A METHOD FOR COMPUTING SURFACE-AIR TEMPERATURE FREQUENCIES OVER THE NORTH ATLANTIC OCEAN[1]

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ABSTRACT

A set of regression equations, which relate the 05, 25, 50, 75, and 95 per cent points of the surface-air temperature frequency distributions over the North Atlantic Ocean to mean temperatures interpolated from charts contained in the *U. S. Navy Marine Climatic Atlas of the World, Vol. I, North Atlantic Ocean*, is obtained. With these equations and the previously mentioned climatic atlas, one can estimate the surface-air temperature frequency distribution at any given point over the North Atlantic Ocean. Tests conducted with independent data indicate that the equations give accurate results.

1. Introduction

As an indicator of human comfort, and also for purposes of applied climatology, it is important to know what percentage of the time various temperatures are exceeded (at the earth's surface) during particular months at given locations [1; 3]. As pointed out by Court [1], this information is best summarized by including, in a single frequency distribution, temperatures measured at different hours of the day. At land stations, frequency distributions of hourly temperatures have been used for the purposes cited above (for example, [1; 3]).

To obtain frequency distributions of a similar nature

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TABLE 1. Positions of nine North Atlantic OVS.

Station	Latitude	Longitude
A	62.0N	33.0W
B	56.5N	51.0W
C	52.8N	35.5W
D	44.0N	41.0W
E	35.0N	48.0W
H	36.7N	69.6W
I*	59.3N	16.4W
J	52.5N	20.0W
M	66.0N	02.0E

* Station I is alternately operated from two positions: 59.0N–19.0W, and 60.7N–13.7W [2]. To make the records of station I comparable with those at the other OVS, an average position of 59.3N–16.4W was selected for this station. Consistent with the international agreement which determines "on station" observations for the OVS [2], only observations made within a square, having sides of 210 n m, centered on the point 59.3N–16.4W, were included in the station I tabulations.

TABLE 2. Percentage frequency of the various 3-hourly temperatures (F) at station A.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
17 and 18	00.0											
19 and 20	00.4											
21 and 22	00.1	00.0	00.0	00.0								
23 and 24	01.2	00.5	00.1	00.2								00.0
25 and 26	01.5	01.3	01.4	00.9								00.3
27 and 28	05.8	03.2	04.0	01.3						00.0	00.0	02.9
29 and 30	06.5	04.7	05.6	02.4						00.3	00.2	02.4
31 and 32	08.4	07.4	12.6	05.0						00.3	00.4	07.0
33 and 34	13.4	13.9	11.5	12.6	00.0					00.4	01.3	14.2
35 and 36	19.7	17.6	16.2	17.0	00.7				00.0	01.9	03.0	20.9
37 and 38	20.7	18.1	16.4	14.1	05.2	00.0			00.1	04.3	08.5	14.3
39 and 40	10.7	14.8	14.5	19.9	18.1	01.1			01.4	12.1	23.7	15.1
41 and 42	05.9	08.5	08.5	13.4	23.3	03.2	00.0		02.6	26.5	24.3	10.0
43 and 44	04.3	08.1	07.1	10.8	16.6	11.5	02.5	00.0	08.7	25.9	19.1	07.2
45 and 46	01.1	01.4	01.9	02.4	21.5	33.0	12.4	01.9	22.2	15.0	18.1	05.6
47 and 48	00.0	00.1	00.2	00.0	04.0	38.1	19.6	15.3	27.8	10.6	01.5	00.0
49 and 50		00.0	00.0		00.4	11.5	36.3	46.4	26.4	03.1	00.0	
51 and 52					00.1	01.5	22.5	29.6	09.9	00.0		
53 and 54					00.0	00.0	05.8	06.3	01.0			
55 and 56							00.6	00.6	00.1			
57 and 58							00.3	00.0	00.0			
59 and 60							00.0					

