SUNSHINE DURATION IN THESSALONIKI - GREECE

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S u m m a r y : In this paper we study sunshine duration in Thessaloniki for the 1930 - 1968 period, in annual, (2621 hours ± 93,3), monthly, daily, and also hourly values. We give Tables of hourly values of sunshine duration for technologieal applications and exploitation of solar energy in this northern area of Greece.

Introduction.

Interest in the subject of sunshine duration is almost a tradition with members of the staff of the Meteorological Institute at the University of Thessaloniki, who have worked here at various times and periods: ALEXANDROU in 1933 [2] published the first data of sunshine duration, obtained from the initial observations with a Campbell - Stokes recorder (Manufactured by Casella), for the very short period between August 1930 to July 1931. Tbe same research worker published again tn 1940 [3] data of sunshine duration for the 1931 - 1937 period. MARIOLOPOULOS [10] in 1939 published data of sunshine, based upon estimations of cloudiness. KYRIAZOPOULOS in 1939 [4] also published data of sunshine duration for the period between August 1930 to December 1937.

The former of us has published in 1969 monthly values of sunshine duration in Thessaloniki for the 1930 - 1968 period [6]. In the next year (1970), the two of us together with Mr. Malthoyannis have published daily and hourly values of sunshine duration for this same period [8]. In the present paper we examine sunshine duration in tbe city of Thessaloniki from the following view - points: first as a classical climatic element, with mean and extreme values for the sbortest and longest intervals (day, month, year); then as a factor to be used in technological

applications, for which we attend particularly to the statistical elaboration of hourly values.

Material.

Measurements of sunshine duration have been obtained at the Meteorological Institute with Campbell - Stokes recorders, the first of which had been working from July 6, 1930 till December 31, 1958 upon the southern wall of the meteorological tower on top of the old building of the University (Fig. I). Another Campbell - Stokes recorder (manufactured by Casella) started working since January 1, 1958 on the roof of the new building of the Meteorological Institute (Fig. II), and at its northern side.

Fig. 1. First period: August 1930 - December 1958. The meteorological tower of the old building (Elevation 49.00 m (M.S.L.) φ · 40°37′, λ: 22°57′).

The second site lies at a distance of 230m to the east of the first one; both are within the University campus (Fig. III).

We give below *in Table I* values of sunshine duration recorded per month in the year 1958, when sunshine recorders have been working simultaneously at sites I and II.

We observe from the above Table I that the difference resulting

Fig. II. Second period: January 1958 - to date. New building of the Institute of Meteorology and Climatology (Elevation 44.65 m (M.S.L.).

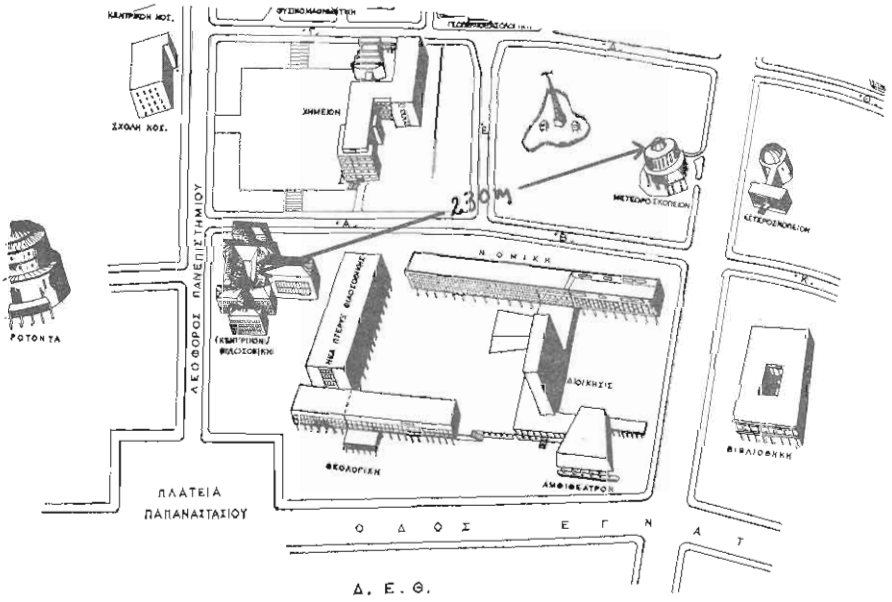


Fig. III

between the two observational locations is comparatively small: about 2,3 % of the annual sunshine duration.

TABLE I

Per month sunshine duration (in hours) during 1958.

