. DMI = Daily Minimum Temperature:

The lowest temperatures occurring day by day in a given month.

4. MDMx = Mean Daily Maximum Temperature:

The average of the DMx's during the period of record.

5. MDMI = Mean Daily Minimum Temperature:

The average of the DMI's during the period of record.

6. RT = Reduced Temperature:

Values derived by subtracting the MDMI from the items of essential and frequency data as in Table I.

7. CPT = Converted Predictive Temperatures:

RT items to be converted to a 100-unit scale as in Table I.

8. CFT = Converted Frequency Temperatures:

Frequency Temperatures changed to 100-unit scale.

9. CABMx = Converted Absolute Maximum:

Reduced AbMx changed to 100 on the 100-unit scale as in Table I.

10. CDMx = Converted Mean Daily Maximum:

Average of the reduced daily maxima converted to the 100-unit scale as in Table I.

11. CMDM = Converted Mean Daily Minimum:

Average of the reduced daily minima converted to zero on the 100-unit scale as in Table I.

12. CDMx = Converted Daily Maximum Temperatures:

Reduced temperature values (Table I, line e) converted to the 100-unit scale (Table I, line f)

13. FPT = Fahrenheit Predictive Temperatures:

CPT values re-converted to Fahrenheit (plus the MDM) (See 7 and 8 above)

APPENDIX B

RESUME AND SEQUENCE IN THE CONSTRUCTION OF THE MULTIPLE NOMOGRAPH AND THE EQUIVALENT TABLE (TABLE III)

1. Selecting 12 representative weather stations in the United States with requisite daily temperature records for three summer months (May, July, September), through 10-year periods.
2. Tabulating daily maximum temperature frequencies similar to those in Table I (36 in all). This had been done in part by U.S. Air Weather Service, Data Control Unit.
3. Assembling tabulations into frequency summaries (CMDMx and CPT, paired) corresponding to those on Table II.
4. Plotting frequency data (CPT) from (2) and (3) above, thus deriving Basic Section of the Nomograph.
5. Constructing Table III, Basic Section, from the Nomograph.
6. Extrapolation of CPT values in Table III, Basic Section, by use of Skew-Log Probability Scale, thus deriving CPT values in the Extrapolated Section of Table III (underlined figures) and Extrapolated Section of the Nomograph.
7. Computing and entering Identification CMDMx values (numbers not underlined) in Table III.
8. Constructing Nomograph "Duration" Section from CMDMx items derived in (7) above.
9. Validation of method.
10. Solution of problems by use of Nomograph, Appendix C.
11. Solution of problems by use of Table III, Appendix D.

APPENDIX C

FIGURE 2 - THREE-SECTION NOMOGRAPH FOR PREDICTING THE LEVEL
AND FREQUENCY OF HIGH TEMPERATURES OF SUMMER

SECTIONS OF THE HIGH TEMPERATURE NOMOGRAPH:

The Basic Section was constructed from tabulated converted daily maximum temperatures secured for May, July and September for 10 years from 12 widely distributed weather stations in the United States (Fig. 1). For construction see Part II. The Extrapolated Section was derived by extrapolation from the Basic Section. For construction see Part III. The "Duration" Section is used to find the 10-year pattern in the Basic or Extrapolated Section to be used when the basic abbreviated record is longer than 10 years. For its construction see Part IV.

EXPLANATION OF NOMOGRAPH:

The horizontal lines (36 to 80, left margin) represent CMMx temperatures; the vertical lines (10 to 128), represent CPT temperatures; the curved sloping lines (Basic and Extrapolated Sections) represent prediction values for indicated intervals of time from 25 days in 1 month (25/31 days) to 1 day in 100 months, e.g., 100 Mays (100 yrs or 1/3100 days); sloping lines in the "Duration" Section are designed to find the 10-year equivalent for any length of abbreviated record up to 100 years.

USING THE NOMOGRAPH: Example A - 10-Year Record. "Duration" Section not involved.

