

STATISTICAL PROCESSING OF AIR TEMPERATURE DATA
FROM THE CITY OF ATHENS FOR THE PERIOD
1946 - 1973

by

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Abstract: *In this paper we study monthly and daily mean values of air temperature in Athens for the period 1946 - 1973.*

We distinguish tropical days and partial frost days, finding their frequency per month.

Comparison is made between corresponding temperature values in Athens and Thessaloniki, whenever this is of interest.

Finally we distinguish temperatures favorable and unfavorable for plant growth.

INTRODUCTION

Temperature of the air has been the subject of a number of research works by AEGINITIS^{1,2}, ALEXANDROU^{3,4}, Ph. and L. KARAPIPERIS^{11,12}, MARIOLOPOULOS¹⁶, LIVADAS^{14,15}, FLOCAS⁹, ARSENI - PAPADIMITRIOU⁵ to mention only the greek scientists who studied this element in the Greek region.

Aim of the present paper is the statistical processing of air temperature data from the city of Athens, that is a work similar to the one effected for the city of Thessaloniki (ARSENI⁶).

Besides, we examine data of the same 1946 - 1973 period as for Thessaloniki, in order to render comparison possible between temperature values of the largest two urban centers of the country.

All the data employed herein come from the «Climatological Bulletin», published by the National Observatory of Athens.

Mean and Extreme Annual Values.

Data on air temperature in Athens and a detailed study for 115 years, that is for the period 1858 - 1972, exist in a previous work (ARSENI⁵). Still, we give below (Table I) annual values of the above period as well as the ones resulting from the 28 - years period examined herein,

TABLE I

Mean and extreme annual values.

	(1858 - 1972)	(1946 - 1973)	Δ
Max	18.9(1927)	18.7(1952)	0.2
Mean	17.7 \pm 0.52	17.8 \pm 0.53	-0.1
Min	16.7(1884, 1949)	16.7(1949)	0.0

and the differences between values of these two periods. This comparison indicates a decrease of maximum temperatures by 0.2° C, an increase of the mean, and the same minimum.

Mean and Extreme Monthly Values.

In the following Table II we give the mean and extreme monthly values, the standard deviation (σ) and the difference between extreme values of each month. The difference between values mentioned in Table II and the ones previously published for the city of Athens, have as follows:

TABLE II

Monthly mean values of Athens (1946-1973).

Month	Max	Year	Mean	$\pm\sigma$	Min	Year	Δ
J	12.2	1948	9.4	1.39	6.7	1964	5.5
		1955					
F	13.3	1955	10.0	1.87	7.5	1959	5.8
M	15.2	1947	11.3	1.20	8.1	1956	7.1
A	17.7	1947	15.4	1.24	13.0	1954	4.7
M	23.0	1968	20.2	1.19	18.1	1954	4.9
J	26.2	1946	24.7	0.75	23.1	1948	3.1
J	28.6	1950	27.2	0.81	25.3	1969	3.3
A	29.5	1946	27.3	1.20	24.8	1949	4.7
S	26.4	1952	23.4	1.17	21.5	1949	4.9
O	21.4	1966	18.3	1.38	15.5	1951	5.9
N	17.2	1960	14.9	1.17	11.6	1953	5.6
D	14.2	1960	11.3	1.55	6.9	1948	7.3

Maximum values have zero difference in 5 months, in another 6 months differences vary between 0.0°-1.0° C and in 1 month only the difference is between 1.0°-2.0° C.

Minimum values of the 28 - year period appear higher than those of the period 1858 - 1972, with differences ranging between 0.2° - 2.4° C.

