THE COOLING POWER IN THESSALONIKI - GREECE

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Introduction

In a previous paper the first of the authors has studied values of cooling power in Thessaloniki, based upon data of systematic observations effected in the Meteorological Institute of the University of Thessaloniki, for the period between January 1, 1951 to December 31, 1956. During this period the Institute was housed in the old building of the University, and measurements of cooling power were taken in the gardens of the University, within the enclosure of the Meteorological Station of the Institute of Meteorology and Climatology (elevation 26 m) (Fig. 1) (Livadas, 1).

On January 1, 1957 the Institute has moved to its new building (Fig. 2), and measurements of c.p. have been taken ever since on the roof of this new building (elevation 45 m), always in the shade, and at a distance of some 100 m from the meteorological shelter.

The instruments used for these measurements have always been Hill Katathermometers *.

In the present paper results of c.p. measurements, from the 13 : 30 observations (local time = GMT + 2h) are studied for the twelve-year period from 1.1.1957 till 31.12.1968; as already mentioned, all these observations have been held in the new building of the Institute.

Mean c. p. values.

From the total number of 4383 observations possible, 4088 have been realized, that is a percentage of 93,3 %; measurements have been impossible because of extremely high air temperature ($t_{air} > 35°C$) in 229 cases, that is a percentage of 5,2 %.

* Manufacturers : J. J. Hicks - England, and R. Fuess - West Berlin.