Given: In May at Shreveport, during a 10-year period:
AbMx, 93F MDMx, 83F MDM1, 62F

Required: What May maximum may be equaled or exceeded -
3 days in a year, i.e., 3 days in 1 May, 3/31?
1 day in 3 years (3 Mays) 1/93? In 30 years, 1/930?
In 70 years, 1/2170?

Solution:

a. Find CMMx

$$\text{Formula: } \text{CMMx} = \frac{100 (\text{MDMx} - \text{MDM1})}{\text{AbMx} - \text{MDM1}}$$

$$(\text{Substituting:}) \frac{100 (83 - 62)}{93 - 62} = 67.7 \text{ or } 68 \text{ (rounded)}$$

CMDMx 68 is the pattern for predicting DMx temperature for May at Shreveport.

- b. Find required CPT's (converted predictive temperatures for required time intervals)

Method: Follow CMDMx 68 from the left margin of the nomograph (Sign b) to prediction lines and thence upward to respective CPT's (as Nomograph, line 68, Example A)

3/31, CPT 88	1/93, CPT 95
1/930, CPT 104	1/2170, CPT 107

- c. Reconvert to °F

Formula: DMx associated with given frequencies:

$$\frac{\text{CPT (AbMx - MDM1)} + \text{MDM1}}{100}$$

(Substituting CPT's from b above:)

Probable 1-day maximum temperature -

$$3/31 \text{ (3 May days in 1 year)} \quad \frac{88 (93 - 62)}{100} + 62 = 89\text{F}$$

$$1/93 \text{ (1 May day in 3 years)} \quad \frac{95 (93 - 62)}{100} + 62 = 91\text{F}$$

$$1/930 \text{ (1 May day in 30 years)} \quad \frac{104 (93 - 62)}{100} + 62 = 94\text{F}$$

$$1/2170 \text{ (1 May day in 70 years)} \quad \frac{107 (93 - 62)}{100} + 62 = 95\text{F}$$

Therefore the expected May maximum temperature at Shreveport will be 89F or more 3 days in a year; 91F in 3 years; 94F in 30 years; 95F in 70 years.

USING THE NOMOGRAPH: Example 3 - 70-Year Record. "Duration" Section needed for solution.

Given: In September* in Shreveport, during a 71-year record:
AbMx, 105F MDMx, 89F MDM1, 67F

Required: What September daily maximum temperature may be expected:

*See note associated with Table II.

5 days in 1 year, i.e., 5 days in 1 Sept, 5/30?
 1 day in 5 years (5 Septembers) 1/150?
 1 day in 10 years (10 Septembers) 1/300?
 1 day in 40 years, 1/1200? (to agree with other 30-day figs.)

Solution:

a. Find the 70-Year CMDMx

For 1a (as Example A) $CMDMx = \frac{100 (MDMx - MDM1)}{AbMx - MDM1}$

(Substituting:) $\frac{100 (89 - 67)}{105 - 67} = 57.9 \text{ or } 58 \text{ (rounded)}$

b. Find the 10-year (record) equivalent CMDMx

Method: Follow arrows and signs (ø) on vertical line 70 (70 years) in "Duration" Section of Nomograph downward to CMDMx 58 thence left and upward on nearest sloping line to 10-yr vertical line (accentuated). This intersection is on CMDMx 63. Use the CPT values of CMDMx 63 for predicting on the 10-year nomograph.

c. Find associated CPT values

Method: On CMDMx 63, in the Basic and Extrapolated Sections, find the place where it crosses the required curved prediction lines,* follow this up to the CPT value at top of graph. These CPT's are:

5/31, 82 1/155, 97 1/310, 100
 1/1240, 106; 1/2170, 108; 1/2790, 109

d. Find AbMx for 10 years (i.e., equaled or exceeded in 10 Septembers)

Method: In the Extrapolated Section follow CMDMx 63 to the 70-yr predictive line, thence upward to CPT 108. The 70-yr AbMx (105F) is CPT 108 on the 10-yr nomograph

Formula: $10\text{-yr Mx} = \frac{100 (70 \text{ yr AbMx} - 70 \text{ yr MDM1})}{70 \text{ yr CPT, CMDMx } 63} + MDM1$