TABLE III
Daily mean air temperature values in Athens. (1946-1973)

	J	F	M	A	M	J	J	A	S	O	N	D
1	11.4	9.6	10.2	14.4	17.9	23.1	26.3	27.8	25.3	20.8	16.4	13.0
2	10.5	9.8	10.1	14.5	18.3	23.2	26.4	27.8	25.1	20.7	16.1	12.8
3	10.6	8.6	10.0	14.2	18.2	23.1	25.6	27.8	24.9	21.0	16.2	12.2
4	10.5	8.3	10.1	14.1	18.3	22.8	25.9	27.9	24.9	20.6	16.5	12.2
5	9.6	8.3	9.9	14.0	18.6	23.0	26.1	27.8	24.0	19.8	16.5	12.2
6	9.6	8.6	10.2	14.2	18.4	22.7	26.8	27.8	25.0	19.6	16.3	11.9
7	9.8	8.8	10.5	14.2	18.5	23.0	27.2	27.9	24.6	19.2	16.2	11.8
8	9.6	8.8	11.1	14.6	18.8	23.2	27.2	28.0	24.3	19.1	16.1	11.8
9	9.4	9.4	11.1	14.6	19.4	23.6	27.0	27.9	24.4	19.2	15.8	11.7
10	9.7	10.0	10.6	15.0	19.4	24.4	27.0	28.0	24.5	18.8	16.2	12.0
11	10.1	10.4	10.5	15.1	19.2	24.4	26.6	27.9	24.3	18.4	16.3	11.8
12	9.9	10.2	10.6	14.7	19.5	24.2	26.5	28.1	24.1	18.3	16.2	11.8
13	9.8	10.3	10.4	14.6	19.7	24.4	27.0	27.8	24.0	18.0	16.4	11.8
14	9.0	10.8	10.8	14.7	19.6	24.4	27.1	28.0	23.6	18.3	16.0	12.1
15	9.3	10.6	11.1	15.2	19.8	24.5	27.3	28.0	23.3	18.6	15.9	11.0
16	9.6	10.5	11.2	14.7	19.9	24.3	27.7	27.9	23.9	18.5	15.8	10.5
17	9.6	10.3	11.0	14.7	19.6	24.9	28.1	27.7	23.5	18.4	15.1	10.7
18	9.2	10.6	10.9	15.1	19.9	25.1	28.2	27.5	23.4	18.1	15.2	10.2
19	9.3	10.7	11.3	15.1	20.4	25.3	27.9	27.0	23.2	17.6	14.7	10.2
20	8.9	11.1	11.4	15.5	20.8	25.2	27.6	26.9	23.0	16.8	14.4	10.5
21	8.9	10.8	11.3	16.1	20.9	25.9	27.4	26.9	22.8	17.3	13.4	10.0
22	8.4	10.7	11.7	16.5	21.4	25.8	27.5	26.8	22.2	17.6	12.6	10.1
23	8.2	10.3	11.9	16.6	21.6	25.9	27.4	26.8	21.7	17.4	12.7	10.4
24	8.4	10.4	12.3	16.8	21.6	26.0	27.5	26.5	21.6	17.2	13.1	10.5
25	8.4	10.9	12.3	17.1	21.7	26.2	27.7	26.5	21.4	17.0	12.9	10.3
26	8.2	11.3	12.4	16.7	22.0	26.1	27.3	26.8	21.3	17.1	12.5	10.7
27	8.3	11.0	12.4	16.4	22.3	26.2	27.2	26.9	21.8	17.0	12.6	10.7
28	8.1	10.4	12.9	17.1	22.4	26.1	27.6	26.4	22.3	16.5	12.5	11.0
29	8.7	8.7	13.4	17.8	22.6	26.3	27.6	25.7	21.6	16.6	12.6	10.9
30	9.5		13.8	17.9	22.7	26.1	27.9	25.4	21.0	17.0	12.7	11.0
31	9.6		14.1		23.0		27.8	25.5		16.7		11.5
Mean	9.4	10.0	11.3	15.4	20.2	24.7	27.2	27.3	23.4	18.3	14.9	11.3

Only the months of October and December have the same minima in both periods.

As to mean monthly values, their differences are sometimes negative and sometimes positive; yet their absolute value is never above 0.7°C .