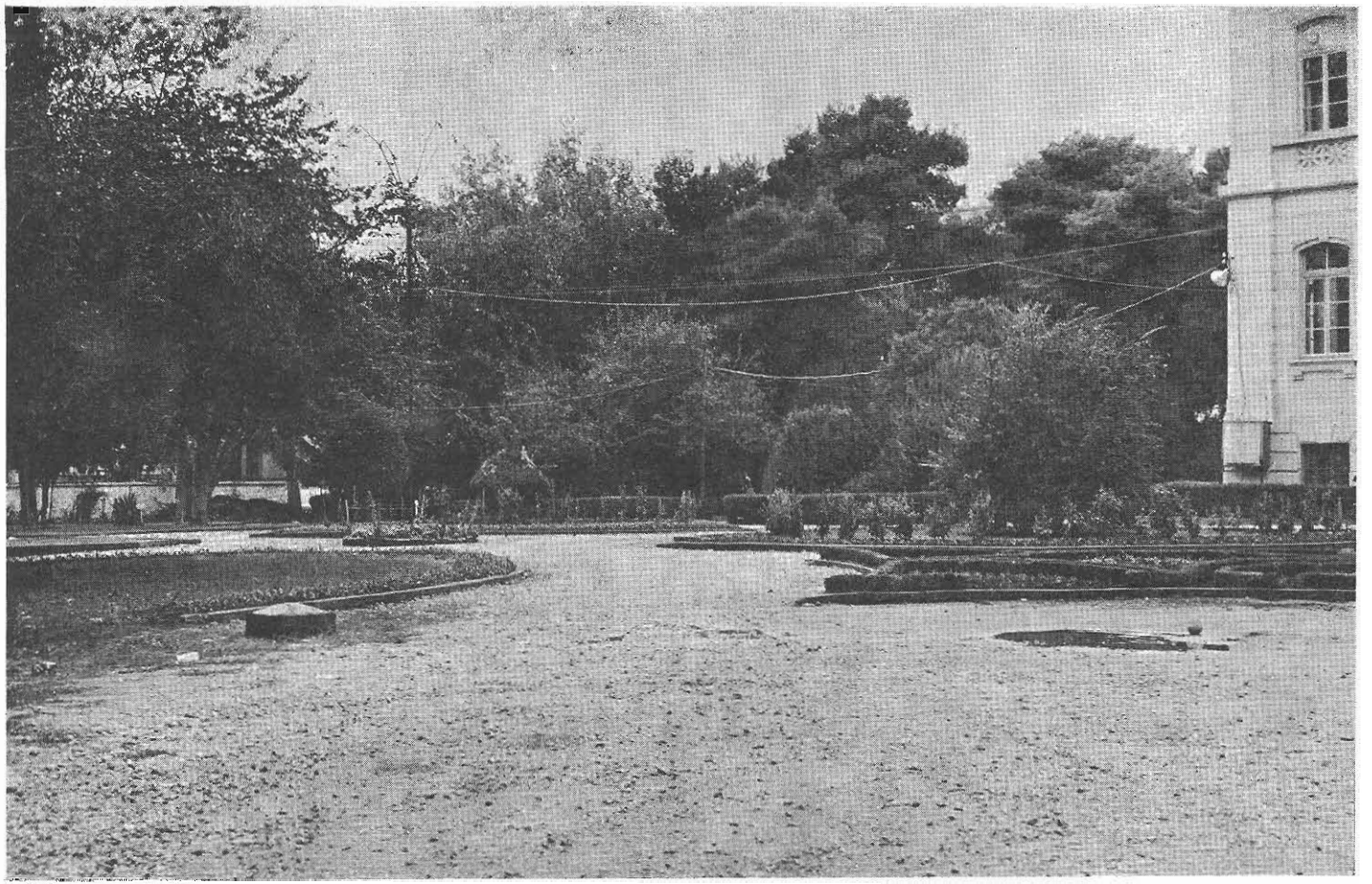


Fig. 1. Site of the old meteorological station (marked with an arrow) within the University Gardens.

Fig. 2. The building of the Institute of Meteorology and Climatology with the Meteorological Station in the background.

From T a b l e I we draw the following conclusions, as to the distribution of these 229 cases, during which it has been impossible to take the readings of the katathermometer because of extremely high air temperatures:

T A B L E I

Distribution of cases with air-temperatures >35°C.

	Period : 1957 - 1968				*Period : 1951 - 1956*			
May	11	cases	4.8 %		0	cases	—	
June	47	»	20.5 %		19	»	18.8 %	
July	**78**	»	34.1 %	72.1 %	**34**	»	33.7 %	76.3 %
August	**87**	»	38.0 %		**43**	»	42.6 %	
September	6	»	2.6 %		5	»	5.0 %	
T o t a l	229	»	100.0 %		101	»	100.1 %	

The entire number of these cases is assembled in the properly summer season for the city of Thessaloniki (May - September). The 3/4 of such cases belong to the main two summer months of July and August; these two months hold 72 % of such cases during the period examined. The former of the authors has come to similar conclusions (percentage of 76 %), for measurements effected at a distance of about 250 m from the new observing site (L i v a d a s , I).

Based upon data of the period examined, we have drawn the following T a b l e II.

From the data of the T a b l e I I, we draw the conclusion that January, which is also the coldest month of the year, has the highest mean monthly values of cooling power (18.67 ± 1.97).

The above value, according to the D o r n o and also the M ö r i k o f f e r (II) classification, give as a mean a feeling of c o l d. This same feeling is also attributed as a mean, to the other two winter months of December and February; while the remaining three months of the semester, November, March, and April remain in the 10 - 15 grade of c.p. values, giving a feeling of c o m f o r t a b l e c o l d or c o m f o r t a b l y c o o l,

July, being the hottest month of the year, has the smallest mean monthly value of c.p., followed by the equally warm month of August (July: 3.43, August: 3.53).

The above values, according to the M ö r i k o f f e r classicification, give a d i s c o m f o r t a b l y w a r m or h o t f e e l i n g.

The remaining four months of the warm season stay in the 5 - 10 grade of c.p. values, meaning that during these months we have a comfortably warm feeling.

The winter months of February and December show the largest range of monthly values, having also the largest standard deviation (S.D.) values.

TABLE II

Monthly mean, maxima and minima observed in Thessaloniki (time of observ.: 13:30h local time; period of observations 1.1.1957- 31.12.1968).*

	Maxima		*Mean*	$\pm\sigma$	*Minima*	
J	22.00	(1967)	**18.67**	1.97	16.19	(1962)
F	**22.24**	(1967)	16.80	2.20	12.78	(1966)
M	16.90	(1958)	14.39	1.57	12.46	(1965)
A	14.05	(1965)	11.04	1.54	8.32	(1961)
M	10.57	(1965)	7.90	1.61	5.57	(1958)
J	6.24	(1965)	5.08	0.77	4.15	(1964)
J	6.26	(1965)	**3.43**	1.11	1.97	(1963)
A	7.28	(1965)	3.53	1.28	**1.39**	(1967)
S	8.18	(1964)	6.62	1.05	4.88	(1961)
O	11.37	(1959)	9.47	1.31	7.19	(1960)
N	14.09	(1968)	12.05	1.26	10.10	(1963)
D	19.92	(1968)	16.28	2.95	12.49	(1960)
Year	22.24	(Febr. 1967)	10.44	$\pm$0.56	1.39	(Aug. 1967)