TABLE 3. Percentage frequency of the various 3-hourly temperatures (F) at station B.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
3 and 4	00.0											
5 and 6	00.2											
7 and 8	00.2											
9 and 10	00.1	00.0										
11 and 12	00.3	00.1										
13 and 14	00.5	00.4										00.0
15 and 16	01.2	00.9	00.0									00.1
17 and 18	02.3	03.7	00.3									00.4
19 and 20	07.6	06.1	00.6	00.0							00.0	01.6
21 and 22	09.5	06.5	01.1	00.2							00.3	02.0
23 and 24	09.3	07.5	03.2	02.1							00.2	02.1
25 and 26	10.8	09.6	05.2	03.8							00.6	05.2
27 and 28	09.8	10.0	05.5	05.0							00.8	12.0
29 and 30	10.0	10.7	09.0	03.5	00.0					00.0	02.7	13.7
31 and 32	09.5	11.1	13.0	04.3	00.1	00.0			00.0	00.2	09.6	13.6
33 and 34	11.3	10.0	16.2	12.6	00.7	00.1			00.2	02.8	15.9	12.8
35 and 36	09.9	07.7	17.6	21.3	14.0	00.3			00.4	11.9	17.9	13.0
37 and 38	04.3	06.9	17.0	25.0	25.9	03.9			00.9	19.5	21.0	09.5
39 and 40	02.2	05.3	08.0	18.5	33.8	17.1	00.0		04.4	22.2	17.7	09.7
41 and 42	00.8	03.0	03.2	03.3	21.4	28.3	02.3	00.0	07.7	21.1	10.1	03.5
43 and 44	00.1	00.3	00.1	00.3	03.9	26.0	07.8	02.3	12.7	13.5	02.6	00.7
45 and 46	00.0	00.0	00.0	00.1	00.3	18.2	30.4	17.5	27.1	06.4	00.6	00.0
47 and 48				00.0	00.0	04.9	31.6	33.7	23.4	02.3	00.0	
49 and 50						01.1	19.8	28.1	19.1	00.2		
51 and 52						00.2	07.6	13.4	04.0	00.0		
53 and 54						00.0	00.7	04.7	00.0			
55 and 56							00.0	00.3				
57 and 58								00.0				

for ocean locations, it is, in general, necessary to employ indirect methods.[2] This is so because only at the ocean-vessel stations (hereafter designated by OVS) do there exist meteorological observations made at consecutive and equal intervals of time.[3] It is the purpose of this article to show that frequency distributions of temperature, constructed from observations made at the North Atlantic OVS, can be used in conjunction with a climatic atlas of the North Atlantic Ocean to obtain an estimate of the temperature frequency distribution for any month at any location over the North Atlantic Ocean.

2. Procedure

The nine North Atlantic OVS considered here are identified by table 1. Tables 2 through 10 give frequency distributions of temperature[4] for each month at each of these OVS. These tables contain a total of

[2] Indeed, because of data problems, it has been found necessary to resort to indirect methods even at land stations [3].

[3] The ocean-vessel stations make eight 3-hourly observations of surface-air temperature per day.

[4] All temperatures in this paper are given in degrees Fahrenheit.

TABLE 4. Percentage frequency of the various 3-hourly temperatures (F) at station C.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
25 and 26	00.0	00.0										
27 and 28	00.4	00.1										00.0
29 and 30	01.2	01.4	00.0									00.1
31 and 32	02.0	03.3	00.1	00.0								00.6
33 and 34	03.0	05.0	00.6	01.2							00.0	01.9
35 and 36	09.2	08.0	03.0	02.7	00.0						00.7	03.8
37 and 38	12.7	12.2	11.7	04.5	00.1					00.0	01.9	07.2
39 and 40	13.1	16.3	16.7	12.6	00.5	00.0				00.9	06.6	11.1
41 and 42	13.7	12.0	23.4	17.8	07.1	00.1			00.0	02.3	15.2	15.8
43 and 44	11.2	12.3	20.1	17.7	14.4	00.7			00.1	09.0	18.1	17.9
45 and 46	10.0	13.3	14.7	18.4	23.1	05.8	00.0	00.0	00.8	15.5	18.6	16.6
47 and 48	11.4	08.6	06.6	14.3	21.0	11.3	00.5	00.2	04.4	21.1	13.9	09.8
49 and 50	07.8	03.6	02.0	08.6	19.2	22.1	08.3	03.6	14.2	22.7	15.1	08.9
51 and 52	04.2	03.6	01.2	02.1	11.0	16.6	26.0	20.8	22.9	12.7	08.3	06.0
53 and 54	00.3	00.5	00.0	00.3	03.0	19.7	22.2	29.3	19.4	09.4	01.5	01.0
55 and 56	00.0	00.0		00.0	00.6	08.9	23.7	19.8	18.6	04.4	00.0	00.3
57 and 58					00.1	04.3	08.0	12.9	07.0	01.4		00.0
59 and 60					00.0	00.6	06.9	08.1	03.6	00.6		
61 and 62						00.0	03.6	04.5	06.9	00.0		
63 and 64							00.7	00.7	02.1			
65 and 66							00.0	00.0	00.1			
67 and 68									00.0			