While in the city of Thessaloniki extreme values of both periods are quite near (except for the two already mentioned cases of the October maximum and the July minimum), in Athens differences are quite higher. Thus differences of absolute maxima range between 0.0°C to 5.5°C , and those of absolute minima from -6.6°C to 0.0°C . Hence absolute maxima of the 28 - year period appear smaller than those of the period 1858 - 1972, while the corresponding minima appear higher.

Daily Mean Air Temperature Values.

The curve of daily mean values (Graph I, Table II) has a fluctuation with a primary maximum (28.2°C) in the second ten - days of July and a primary minimum (8.1°C) in the last ten - days of January. The variation curves of daily mean temperature in Athens and Thessaloniki correspond, but changes are sharper in Thessaloniki.

In Athens, as in Thessaloniki, the secondary minimum occurs in the first ten-days of February and is followed by an increase of temperature till early April. Then, after a certain stop of this increasing trend, it starts again from mid - April till it reaches its maximum value.

A secondary maximum appears in the first fortnight of August,

TABLE IV

Absolute thermometric data of Athens (1946-1973)

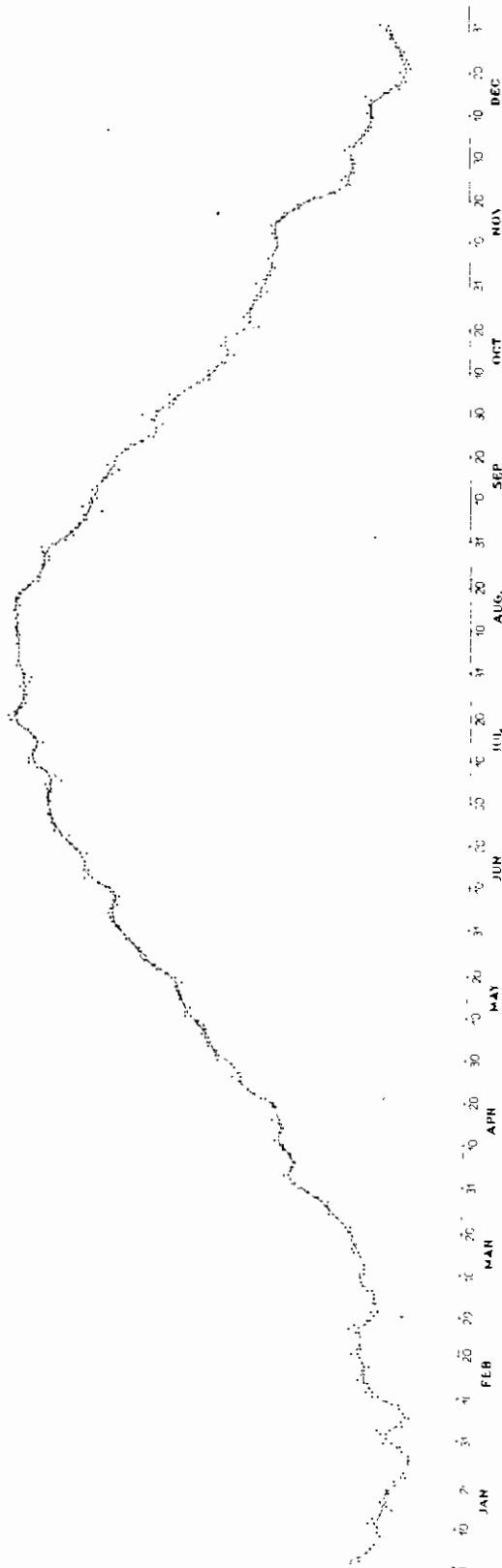
Month	Max	Date	Min	Date	$\Delta(\text{Max-Min})$
J	21.5	3/1962	-4.5	14/1968	26.0
F	22.5	20/1955	-3.0	16/1947	25.5
M	27.8	30/1952	-0.3	13/1971	28.1
A	32.2	21/1950	3.4	10/1956	28.8
M	36.1	29/1950	7.7	3/1970	28.4
J	37.5	25/1963	14.6	17/1958	22.9
J	41.2	20/1973	16.0	12/1949	25.2
A	42.6	22/1952	15.5	21/1949	27.1
S	37.8	9/1946	10.5	30/1970	27.3
O	32.6	1/1965	5.9	30/1971	26.7
N	26.2	1/1955	-1.1	26/1948	27.3
D	22.2	12/1947	-2.7	22/1967	24.9

Absolute temperature range: 47.1°C .