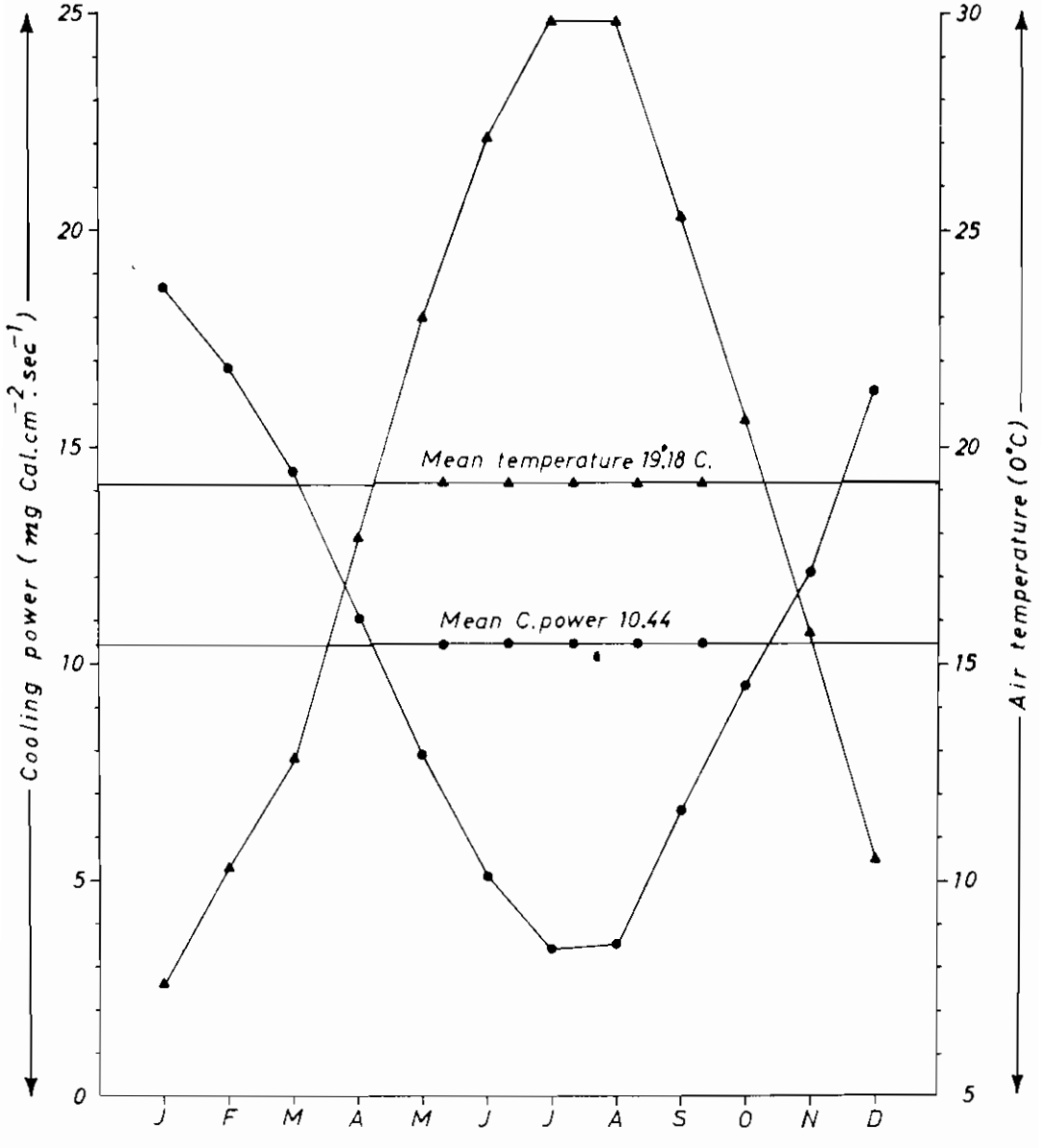
* Local time of Thessaloniki = GMT + 2.

The summer months of June and September, that is the two months adjoining the discomfortably warm high summer season, have also the smallest range.

The annual variation of cooling power and air-temperature is given in Graph I.

The above graph shows that the annual variation of c.p. values is inversely proportionate to that of air temperature: as air temperature increases, c.p. decreases, and vice versa, when air temperature starts falling, c.p. rises. The two curves tend to become the reflected image of each other.

The annual cooling power values for the period examined, have as follows:



Graph. I : Showing curves of air - temperature and cooling - power in Thessaloniki (period : 1957 - 1968).