$100 \frac{(105 - 67)}{108} + 67 = 102F$

*See footnote Section 14. See "Example B", far left on the Nomograph

e. Reconvert to °F as in Example A

Formula (DMx associated with given frequencies):

$$\frac{\text{CPT (10-yr AbMx - 70-yr MDMi)}}{100} + \text{MDMi}$$

Substituting CPT's from c above:

$$\text{Predicted DMx 5/31} \quad \frac{82 (102 - 67)}{100} + 67 = 96\text{F}$$

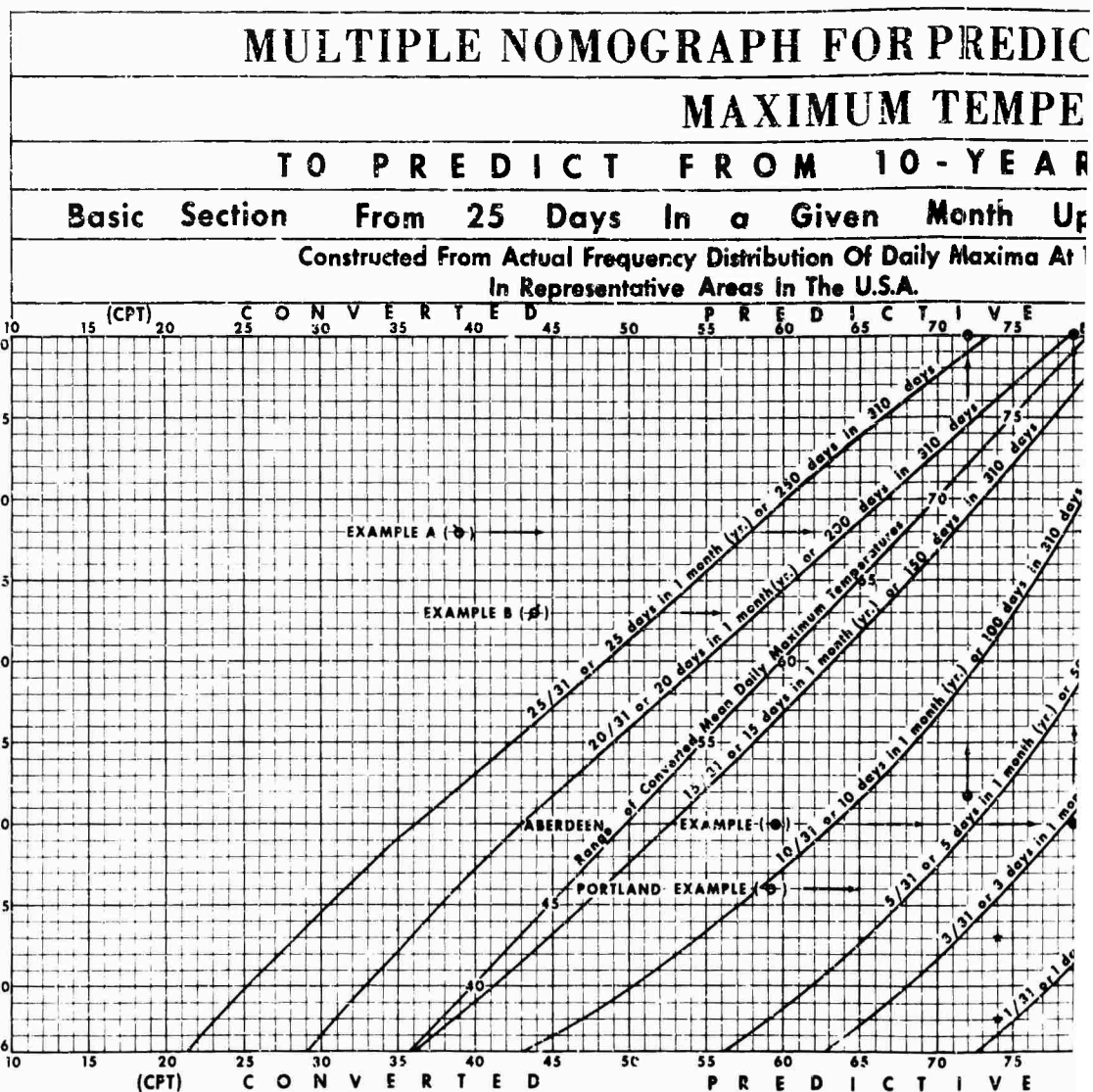
$$\text{Predicted DMx, 1/155} \quad \frac{97 (102 - 67)}{100} + 67 = 101\text{F}$$