GRAPH I

Variation of mean daily values

— 5-days running mean
- - - mean daily values



and immediately afterwards the temperature starts falling, but with a smoother curve than its increase of the first semester. This decrease of temperature continues till mid - December, and then towards the end of this month we have again a slight increase of 1.5° C.

But while in Thessaloniki extreme values occur in the above mentioned intervals of the curve of daily mean values, in the city of Athens extreme values have been recorded out of these intervals. (*Table IV*). Thus for instance, the absolute maximum of 42.6° C was recorded in the last ten - days of August, while the absolute minimum of -4.5° C was recorded in the second ten - days of January.

Differences between extreme daily values (*Table V*) appear larger

TABLE V
Extreme daily values of air temperature

	Max	Min	Δ (Max-Min)
J	16.3(3/1962)	-2.3(14/1968)	18.6
F	17.7(18/1955)	-0.2(16/1946)	17.9
M	22.2(30/1952)	2.9(2/1957 & 13/1971)	19.3
A	25.5(21/1950)	6.9(9/1956)	18.6
M	28.7(29/1950)	10.5(3/1970)	18.2
J	31.0(26/1957)	18.2(4/1949)	12.8
J	34.4(19/1973)	21.2(1/1957)	13.2
A	35.3(24/1958)	20.4(25/1972)	14.9
S	31.3(9/1946)	12.5(30/1970)	18.8
O	24.8(1/1965)	9.0(29/1971)	15.8
N	21.8(14/1961)	1.2(26/1948)	20.6
D	18.9(21/1963)	0.4(2/1957)	18.5

in November (20.6° C) and March (19.3° C), and smaller in June (12.8° C) and July (13.2° C). Still these differences do not have their extreme values on the same months as in Thessaloniki.

Tropical Days.

We call *tropical days* those days on which the air temperature maximum was $\geq 30.0^{\circ}$ C.

We give below the number of such cases as well as percentages for the earliest and latest date of tropical days for each month.

	First Tropical Day				Last Tropical Day		
	A	M	J	Total	S	O	Total
No. of cases	1	19	8	28	25	3	28
%	3.6	67.9	28.6	100.1	89.3	10.7	100.0

The earliest tropical day recorded in Athens was the 20th April 1950 and the latest the 5th October 1957, while in Thessaloniki such days were the 31st March 1952 and the 29th September 1967.

We characterize as tropical period the interval between the first and the last tropical day of a year. The average tropical period lasts in Athens 123.1 days, exceeding by 5.3 days that of Thessaloniki. The longest tropical period was 163 days in 1950, and the shortest with 95 days in 1967. The corresponding figures for Thessaloniki are 182 days in 1952 and 72 days in 1972. Thus we observe that the extreme values of tropical period in the largest two cities of Greece do not coincide.

Not every day within a tropical period is a tropical day. The average per year number of true tropical days in Athens is 80.2 days, that is 11.4 days more than in Thessaloniki. The maximum number of truly tropical days in Athens was 105 days (in 1946) and the minimum was 55 days (in 1949), while the corresponding figures for Thessaloniki are 104 days (in 1954) and 43 days (in 1965).

In the following *Table VI* we give the number, the arithmetic mean,

TABLE VI

Tropical days in Athens during the 1946-1973 period.