TABLE 5. Percentage frequency of the various 3-hourly temperatures (F) at station D.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
33 and 34	00.0											
35 and 36	00.1	00.0										
37 and 38	00.5	00.6	00.0	00.0								00.0
39 and 40	01.5	01.5	00.1	00.4								00.2
41 and 42	02.1	02.3	01.7	00.5								00.5
43 and 44	04.1	04.7	02.0	00.5	00.0	00.0					00.0	02.7
45 and 46	05.4	05.5	05.8	02.9	00.3	00.1				00.0	00.2	04.0
47 and 48	06.1	06.2	07.3	03.7	01.6	00.0				00.5	00.6	06.8
49 and 50	09.4	08.8	08.5	07.4	03.9	00.2				01.2	02.7	06.2
51 and 52	07.1	09.2	11.2	07.4	07.0	00.8				03.9	04.4	05.7
53 and 54	08.2	09.5	12.4	09.7	09.4	03.2			00.0	05.1	07.0	08.2
55 and 56	09.6	10.5	12.8	10.4	14.8	04.7	00.0		00.4	08.0	10.3	08.0
57 and 58	07.5	09.2	10.0	14.5	14.5	09.1	01.2	00.0	01.6	12.3	13.4	07.6
59 and 60	09.5	12.2	12.8	17.1	17.0	10.9	04.6	00.4	03.8	13.2	14.4	12.0
61 and 62	12.6	13.2	10.6	14.7	15.9	16.8	07.1	00.8	07.6	11.9	12.7	13.1
63 and 64	13.0	06.2	04.1	09.2	12.9	22.3	10.7	03.3	12.0	12.0	11.3	13.2
65 and 66	04.2	00.2	00.8	01.6	02.1	21.3	18.8	09.5	19.9	14.3	13.2	08.1
67 and 68	00.1	00.0	00.1	00.0	00.5	09.8	20.0	16.5	19.6	10.3	06.7	03.5
69 and 70	00.0		00.0	00.1	00.0	00.6	15.3	17.4	14.1	04.9	02.5	00.0
71 and 72				00.0		00.1	13.0	15.9	09.6	02.2	00.7	
73 and 74						00.0	07.2	16.9	08.6	00.2	00.0	
75 and 76							02.1	15.1	02.2	00.0		
77 and 78							00.0	04.1	00.2			
79 and 80								00.3	00.1			
81 and 82								00.0	00.0			

108 frequency distributions (9 stations × 12 months). The distributions are based on 4 years of record (1951 through 1954 for the months January through June; 1950 through 1953 for the months July through December). The number of 3-hourly observations available for the construction of each of these distributions is given by table 11.

As a first step in relating these frequency distributions to data which are generally available, mean temperatures ($\bar{T}_A$) were interpolated, for each month at each OVS, from the *U. S. Navy Marine Climatic Atlas of the World, Vol. I, North Atlantic Ocean* [4]. These are given by table 12. Next, scatter diagrams of $\bar{T}_A$ against each of the 05, 25, 50, 75, and 95 per cent points[5] of the frequency distributions were plotted (figs. 1 through 5). These scatter diagrams are based on only 90 of the 108 distributions. Eighteen distributions, identified by table 13, were withheld in order to have independent data upon which to test whatever relationships might evolve from the scatter diagrams. These 18 distributions were selected at random with, however, the stipulation that each OVS be represented twice and only twice. The selection was made by drawing slips of paper from a hat until two months had been drawn for each station.

[5] The ξ per cent point of a frequency distribution is that value of the variate which is exceeded by 100-ξ per cent of the observations.

TABLE 6. Percentage frequency of the various 3-hourly temperatures (F) at station E.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
47 and 48		00.0	00.0									
49 and 50		00.1	00.2									
51 and 52	00.0	00.0	00.1	00.0								
53 and 54	00.1	00.8	00.6	00.6								
55 and 56	01.2	02.0	01.9	00.8	00.0							00.0
57 and 58	03.6	06.2	05.6	01.5	00.4						00.0	00.3
59 and 60	04.9	08.3	09.5	05.4	01.6						00.1	01.9
61 and 62	11.6	15.5	17.6	08.1	02.7	00.0				00.0	00.3	04.8
63 and 64	17.9	18.5	24.6	24.3	09.9	00.2				00.3	04.0	10.6
65 and 66	27.4	27.1	26.2	35.6	22.0	02.5				00.5	05.8	23.5
67 and 68	23.1	17.1	12.6	19.6	31.8	06.3			00.0	02.3	13.1	25.2
69 and 70	09.7	04.3	01.1	03.6	26.0	16.7	00.0		00.4	07.3	20.5	23.4
71 and 72	00.4	00.0	00.0	00.4	05.1	34.6	02.3	00.0	01.1	11.1	31.2	09.3
73 and 74	00.0			00.0	00.6	26.6	09.2	00.5	08.5	20.9	20.0	01.0
75 and 76					00.0	10.1	29.8	03.4	21.7	38.2	05.0	00.0
77 and 78						02.3	38.5	27.3	32.6	16.2	00.0	
79 and 80						00.6	17.9	46.3	26.8	02.7		
81 and 82						00.0	02.2	18.5	08.2	00.1		
83 and 84							00.2	03.8	00.6	00.0		
85 and 86							00.0	00.2	00.0			
87 and 88								00.0				