$$\text{Predicted DMx 1/310} \quad \frac{100 (102 - 67)}{100} + 67 = 102\text{F}$$

$$\text{Predicted DMx 1/1240} \quad \frac{106 (102 - 67)}{100} + 67 = 104\text{F}$$

$$\text{Predicted DMx 1/2170} \quad \frac{108 (102 - 67)}{100} + 67 = 105\text{F}$$

$$\text{Predicted DMx 1/2790} \quad \frac{109 (102 - 67)}{100} + 67 = 106\text{F}$$



Explanation of General Symbols:

- ★ Stars in the Basic Section represent paired converted temperature values(CM
- ▲ Triangles in the Extrapolated Section represent CPT values extrapolated from and used to construct the 1/620 prediction curved line.
- Dots in the "Duration" Section for line "xy", identifying the CMDMx 60 (on values to use in place of 12 different patterns of longer or shorter records(1, Examples A and B are discussed in Appendix C.
- Examples Aberdeen and Portland are discussed in the text, Sections 6 and

Figure 2

Predicting From Long Records Up to 100 Years

Extropolated Section
Increments, 20 to 100 years

Duration Section

**Extrapolated From
Basic Section**

TO FIND THE 10 YEAR CMGMx EQUIVALENTS



APPENDIX D

**TABLE III - PATTERNS OF CONVERTED MEAN DAILY MAXIMUM TEMPERATURES (CMDMx)
WITH ASSOCIATED CONVERTED PREDICTION TEMPERATURE VALUES CPT KEYED TO
A 100-UNIT SCALE AND A 10-YEAR RECORD, AND USED TO CALCULATE THE
PROBABLE LEVEL AND FREQUENCY OF DAILY MAXIMUM TEMPERATURES**

Explanation and Use:

1. This is a table of constant values taken from the Multiple Nomograph (Fig. 2). It is presumed to cover (approximately) the various patterns of daily maximum temperature distributions through the 5 or 6 summer months. The table is constructed to resemble somewhat the nomograph from which the data are taken.
2. There are 45 Converted Mean Daily Maxima (CMDMx 36 to 80, left column) and associated with each in the rectangular cells on the same line are (numbers underlined) converted predictive temperatures (CPT) which probably will be equaled or exceeded in the time span specified at the top of the columns. For example, CPT values 35 in column 25/31 is associated with CMDMx 50 pattern. The other CPT's (underlined numbers) in this pattern are: 20/31, 44; 15/31, 52; 10/31, 63; 5/31, 72; etc., to 1/310, 100 and 1/3100, 115 (19 CPT underlined values associated with each CMDMx (36 to 80, left margin).
3. Notice that the table centers on the accentuated double column (1/310) 1 day in 10 years, 310 days, because the nomograph was constructed from 36, 10-year (monthly) records. For this reason, the 10-year Daily Maximum is always 100-units on the converted scale. Note that the CMDM1 is always reduced to zero (0) in this study.
4. Using Table III for Predictions. Example A - 10-Year Record.*
(Only underlined numbers on the table are involved).

Given: In May at Aberdeen, Maryland, during a 10-year period:
AbMx, 95F MDMx, 74F MDM1, 53F

Required: What May maximum temperature may be equaled or exceeded in 5 years? 30 years? 60 years? 90 years?