	A	M	J	J	A	S	O	Total
No. of days	3	80	407	733	734	284	5	2246
Mean	0.1	2.9	14.5	26.2	26.2	10.1	0.2	80.2
Percentage	0.1	3.6	18.1	32.6	32.7	12.6	0.2	99.9 %

and the percentage of true tropical days per month. The percentage of August (32.7 %) is slightly higher than that of July (32.6 %), while the smallest percentage belongs in April (0.1 %) with October coming next (0.2 %).

In the 28 - year period examined herein, 13 days with temperature $\geq 40.0^{\circ}$ C have been recorded; all these days occurred in the main two summer months, 4 in July (30.8 %) and 9 in August (69.2 %). These occurred in couples of consecutive days except for the years 1951 and 1957.

Below are listed these maximum temperatures with their respective dates:

42.5° C	11/8/1951
42.6° C and 40.6° C	22 & 23/8/1952
40.1° C and 40.1° C	29 & 30/7/1954
40.0° C and 40.3° C	12 & 14/8/1957

40.7° C and 40.0° C	17 & 18/8/1963
42.0° C and 41.1° C	24 & 25/8/1968
40.4° C and 41.2° C	19 & 20/7/1973

Days of Total and Partial Frost.

We call *days of total frost* those on which the maximum temperature was $\leq 0.0^{\circ}$ C, and *days of partial frost* those on which the minimum temperature $\leq 0.0^{\circ}$ C.

We shall consider as frost periods the cold seasons between the 1st November 1945 and 31 October 1973, since the winter season begins in November and ends in April of the next calendar year.

In Athens, during the whole 28 year period examined herein, no total frost day has been recorded.

Examination of partial frost days, indicates as earliest date of partial frost in Athens the 26th November 1948 and as latest the 13th March 1971. The corresponding dates for the city of Thessaloniki are: the 9th November 1956 and the 18th March 1952.

There are 9 winter seasons within the period examined (32.1 %) in which no frost days was recorded. These are the following winters: 1947 - 1948, 1950 - 1951, 1952 - 1953, 1954 - 1955, 1956 - 1957, 1958 - 1959, 1961 - 1962, 1969 - 1970 and 1971 - 1972.

The number of cases and the percentage of earliest and latest dates of frost days per month, for the remaining 19 winter seasons, have as follows:

	<i>First Frost Day</i>					Total	<i>Last Frost Day</i>					Total
	N	D	J	F	M		D	J	F	M		
No of cases	1	4	10	3	1	19	1	8	8	2	19	
%	5.3	21.1	52.6	15.8	5.3	100.1	5.3	42.1	42.1	10.5	100.0	

The highest figure of partial frost days (7 days) has been recorded in two winter seasons: in 1949 - 1950 and 1967 - 1968. The maximum number of partial frost days per year in Thessaloniki is 46 days.

TABLE VII

Days of partial frost in Athens for the period 1946-1973.

	N	D	J	F	M	Total
No. of days	2	8	32	24	2	68
Mean	0.1	0.3	1.1	0.9	0.1	2.4
Percentage	2.9	11.8	47.1	35.3	2.9	100.0

In the above *Table VII* we give the total number of cases, their average and their percentage per month for the 28 year period.

In both cities January has the highest percentage and November the smallest.

Distribution of Daily Mean Values.

Daily mean values of air temperature for the 1946-1973 period have been distributed, as in a previous paper for Thessaloniki, in non equidistant grades, according to the importance of each grade for a certain sector of human activity (i.e. Agriculture, Industry e.t.c.). Thus there are grades of 1°, 2° and 5° C (*Table VIII*). The highest percentage (64.28%) is for temperatures between 10.0°-24.9°C, likewise as in Thessaloniki (57.05%). However, the next percentage (21.15%) for Athens belongs in the grade of temperatures $\geq 25.0^\circ$ C, while for Thessaloniki this was in the grade between 0.0°-9.9° C (24.70%).

Plants and Temperature.

Extreme temperatures may withhold the growth of sturdy plants or even destroy more sensitive ones.

This harm produced on plants by excessively high temperatures depends, not only from their height, but also from how long they last. Temperatures $> 35.0^\circ$ C are generally harmful for vegetation.