Maximum : 11.43 (1967)
Mean : 10.44 ± 0.56
Minimum : 9,65 (1960).

This means that the city of Thessaloniki, according to V. Conrad's climatic classification, based upon dry cooling power, belongs to the relaxing climate group, but very near the dividing line between this group and that of warm climates; while the S. D. as well as its range are very small.

Extreme c.p. values.

In Table III we have included mean values and also the absolute maxima and minima recorded in Thessaloniki, during the period examined.

TABLE III

	Maxima			*Mean*		*Minima*		
	Absolute		*Mean*	*Monthly*		*Mean*	*Absolute*	
J	54.16	(13/1968)	40.21	18.67	±1.97	9.32	7.92	(1/1962)
F	49.29	(9/1967)	37.63	16.80	2.20	8.35	5.16	(17/1966)
M	40.39	(16/1962)	31.05	14.39	1.57	7.88	5.98	(21/1957)
A	29.38	(3/1965)	22.15	11.04	1.54	5.64	3.14	(27/1961)
M	30.77	(13/1965)	16.90	7.90	1.61	—	—	*
J	21.38	(3/1966)	13.57	5.08	0.77	—	—	*
J	17.80	(28/1965)	10.53	3.43	1.11	—	—	*
A	14.47	(21/1968)	9.86	3.53	1.28	—	—	*
S	21.28	(21/1964)	14.65	6.62	1.05	—	—	*
O	28.40	(17/1958)	20.47	9.47	1.31	5.26	3.42	(2/1961)
N	35.60	(30/1957)	26.20	12.05	1.26	6.20	5.83	(23/1965)
D	60.00	(21/1967)	35.18	16.28	2.95	7.88	6.25	(12/1957)
Year	60.00	(21.12.1967)		10.44	±0.56		*	

* See Table I.

The coldest month of the year is January (mean monthly air temperature at 13h30 : 19.2° C; ± 0.46); this month comes first in all the mean values.

Mean Maximum : 40.21 cal cm^{-2} sec^{-1}.
Mean : 18.67 »
Mean Minimum : 9.32 »

Also the absolute minimum reading of this month (7.92) is higher than any other absolute minimum.

The two neighboring months of February and December come next in «d i s c o m f o r t» c.p. values. The absolute maximum reading of c.p. has been recorded on December 21, 1967.

We also observe that values >20, that is values of cooling power giving a a d i s c o m f o r t a b l y c o l d feeling, can also be recorded during the mid-day observation, from September till June. Which means that c.p. values remain small only during the two main summer months of July and August.

The absolute maxima remain remarkably high (>35) from November till March. Readings of c.p. ⩾ 50 have been recorded during the high winter season, from December till February. These cases occured with extremely low temperatures, snow-covered ground, and strong northerly winds. In the cases of 21.12.1957 and 9.2.1967 the prevailing weather type has been Xb*, that is the type of the beginning of a cold invasion: A ridge above the Balkans; cP air masses, and in certain cases even arctic air; a low over the Aegean Sea; strong gradient; successive cold fronts. This is the weather pattern that produces the heaviest weather conditions in the Greek area, and particularly in Northern Greece (L i - v a d a s , III , IV).

TABLE IV

W.T.	*Xb*	*XI*	*VII*	*I*
	17.10.68	13.1.68*	13.5.65	28.7.65
	30.11.57	3.4.65	3.6.66	21.8.68
	21.12.67			21.9.64
	9. 2.67			
	16. 3.62			
	Cold invasion	Vardaris wind	Rain with northerly wind in the area of Thessaloniki	Strong northerlies (Etesians).

In the case of 13.1.1968, the prevailing weather type has been XI (IV), meaning that the characteristic northwesterly wind of the Axios Valley (bearing the popular name of «Vardaris») was blowing (Mariolopoulos (VI), Kyriazopoulos (V), Philippson (VII), Livadas (III, IV) et al.).

* On this date has been recorded the absolute minimum of air temperatutre for the city of Thessaloniki : -12.6° (period 1893 - 1970).

Weather conditions during the days when absolute maxima of c.p. have been recorded, can be grouped in general, as follows:

The above Table IV shows that in such cases, high pressure systems prevail to the north of the area of Thessaloniki.

On the other hand, the absolute minima have been recorded with cold weather patterns (weather type IX)*, or cyclonic weather patterns, fogs and light rains on this same day but not at the time of observation, and usually calm.