TABLE 7. Percentage frequency of the various 3-hourly temperatures (F) at station H.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
31 and 32		00.0										
33 and 34		00.1										
35 and 36		00.3	00.0									
37 and 38	00.0	00.3	00.1									00.0
39 and 40	00.2	00.3	00.1									00.2
41 and 42	00.5	00.5	00.4									00.3
43 and 44	00.7	01.2	01.0								00.0	00.8
45 and 46	01.9	01.2	01.4	00.0							00.1	01.5
47 and 48	01.9	01.6	04.5	00.8							00.3	01.7
49 and 50	04.1	03.8	05.5	00.5							00.6	04.0
51 and 52	07.0	04.8	06.9	01.7							00.5	04.1
53 and 54	07.9	11.0	09.3	01.6						00.0	01.3	06.4
55 and 56	07.4	15.1	12.4	02.5	00.0					00.3	03.3	07.5
57 and 58	10.8	13.7	10.8	06.3	00.5					01.0	04.4	11.1
59 and 60	10.3	11.7	12.5	09.2	01.2					00.6	06.0	12.2
61 and 62	08.6	08.4	09.4	10.2	04.8				00.0	01.1	09.2	10.6
63 and 64	09.7	10.2	09.5	11.0	07.3	00.0			00.3	01.4	11.1	10.7
65 and 66	16.3	09.6	10.0	19.7	11.5	01.0			00.7	03.9	11.1	09.3
67 and 68	11.1	05.7	05.8	20.8	14.2	04.0	00.0		01.6	07.8	11.2	09.9
69 and 70	01.5	00.5	00.4	12.3	18.9	05.6	00.5	00.0	04.1	14.9	15.0	06.9
71 and 72	00.0	00.0	00.0	03.0	23.2	17.0	00.9	01.0	06.8	20.3	12.7	03.8
73 and 74				00.5	11.4	22.8	04.1	04.3	10.9	21.8	08.3	00.1
75 and 76				00.0	04.9	21.1	09.4	11.3	18.2	17.4	04.4	00.0
77 and 78					01.8	19.8	25.0	20.0	27.9	07.8	00.4	
79 and 80					00.2	07.3	36.0	32.5	19.4	01.4	00.0	
81 and 82					00.1	01.5	18.7	23.1	08.3	00.1		
83 and 84					00.0	00.1	04.6	07.2	01.7	00.0		
85 and 86						00.0	00.7	00.6	00.0			
87 and 88							00.1	00.0				
89 and 90							00.0					

Figs. 1 through 5 indicate that fairly strong linear relationships exist between $\bar{T}_A$ and each of the 05, 25, 50, 75, and 95 per cent points (T_{05}, T_{25}, T_{50}, T_{75}, and T_{95}, respectively). Hence, linear-regression equations were obtained by the method of least squares for each of the scatter diagrams. These equations, together with the corresponding linear correlation coefficients, are listed below.

$$\hat{T}_{05} = 1.05\ \bar{T}_A - 8.59, \quad r = 0.98 \qquad (1)$$

$$\hat{T}_{25} = 1.02\ \bar{T}_A - 3.47, \quad r = 0.98 \qquad (2)$$

$$\hat{T}_{50} = 1.01\ \bar{T}_A + 0.18, \quad r = 0.98 \qquad (3)$$

$$\hat{T}_{75} = 0.98\ \bar{T}_A + 4.28, \quad r = 0.97 \qquad (4)$$

$$\hat{T}_{95} = 0.96\ \bar{T}_A + 7.99, \quad r = 0.97 \qquad (5)$$

It should be pointed out that the exceptionally high correlation coefficients obtained above are partially due to the fact that $\bar{T}_A$, T_{05}, T_{25}, T_{50}, T_{75}, and T_{95} have annual variations which are very much in phase. Hence, a certain amount of month-to-month persistence (serial correlation) is reflected in the correlation

TABLE 8. Percentage frequency of the various 3-hourly temperatures (F) at station I.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
25 and 26		00.0										
27 and 28		00.1		00.0							00.0	00.0
29 and 30	00.0	00.7	00.0	00.6	00.0						00.1	01.3
31 and 32	00.2	00.8	00.4	00.8	00.1						00.4	01.6
33 and 34	01.4	01.8	01.7	00.7	00.0					00.0	00.0	03.5
35 and 36	04.3	04.2	02.9	03.9	00.2					00.1	00.4	04.2
37 and 38	07.1	06.7	04.4	05.3	00.4	00.0				00.3	00.7	05.0
39 and 40	11.1	14.1	11.8	12.2	04.5	00.1				01.1	02.7	07.2
41 and 42	11.1	13.8	14.1	14.0	04.6	00.9			00.0	02.2	11.0	08.2
43 and 44	16.0	13.0	15.5	18.5	04.4	01.0			00.6	04.6	15.1	13.8
45 and 46	17.1	18.5	15.8	15.6	09.5	04.6		00.0	01.1	10.8	20.0	19.9
47 and 48	17.7	17.8	21.5	19.8	26.2	13.7	00.0	00.1	07.2	19.8	14.5	13.3
49 and 50	13.3	07.9	11.8	08.5	38.4	28.7	01.9	02.1	11.7	27.4	20.9	15.3
51 and 52	00.7	00.5	00.2	00.0	11.3	32.1	22.0	13.8	21.6	23.7	12.6	07.0
53 and 54	00.1	00.0	00.0		00.6	16.3	37.2	38.2	35.6	08.6	01.7	00.0
55 and 56	00.0				00.0	02.3	33.7	38.1	19.9	01.4	00.0	
57 and 58						00.2	04.7	07.1	02.4	00.0		
59 and 60						00.0	00.4	00.5	00.1			
61 and 62							00.0	00.2	00.0			
63 and 64								00.0				