In the area of Athens during the whole 28-year period examined, a daily mean temperature $> 35^\circ$ C has been recorded only once, on the 24th August 1958.

Temperatures favoring the life process of plants are those between 10.0°-35.0° C: A percentage of 85.4% of air temperatures in Athens are included within this interval (*Table IX*). It is worth mentioning that every month has its part of such temperatures, favorable for plant growth.

There are only 8 days with extremely low daily mean temperatures (*Table VIII*), while periods of partial frost are rather short (*Table VII*), totalling 68 days for the whole 28-year period.

CONCLUSIONS

Examination of air temperature in Athens for the period 1946-1973, leads to the following conclusions:

— The annual mean, and the monthly mean and extreme values of the 28-year period, slightly differ from the ones already published for

TABLE VIII

Distribution of daily mean values of air temperature in Athens. (1946-1973)

	J	F	M	A	M	J	J	A	S	O	N	D	S'	S''	%
≥35.0								1					1		0.01
30.0 - 34.9						9	76	92	4				181		1.77
25.0 - 29.9				1	46	380	670	652	232				1981	2163	19.37
20.0 - 24.9		2		35	407	427	122	123	519	266	14		1915		18.72
18.0 - 19.9			15	123	215	24			63	231	96	5	772		7.52
15.0 - 17.9	19	38	108	324	174				20	260	364	111	1418		13.87
10.0 - 14.9	395	403	437	338	26				2	109	303	456	2469	6574	24.14
8.0 - 9.9	169	143	164	15						2	36	141	670		6.55
6.0 - 7.9	151	102	90	4							16	111	474		4.63
5.0 - 5.9	39	42	34								6	14	135		1.32
4.0 - 4.9	31	23	10								1	16	81		0.79
2.0 - 3.9	45	26	8								3	12	94		0.92
0.0 - 1.9	12	13									1	2	28	1482	0.27
-2.0 - (-0.1)	6	1											7		0.07
-4.0 - (-2.1)	1												1		0.01
-6.0 - (-4.1)															
-8.0 - (-6.1)															
S	868	791	868	840	868	840	868	868	840	868	840	868	10227	10227	99.99
														8	

TABLE IX

Percentage distribution of daily air temperature values.

J	F	M	A	M	J	J	A	S	O	N	D	S
≥25.0				0.12	5.30	46.31	85.94	85.83	28.10			21.15
10.0-24.9	47.70	55.75	64.75	97.62	94.70	53.69	14.06	14.17	71.90	99.77	92.50	65.90
0.0 - 9.9	51.50	44.12	35.25	2.26						0.23	7.50	34.10
-8.0 - (-0.1)	0.81	0.13										0.08
	100.01	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

the period 1858-1972 (ARSENI⁵), to the contrary of extreme temperatures whose differences range from -6.6° C to 5.5° C.

— The fluctuation of daily mean temperatures has a primary maximum in July and a primary minimum in January, while the variation curve of these temperatures appears smoother in the second than in the first semester.

— The *tropical period* in Athens, beginning in May and ending in September, lasts as an average 123.1 days, the highest percentage of which belongs in August with July coming next with a slight difference.

— Days of total frost have not been recorded in Athens during the 28 years examined. The small number of partial frost days is distributed among the 5 months from November to March, with January holding the largest percentage of almost 50%.

— A percentage of 64.28% of daily mean values range between 10.0° -to 25.0° C.

— Only one day with excessively high temperature, harmful to plants, has been recorded in Athens. The largest percentage of temperatures recorded are favorable for plant growth, and every month has its share of such temperatures, while the dangerously low temperatures represent only 0.08% of the amount of daily mean values for the period 1946-1973.