Solution:

a. Find CMDMx

$$\text{Formula: } \text{CMDMx} = \frac{100 (\text{MDMx} - \text{MDM1})}{\text{AbMx} - \text{MDM1}}$$

*This example was also discussed in section 6, using Nomograph

$$(\text{Substituting:}) \quad \frac{100 (74 - 53)}{95 - 53} = 50$$

CMIMx 50 is the May pattern for predicting DMx temperatures at Aberdeen

- b. Find required CPT's (converted predictive temperatures for required time intervals)

Method: Follow CMIMx 50 from left margin to each required time interval - indicated in column heading at top of nomograph. These CPT's are:

For 5 yrs, <u>96</u>	30 yrs, <u>107</u>
60 yrs, <u>112</u>	90 yrs, <u>114</u>

- c. Reconvert to °F

Formula: (DMx associated with given frequency)

$$\frac{\text{CPT} (\text{AbMx} - \text{MIMx})}{100} + \text{MIMx}$$

(Substituting CPT's from b above:)

$$\text{Predicted 5-yr Max (1/155)} \quad \frac{96 (95 - 53)}{100} + 53 = 93\text{F}$$

$$\text{Predicted 30-yr Max (1/930)} \quad \frac{107 (95 - 53)}{100} + 53 = 98\text{F}$$

$$\text{Predicted 60-yr Max (1/1860)} \quad \frac{112 (95 - 53)}{100} + 53 = 100\text{F}$$

$$\text{Predicted 90-yr Max (1/2790)} \quad \frac{114 (95 - 53)}{100} + 53 = 101\text{F}$$

Therefore the expected May maximum temperature at Aberdeen in 5 years will equal or exceed 93F. In 30 yrs, 98F. In 60 yrs, 100F and in 90 yrs 101F.

5. Using Table III. Example B - 67-Year Record.
(Numbers not underlined on the table are involved).

Given: In July at Kansas City, Missouri, during a 67-year record:
AbMx: 112F MIMx, 92F MIMI, 71F

Required: What July maximum temperature may be equaled or exceeded 1 day in: 10 years? 3 years? 40 years? 60 years? 90 years?

Solution:

- a. Find the 70-year record CNDMx

$$\text{Formula: } \text{CNDMx} = \frac{100 (\text{MDMx} - \text{MDM1})}{\text{AbMx} - \text{MDM1}}$$

$$(\text{Substituting:}) \quad \frac{100 (92 - 71)}{112 - 71} = 51.2 \text{ or } \underline{51} \text{ (rounded)}$$

- b. Find the 10-yr (record) equivalent to CNDMx 51 in 70-yr column:

Method: Follow down the 70-year column to the number 51 (not underlined). This is found on the CNDMx 56 line. Therefore, the CNDMx 56 pattern of CPT values will be used for prediction.

- c. Find the required CPT's (converted predictive temperatures for required time intervals) using CNDMx 56 pattern.

Method: As in Example A above. These CPT's are:
For 10 yrs, 100 For 3 yrs, 94 For 40 yrs, 107
For 60 yrs, 110 For 90 yrs, 111

- d. Find the 10-yr (record) predicted Absolute Maximum

$$\text{Formula: } \frac{100 (70 \text{ yr AbMx} - 70 \text{ yr MDM1})}{70 \text{ yr CPT, CNDMx 56}} + \text{MDM1}$$

*(this value is in the 70-yr column, CNDMx 56 line of table. That is, the 70-yr AbMx is CPT 110 on the 10-yr table)

$$(\text{Substituting:}) \quad \frac{100 (112 - 71)}{110} + 71 = 108^{\circ}\text{F}$$

- e. Reconvert to °F (using 108°F as AbMx)

Formula: DMx associated with given frequencies:

$$\frac{\text{CPT (10-yr AbMx} - 70\text{-yr MDM1)}}{100} + \text{MDM1}$$

(Substituting CPT's from
c above:)

$$\text{Predicted 3-yr maximum } \frac{94(108 - 71)}{100} + 71 = 106F$$

$$\text{Predicted 40-yr maximum } \frac{107(108 - 71)}{100} + 71 = 111F$$

$$\text{Predicted 60-yr maximum } \frac{110(108 - 71)}{100} + 71 = 112F$$

$$\text{Predicted 90-yr maximum } \frac{111(108 - 71)}{100} + 71 = 112F$$



TABLE III. TABLE EQUIVALENT OF THE RECORDS

Constructed from 10-Year Actual Frequencies
Constructed by Extrapolation from 10-Year Frequency Records