TABLE 9. Percentage frequency of the various 3-hourly temperatures (F) at station J.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
33 and 34	00.0	00.0		00.0								00.0
35 and 36	00.4	00.7		00.5								00.1
37 and 38	01.3	01.0	00.0	00.5	00.0					00.0	00.0	00.4
39 and 40	02.9	04.0	01.1	00.7	00.2					00.1	00.1	01.3
41 and 42	07.0	07.9	02.2	02.2	00.1					00.0	00.2	04.6
43 and 44	10.9	11.8	09.8	05.9	01.4					00.1	01.5	09.4
45 and 46	14.4	12.9	15.9	21.7	01.9	00.0			00.0	01.5	08.0	14.6
47 and 48	15.1	15.2	20.1	19.5	06.8	00.7			00.1	05.8	17.2	18.4
49 and 50	16.8	22.4	21.3	19.1	14.8	03.9		00.0	01.5	09.9	19.9	20.0
51 and 52	21.9	19.2	25.2	23.4	20.0	10.5	00.0	00.6	05.0	20.5	21.2	14.9
53 and 54	08.9	04.5	04.2	05.5	38.2	30.6	02.3	06.5	19.4	21.2	18.3	11.7
55 and 56	00.5	00.0	00.1	00.9	16.3	34.7	19.6	25.1	29.7	26.1	12.8	04.4
57 and 58	00.0		00.0	00.1	00.3	18.2	36.2	38.2	24.5	13.2	00.7	00.2
59 and 60				00.1	00.0	01.5	27.5	26.8	15.3	01.7	00.0	00.0
61 and 62				00.0		00.0	11.3	02.9	04.2	00.0		
63 and 64							03.1	00.1	00.1			
65 and 66							00.1	00.0	00.1			
67 and 68							00.0		00.0			

coefficients. However, for the purposes of the present paper, this is immaterial. We merely wish to establish the fact that $\bar{T}_A$ has a very close concomitant variation with each of T_{05}, T_{25}, T_{50}, T_{75}, and T_{95}. No cause and effect relationship is implied.

3. Results

Equations (1) through (5), in conjunction with the proper values of $\bar{T}_A$ (table 12), were used to specify T_{05}, T_{25}, T_{50}, T_{75}, and T_{95} for the 18 frequency dis-

TABLE 10. Percentage frequency of the various 3-hourly temperatures (F) at station M.

Temperature	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
21 and 22		00.0	00.0									
23 and 24		00.1	00.3									00.0
25 and 26	00.0	00.1	00.5	00.0								00.5
27 and 28	00.4	01.5	01.8	00.1							00.0	01.3
29 and 30	02.6	02.5	01.7	01.3							00.6	01.7
31 and 32	06.5	05.3	07.4	03.8	00.0						01.4	04.2
33 and 34	11.2	10.1	08.3	06.9	00.1	00.0					04.7	06.4
35 and 36	15.1	13.1	15.1	14.6	01.5	00.2			00.0	00.0	08.1	09.5
37 and 38	16.0	13.2	17.3	17.1	05.4	01.3			00.2	00.5	08.7	11.3
39 and 40	16.6	22.3	14.0	16.3	15.6	05.4			01.5	03.4	09.9	15.2
41 and 42	17.2	21.8	14.6	15.9	22.0	13.1	00.0		02.5	05.3	21.3	18.0
43 and 44	11.4	08.4	17.0	16.9	24.5	13.4	01.3	00.0	03.9	10.2	16.8	14.4
45 and 46	02.9	01.7	01.8	07.0	19.8	17.5	06.4	01.7	11.3	22.0	17.0	13.5
47 and 48	00.1	00.0	00.0	00.0	07.0	20.8	15.3	08.7	14.8	22.2	07.7	03.9
49 and 50	00.0				03.2	17.0	27.6	16.9	17.9	24.4	02.6	00.0
51 and 52					00.7	06.6	21.8	17.1	30.6	10.9	00.0	
53 and 54					00.0	03.1	20.1	21.4	14.8	01.1		
55 and 56						01.3	06.1	23.8	02.0	00.0		
57 and 58						00.2	00.4	09.0	00.4			
59 and 60						00.1	00.0	01.2	00.0			
61 and 62						00.0		00.0				

TABLE 11. Number of "on station" 3-hourly temperature observations available for each month at each OVS.