Generally speaking, weather conditions during the days when absolute minimum values have been recorded (besides the 229 cases when readings have been impossible because of air-temperatures $> 35°$ C), can be grouped as in the following Table V:

TABLE V

W. T.	*IX*	*VI/VII/VIII*	*I*
	1.1.1962	23.11.1965	2.10.1961
	17.2.1966	12.12.1965	
	21.3.1957	27. 4.1961	

The case of October 2, 1961, when the minimum has been recorded with a high weather pattern (Weather Type I), can be considered as an exception to the rule. In this case the northern anticyclone was in the weakening stage (anticyclolysis), while air temperature values were extremely high for this season (at 14^h00 local time: 27.8° C, Maximum 28.3° C, while the average monthly for October is 20.8° C).

Regarding the frequency of various c.p. values, we give below Table VI.

Discussion.

The climate of Thessaloniki, as regards the mean values of dry cooling power, could be defined according to V. Conrad's climate classification (VII) as a Relaxing Climate, since the mean annual value of the dry cooling power at 13 : 30 hours is 10.44 ± 0.56 mg cal cm^{-2} sec^{-1} (see Table II).

The standard deviation (S.D.) of ± 0.56 confirms that the normal

* Weather types classification by G. Livadas (IV).

TABLE VI

C. p. scale	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*Total*		
0 - 2.5	0	0	0	0	7	23	39	49	2	0	0	0	120	2.93	2.9
2.6 - 5.0	0	0	0	9	47	135	134	142	94	10	0	0	571	13.96	14.0
5.1 - 7.5	0	7	12	50	122	108	63	57	155	116	32	9	731	17.88	17.9
7.6 - 10.0	25	32	78	125	97	33	20	18	59	125	126	67	805	19.69	19.7
10.1 - 12.5	75	78	91	83	49	13	5	8	15	63	77	79	636	15.55	15.6
12.6 - 15.0	66	50	60	31	22	4	1	4	10	26	47	53	374	9.14	9.1
15.1 - 20.0	73	82	67	37	9	4	1	0	8	23	52	65	421	10.29	10.3
20.1 - 45.0	122	79	62	20	7	1	0	0	1	8	24	91	415	10.15	10.2
>45.0	8	4	0	0	0	0	0	0	0	0	0	3	15	0.36	0.4
Total	369	332	370	355	360	321	263	278	344	371	358	367	4088	99.95	100.1 %
ta>35°C	0	0	0	0	8	33	88	92	8	0	0	0	229		
No data	3	7	2	5	4	6	21	2	8	1	2	5	66		

annual value of air temperature does not show great differences from year to year.

TABLE VII

Normal annual air temperature				(1930 - 1970) (13 30)	: 19.4 ± 0.58
»	»	»	»	(1957 - 1968) (13 30)	: 19.2 ± 0.48

January, being the coldest month of the year, has the highest mean monthly cooling power value, and also the highest mean values of mean maxima and mean minima, as well as the absolute minimum of c.p. (see Table III). Consequently from the point of view of dry cooling power, it should also be considered as the principal winter month. Moreover, the other two properly winter months of December and February have also high c.p. values.

The recorded absolute minima are within the limits of absolute minimum values of the rest of the Mid-European area, and exceed the absolute values of the Mediterranean region.

Comparing the two months of October and November preceding the high winter season, with the two (estival) months of March and April, following this season (Table VIII), we observe that: The two months preceding the cold season are definitely warmer than the March-April pair ($\Delta T = 3$ C); this fact causes as an average a difference of ~ 2 mgcal cm^{-2} sec^{-1} to values of cooling power.

TABLE VIII

Air temperature and cooling power at 13:30.

	t_{air} *(13:30)*	*Cooling power*
October	20.83° C	9.47 ± 1.31
November	15.70	12.05 ± 1.26
March	12.70	14.39 ± 1.57
April	17.80	11.04 ± 1.54

The high values of c.p. during the two estival months, mainly due to the low air-temperatures, prove once more the fact of tardy winters in the area of Northern Greece of (Livadas, III, IV). The main reason for this winter tardiness is the geographic position of Thessaloniki, and Northern Greece. Because of their position at the southern end of the largest and most eastward peninsula of Europe, they are subject to the

continental influence (continentality) of the Balkan peninsula, more than other regions at the northern coast of the Mediterranean.

The high summer two-month period of July and August has the smallest mean values of cooling power. The warmer month of July slightly exceeds August as to the feeling of discomfortably warm (hot climate).

The above two months of the very warm period, consist the interval during which the northern area of Greece is included within the hot-dry season of the Eastern Mediterranean.