Old Frequency in Days	25/31	20/31	15/31	10/31	5/31	3/31	1/31	1/93	1/155	1/310	1/600	1/930	1/1240	1/1550	1/1860	1/2170	1/2480	1/2790	1/3100	Old
Frequency in 5 Years of Record	64.5	46.4	32.3	16.1	9.08	3.47	1.075	1.075	1.075	1.075	1.075	1.075	1.075	1.075	1.075	1.075	1.075	1.075	1.075	Max
80	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	80
79	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	79
78	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	78
77	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	77
76	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	76
75	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	75
74	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	74
73	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	73
72	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	72
71	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	71
70	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	70
69	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	69
68	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	68
67	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	67
66	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	66
65	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	65
64	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	64
63	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	63
62	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	62
61	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	61
60	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	60
59	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	59
58	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	58
57	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	57
56	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	56

70	100 70	103 68	104 67	105 67	106 66	106 66	107 65	107 65	108 65	108 65	70
69	100 69	103 67	104 66	105 66	106 65	106 65	107 64	107 64	108 64	108 64	69
68	100 68	103 66	104 65	105 65	106 64	106 64	107 63	107 63	108 63	108 63	68
67	100 67	103 65	104 64	105 64	106 63	106 63	107 62	107 62	108 62	108 62	67
66	100 66	103 64	104 63	105 63	106 62	106 62	107 61	107 61	108 61	108 61	66
65	100 65	103 63	104 62	105 62	106 61	106 61	107 60	107 60	108 60	108 60	65
64	100 64	103 62	104 61	105 61	106 60	106 60	107 59	107 59	108 59	108 59	64
63	100 63	103 61	104 60	105 60	106 59	106 59	107 58	107 58	108 58	108 58	63
62	100 62	103 60	104 59	105 59	106 58	106 58	107 57	107 57	108 57	108 57	62
61	100 61	103 59	104 58	105 58	106 57	106 57	107 56	107 56	108 56	108 56	61
60	100 60	103 58	104 57	105 57	106 56	106 56	107 55	107 55	108 55	108 55	60
59	100 59	103 57	104 56	105 56	106 55	106 55	107 54	107 54	108 54	108 54	59
58	100 58	103 56	104 55	105 55	106 54	106 54	107 53	107 53	108 53	108 53	58
57	100 57	103 55	104 54	105 54	106 53	106 53	107 52	107 52	108 52	108 52	57
56	100 56	103 54	104 53	105 53	106 52	106 52	107 51	107 51	108 51	108 51	56
55	100 55	103 53	104 52	105 52	106 51	106 51	107 50	107 50	108 50	108 50	55
54	100 54	103 52	104 51	105 51	106 50	106 50	107 49	107 49	108 49	108 49	54
53	100 53	103 51	104 50	105 50	106 49	106 49	107 48	107 48	108 48	108 48	53
52	100 52	103 50	104 49	105 49	106 48	106 48	107 47	107 47	108 47	108 47	52
51	100 51	103 49	104 48	105 48	106 47	106 47	107 46	107 46	108 46	108 46	51
50	100 50	103 48	104 47	105 47	106 46	106 46	107 45	107 45	108 45	108 45	50
49	100 49	103 46	104 45	105 45	106 44	106 44	107 43	107 43	108 43	108 43	49
48	100 48	103 45	104 44	105 44	106 43	106 43	107 42	107 42	108 42	108 42	48
47	100 47	103 44	104 43	105 43	106 42	106 42	107 41	107 41	108 41	108 41	47
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40	100 40	103 37	104 36	105 36	106 35	106 35	107 34	107 34	108 34	108 34	40
39	100 39	103 36	104 35	105 35	106 34	106 34	107 33	107 33	108 33	108 33	39
38	100 38	103 35	104 34	105 34	106 33	106 33	107 32	107 32	108 32	108 32	38
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