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
A	728	775	827	658	741	624	749	687	713	782	626	776
B	947	903	992	920	991	960	969	992	939	991	950	968
C	942	904	922	960	959	960	992	961	916	976	861	946
D	908	852	918	940	986	929	960	980	892	959	958	991
E	955	895	937	960	951	956	991	948	918	817	887	973
H	977	883	981	945	991	958	967	973	922	960	959	961
I	723	805	913	944	895	938	885	828	810	896	854	794
J	991	898	950	910	784	849	852	874	803	786	727	916
M	976	882	984	923	988	933	977	984	935	985	951	984

TABLE 12. Values of $\bar{T}_A$ interpolated from the charts given by [4].

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
A	34	35	36	40	43	45	48	49	48	44	40	38
B	27	28	33	35	37	42	47	48	46	41	37	31
C	42	42	44	46	48	52	54	55	54	50	47	44
D	50	50	52	54	58	62	67	69	67	62	58	54
E	63	62	62	64	67	73	77	78	77	74	69	66
H	58	56	58	63	68	74	78	78	77	72	64	60
I	42	42	45	45	48	51	54	54	52	49	46	45
J	48	48	48	49	52	55	58	59	58	55	51	49
M	38	38	37	50	42	48	53	52	50	45	43	41

tributions identified by table 13. The results of this experiment, expressed as differences between estimates and true values, are given by table 14. The table shows that, on the average, the estimates are quite accurate. The average errors for each of the per cent points (last

TABLE 13. Frequency distributions of 3-hourly temperatures not included in the developmental sample.

Station	Month
A	March
A	December
B	September
B	October
C	June
C	July
D	July
D	November
E	August
E	September
H	February
H	May
I	March
I	August
J	February
J	July
M	February
M	December

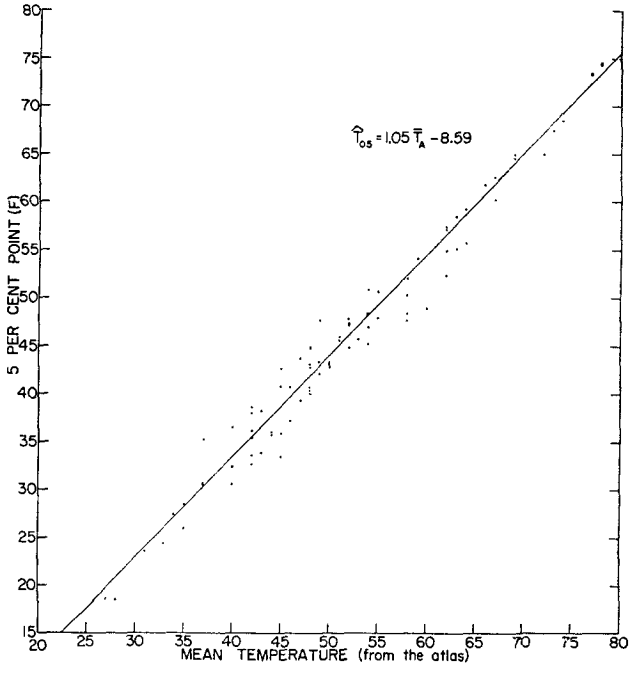

FIG. 1. T_{05} Plotted against $\bar{T}_A$.

TABLE 14. Differences (F) between the estimated per cent points ($\hat{T}_\xi$) and the true per cent points (T_ξ).

Station	Month	$\hat{T}_{05} - T_{05}$	$\hat{T}_{25} - T_{25}$	$\hat{T}_{50} - T_{50}$	$\hat{T}_{75} - T_{75}$	$\hat{T}_{95} - T_{95}$	Average magnitude
A	March	0.9	0.6	0.2	0.1	−0.9	0.5
A	December	1.1	1.0	1.8	1.4	−0.2	1.1
B	September	−0.5	−0.8	0.3	2.0	1.8	1.1
B	October	−0.4	0.9	1.7	2.3	1.9	1.4
C	June	−0.1	0.2	1.3	2.0	1.5	1.0
C	July	−1.8	−0.2	0.9	1.4	−0.5	1.0
D	July	1.5	−0.3	0.7	−0.2	1.2	0.8
D	November	0.9	−0.8	−1.4	−3.1	2.2	1.7
E	August	−3.3	−2.1	−0.2	0.3	0.5	1.3
E	September	−1.2	−0.8	0.3	0.4	0.7	0.7
H	February	2.2	−0.8	−1.2	−3.5	−5.1	2.6
H	May	0.9	−0.6	−0.8	−1.0	−1.9	1.0
I	March	2.2	1.3	1.2	1.0	1.9	1.5
I	August	−3.0	1.5	0.4	1.8	2.7	1.9
J	February	1.5	1.0	0.7	0.9	1.6	1.1
J	July	−2.5	−0.9	1.1	1.8	1.8	1.6
M	February	0.4	0.1	−0.3	0.5	0.8	0.4
M	December	3.2	1.6	1.1	1.1	1.0	1.6
	Average magnitude	1.5	0.9	0.9	1.4	1.6	