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ΠΕΡΙΛΗΨΙΣ

ΣΤΑΤΙΣΤΙΚΗ ΕΠΕΞΕΡΓΑΣΙΑ ΔΕΔΟΜΕΝΩΝ ΘΕΡΜΟΚΡΑΣΙΑΣ ΑΕΡΟΣ ΑΘΗΝΩΝ ΠΕΡΙΟΔΟΥ 1946 - 1973

υ π ο

ΑΓΓΕΛΙΚΗΣ ΑΡΣΕΝΗ - ΠΑΠΑΔΗΜΗΤΡΙΟΥ
(*Εργαστήριο - Μετεωρολογίας και Κλιματολογίας*)

Είς τήν παροῦσαν ἐργασίαν ἐπιχειρεῖται διεξοδική στατιστική ἐπεξεργασία τῆς θερμοκρασίας ἀέρος τῶν Ἀθηνῶν διὰ τήν χρονικὴν περίοδον 1946-1973 καὶ σύγκρισις τῶν ἀποτελεσμάτων μετὰ τὰ ἀντίστοιχα τῆς Θεσσαλονίκης. Μελετῶνται αἱ μέσαι μηνιαῖαι καθὼς καὶ αἱ μέσαι ἡμερήσιαι τιμαί.

Αἱ μέσαι ἡμερήσιαι τιμαὶ παρουσιάζουν ἐν πρωτεῦον μέγιστον πού λαμβάνει χώραν κατὰ τὸ δεῦτερον δεκαήμερον τοῦ Ἰουλίου καὶ ἐν πρωτεῦον ἐλάχιστον κατὰ τὸ τελευταῖον δεκαήμερον τοῦ Ἰανουαρίου. Ἡ καμπύλη μεταβολῆς των παρουσιάζεται ὀμαλώτερη κατὰ τὸ β' ἔξαμηνον, ἀπ' ὅτι κατὰ τὸ πρῶτον.

Ἡ τροπικὴ περίοδος εἰς τὰς Ἀθήνας ἔχει μέσσην διάρκειαν 123,1 ἡμέρας καὶ μέσον ἀριθμὸν ἀληθῶς τροπικῶν ἡμερῶν 80,2 ἡμέρας. Ἡ 20ῆ Ἀπριλίου 1950 εἶναι ἡ ἐνωρίτερον σημειωθείσα τροπικὴ ἡμέρα καὶ ἡ 5ῆ Ὀκτωβρίου 1957 ἡ βραδύτερον. Παραθέτομεν ἀναλυτικὰ τὰς 13 ἡμέρας κατὰ τὰς ὁποίας ἡ μεγίστη ἤτο $\geq 40.0^\circ \text{C}$.

Ἡμέραι ὀλικοῦ παγετοῦ δὲν ἐνεφανίσθησαν εἰς Ἀθήνας. Αἱ ἡμέραι μερικοῦ παγετοῦ ἐμφανίζονται κατὰ τὸ πεντάμηνον Νοεμβρίου - Μαρτίου. Παρατηρήθησαν δὲ 9 συνολικὰ χειμερινὰ περίοδοι ἀπηλλαγμένοι ἡμερῶν μερικοῦ παγετοῦ.

Τὸ 64 % τῶν μέσων ἡμερησίων θερμοκρασιῶν εὐρίσκεται εἰς τὸ διάστημα $10.0^\circ - 24.9^\circ \text{C}$.

Ἐγένετο διαχωρισμὸς τῶν εὐνοϊκῶν καὶ μὴ θερμοκρασιῶν διὰ τὰ φυτὰ, καὶ εὐρέθη μόνον μία ἡμέρα καθ' ὅλην τὴν 28ετίαν μετὰ ἐπικίνδυνον διὰ τὰ φυτὰ ὑψηλὴν θερμοκρασίαν.

Αἱ ἐπικίνδυνοι χαμηλαὶ θερμοκρασίαι κατέχουν τὸ 0.08 % τοῦ συνόλου τῶν μέσων ἡμερησίων τιμῶν. Ἀπαντες οἱ μῆνες ἐμφανίζουν ὑψηλὸν ποσοστὸν εὐνοϊκῶν διὰ τὰ φυτὰ θερμοκρασιῶν.