The greatest frequency of cooling power values that are <2,5 belong to the months of July and August (T a b l e V I), and in these should be included as h i g h d i s c o m f o r t cases, the 229 cases of T a b l e I, when it has been impossible to take readings of the katathermometer, because of air temperatures above 35° C. In the above cases, which are usually termed in Greece as a «real summer day», the katathermometer during the 13:30 observation, receives amounts of heat from the surrounding air, instead of radiating it. As a matter of fact, c.p. values in such days should bear minus (-) symbols, and thus mean monthly values of months with such cases would have been even smaller than they actually seem to be.

In classifying the frequency of cooling power values, according to the feeling that they produce, we come to the following conclusions:

T A B L E IX

Produced feeling/Dry cooling power (13:30)		*Period: 1957-1968(%)*			*1951-1956(%)*	
Discomfortably hot	t > 35 C° (negative)	229 cases	5.30	21.30	4.63	32.16
Discomfortably warm	0 - 5.0	691 »	16.00		27.53	
Comf. warm - Comf. cool	5.1 - 15.0	2546 »	58.97		57.73	
C o l d	15.1 - 20.0	421 »	9.75	18.71	7.48	10.09
Discomfortably cold	>20.1	430 »	9.96		2.61	

The feeling of comfortable surroundings appears at a sufficiently high percentage ~ 60 %.

The feeling of cold or discomfortably (bracing) cold has almost the same percentage with the feeling of discomfortably warm; and for a percentage of almost 5.3 % of cases, this feeling of discomfortably warm becomes still more intense (discomfortably hot), even for native inhabitants of this northern coast of the East Mediterranean.

In comparing results of the present paper, with those ensuing from a previous study by the former of the authors (I), we observe that c.p. values are considerably influenced by the site of observation:

During the first period, from 1.1.1951 til 31.12.1956, readings were taken within the enclosure of the University gardens (Central Building), that is in a position very sheltered from the gusts of strong winds (See Fig. 1); while during the second period of observations, from 1.1.1957 till 31.12.1968, readings were taken, as already mentioned, on the roof of the Meteorological Institute, that is absolutely in the open. (See Fig. 2).

TABLE X

Comparing air temperatures and c.p. values in the two observation periods : a) 1951 - 56 and b) 1957 - 68.

	Period 1951 - 56		*Period 1957 - 68*	
	Cooling Power	*Air temp. (°C)*	*Cooling Power*	*Air temp. (°C)*
J	13.73	9.1	18.67	7.7
F	13.62	10.3	16.80	10.2
M	12.41	13.0	14.39	12.7
A	9.16	18.6	11.04	17.8
M	6.00	24.1	7.90	23.0
J	3.72	29.1	5.08	27.1
J	2.56	31.6	3.43	29.9
A	2.57	31.9	3.53	29.8
S	4.35	27.7	6.62	25.3
O	8.10	20.1	9.47	20.8
N	10.91	14.2	12.05	15.7
D	11.83	11.0	16.28	10.4
Year	8.25	20.1	10.44	19.2

The distance between the two observing sites is of almost 1/4 km; and thus being practically in the same geographic position, there cannot possibly exist any differences of air temperature such as to account for the difference of the mean yearly c.p. value by almost 2,0 mg cal cm^{-2} sec^{-1}. In our opinion, this difference should be attributed to the better ventilation of the newest observing site.

REFERENCES

I. Livadas, G. C., (1971): «The Cooling Power in Thessaloniki - Greece» Meteorologika No. 12 (Univ. of Thessaloniki).

II. Morikofer, W., (1933): «Acta Davossiana» 1 (No. 3).

III. Livadas, G. C., (1955): «On weather Conditions of Groups of Days with sudden decrease of Temperature iu Greece». Doctoral Thesis. Thessaloniki.

IV. Livadas, G. C., (1962): «Hoar - frost Weather in Greece». Scientific Annales of the Faculty of Physics and Mathematics, Aristotelian University of Thessaloniki, Appendix No. 12.

V. Kyriazopoulos, B.D., (1939): «The Climate of Central Greek Macedonia». p. 315, 326 - 330. Athens.

VI. Mariolopoulos, E.G., (1938): «The Climate of Greece». pp. 284-285. Athens.

VII. Philippson, Alf., (1948): «Das Klima Griechenlands» s. 28. Bonn.

VIII. Conrad, V., (1929): «Zeit. angew. Met.» pp. 44 - 50.

ΠΙΝΑΞ ΠΕΡΙΕΧΟΜΕΝΩΝ