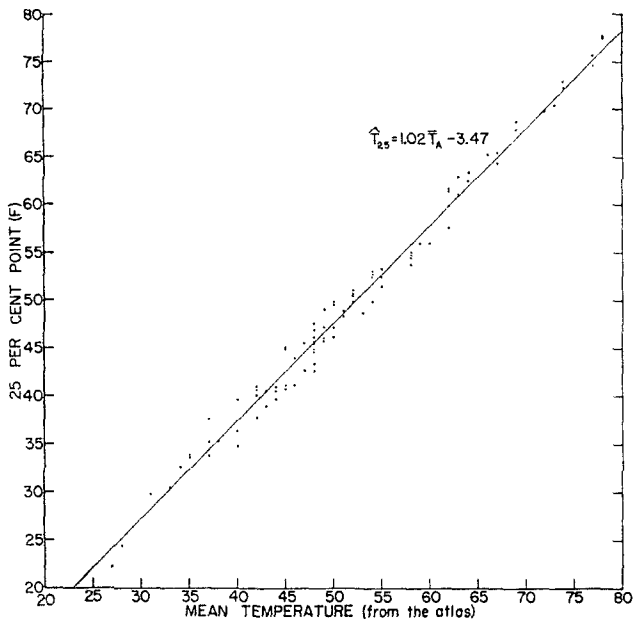

FIG. 2. T_{25} plotted against $\bar{T}_A$.

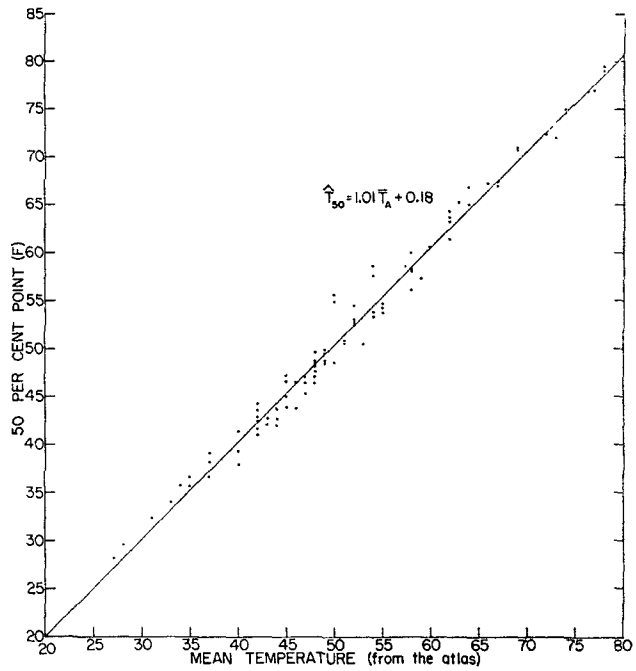

FIG. 3. T_{50} plotted against $\bar{T}_A$.

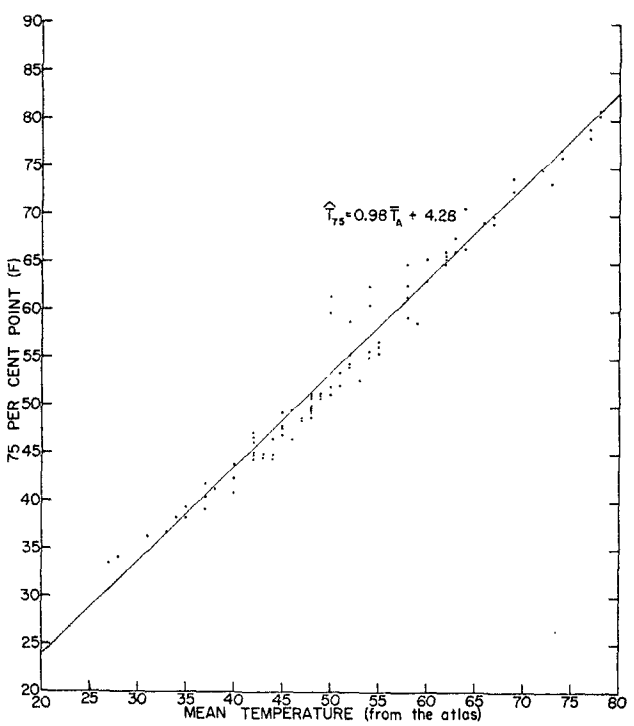

FIG. 4. T_{75} plotted against $\bar{T}_A$.

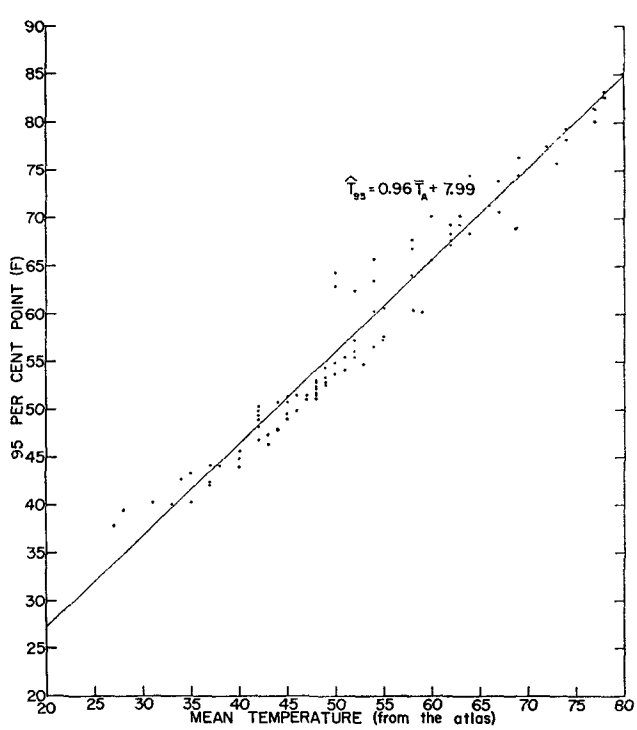

FIG. 5. T_{95} plotted against $\bar{T}_A$.

line of table 14) are less than 1F for the 25 and 50 per cent points and range from 1.4F to 1.6F for the other per cent points. Some of the individual errors are large; the largest is −5.1F (95 per cent point, station H, February).

The last column of table 14 gives the average of the errors obtained in specifying the 05, 25, 50, 75, and 95 per cent points for each of the 18 frequency distributions. As these averages show, the per cent points at station A in March and at station M in February have been very accurately specified; the average errors for these two cases are 0.5F and 0.4F, respectively.

The errors listed by table 14 are summarized, in frequency distribution form, by table 15. Of the 90

TABLE 15. Frequency distributions of the magnitudes of the differences between the estimates of the per cent points and the true per cent points.

Error (F	Cases of $\lvert\hat{T}_{05} - T_{05}\rvert$	Cases of $\lvert\hat{T}_{25} - T_{25}\rvert$	Cases of $\lvert\hat{T}_{50} - T_{50}\rvert$	Cases of $\lvert\hat{T}_{75} - T_{75}\rvert$	Cases of $\lvert\hat{T}_{95} - T_{95}\rvert$
0.0–0.4	3	4	6	4	1
0.5–1.4	6	12	10	7	7
1.5–2.4	5	2	2	5	8
2.5–3.4	4			1	1
3.5–4.4				1	
4.5–5.4					1
Total	18	18	18	18	18

estimates made (five per cent points for each of the 18 distributions), only 8 have errors which exceed 2.4F. Sixty of the 90 estimates have errors of less than 1.5F.

The value of equations (1) through (5), and the seriousness of the errors obtained through their use, cannot be judged on an absolute basis. An error which is too large to be tolerated for one purpose may be unimportant for another purpose. Thus, there may be problems for which equations (1) through (5) give answers which are too crude. However, for general climatological problems and for many applied purposes, these equations are probably sufficiently accurate to be useful.

It should be noted that Spreen [3] has recently published a method for estimating the per cent points of frequency distributions of temperatures at land stations. He utilizes an elaborate graphical correlation method, rather than linear regression, and employs two "in put" statistics, the mean monthly temperature and the mean monthly temperature range. Spreen's tests with independent data give results whose accuracy is roughly the same as that obtained here. After a discussion of the errors obtained using his method, Spreen states, "However, the significance of the investigation lies not in how well the relation fits the data, although this is indeed important, but rather in the demonstration that the temperature distributions from widely different climatic regimes can be brought into one relationship. It is an indication that there are some underlying physical relations which, when discovered, will give the proper shape and parameters of the distributions. Further investigations, both empirical and theoretical, should prove fruitful in this and related problems."

The present author is in full agreement with this statement and believes that it can be applied to this study as well as to Spreen's work.

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REFERENCES

1. Court, A., 1951: Temperature frequencies in the United States. *J. Meteor.*, **8**, 367–380.
2. Crutcher, H. L., and G. W. Whiting (eds.), 1955: *Ocean vessel stations meteorological records survey, Atlantic and Pacific.* Unpubl. ms., U. S. Wea. Bur., 63 pp.
3. Spreen, W. C., 1956: Empirically determined distributions of hourly temperatures. *J. Meteor.*, **13**, 351–355.
4. U. S. Navy, 1955: *Marine climatic atlas of the world, Vol. I, North Atlantic Ocean.* Washington, Chief Nav. Opns.