	Site I The Met. tower (old building)	*Site II New building of Met. Institute*	*Δ*
J	134.95	136.25	—1.30
F	189.40	194.75	—5.35
M	132.82	135.35	—2.53
A	197.04	198.45	—1.41
M	328.65	337.93	—9.28
J	323.26	330.49	—7.23
J	364.17	377.14	—12.97
A	355.01	367.57	—12.56
S	215.40	220.00	—4.60
O	214.63	218.83	—4.14
N	92.45	90.99	+1.46
D	116.47	117.76	—1.29
Year	2664.31	2725.51	—61.20

From the above mentioned observational period, between the years 1930 - 1968, we have excluded the interval between November 1940 till December 1945, that is the years of war and german occupation of the country, since Northern Greece has been among the areas most hardly tried by the fates of war during World War II *.

In the present study we have used observational data from the periods between November 1930 - October 1940, and January 1946 - December 1968, totalling 396 months, that is 33 years, 32 of which have been full calendar years (1931 - 1939 and 1946 - 1968).

The largest part of these data has been published in issues of the series «Observations Météorologiques de Thessaloniki» (MARIOLOPOULOS 1930 - 1937 [11], KYRIAZOPOULOS 1938 - 1958 [5] and LIVADAS 1959 - 1965 [7]). The material for the remaining interval has been taken from a previous study on sunshine duration in Thessaloniki (LIVADAS [6]). There is a notable fact about this material: all the recorder charts from the year 1938 till 1968 have been elaborated by the same person, a

* For details see (5), issues No 11 and 12.

fact which, in our opinion, renders the homogeneity of the material quite outstanding.

Sunshine Duration.

a. The mean annual sunshine duration in Thessaloniki, for the 32 full years (1931 - 1939 and 1946 - 1968) as well as the annual maximum and minimum duration, are given below in *Table II.*

TABLE II

Annual sunshine duration in Thessaloniki (in hours).

Maximum	2784.83	(1938)
Mean	2621.43	±93.3 (Coef. of variation 3,56%)
Minimum	2408.71	(1963)

An examination of deviations from the mean annual value, shows that the standard deviation σ is ± 93.3 hours, and their distribution has as follows:

$+3\sigma$	$+2\sigma$	$+\sigma$	$-\sigma$	-2σ	-3σ	Σ (years)
0	7	12	6	5	2	32
	21.87%	56.25%		15.62%	6.25%	

This means that annual sunshine duration can be considerably shorter than its mean, while deviations are of the order of ($\pm \sigma$) for the large percentage of 56 %.

b. The mean monthly sunshine duration for the 396 months of the period examined, as well as the monthly maxima and minima are given in *Table III.*

This Table III shows that the largest sunshine duration corresponds to the month of July, which has also the largest value of theoretical sunshine duration (see Table IX), the longest monthly maximum and the longest monthly minimum. On the other hand, the smallest monthly minimum is recorded in December, that is the month with the shortest theoretical sunshine duration, and also the month with the shortest monthly maximum and the absolute minimum of sunshine duration ever recorded.

We can consider as proof of the variability of sunshine duration during the year, the fact that absolute maxima and absolute minima

TABLE III

Mean and extreme monthly values of sunshine duration (in hours) for 396 months in Thessaloniki

	Maximum	Year	Mean	± σ	Minimum	Year	Coefficient of variation
J	193.65	1932	121.27	31.12	57.79	1955	25.66%
F	209.61	1959	146.83	38.70	52.70	1954	26.36
M	239.04	1953	163.66	40.35	80.27	1960	24.65
A	295.73	1947	222.57	30.13	173.17	1959	13.54
M	328.65	1958	276.80	28.73	208.94	1957	10.38
J	378.07	1938	313.82	25.81	271.65	1964	8.22
J	393.15	1968	363.36	18.31	322.85	1967	5.04
A	378.01	1946	346.48	16.75	313.15	1963	4.83
S	294.50	1940	252.62	26.64	184.10	1960	10.55
O	234.95	1935	179.53	39.29	52.42	1951	21.88
N	189.01	1930	124.29	26.40	83.80	1968	21.24
D	162.84	1955	109.20	31.58	41.38	1938	28.85
Year			2620.43				

have been recorded within the same year, as per the following *Table IV*.

TABLE IV

Absolute monthly maxima and minima recorded within the same year.

Year	Month		Sunshine duration (in hours)	Theoretical sunshine duration	Fraction of sunshine
1938	June	Max.	378.07	451.33	0.84
	December	Min.	41.38	289.02	0.14
1959	February	Max.	209.61	297.85	0.70
	April	Min.	173.17	398.77	0.43
1968	July	Max.	393.15	457.83	0.86
	November	Min.	83.80	298.25	0.28

The above Table IV also shows that monthly values are independent from each other, since maxima and minima occur at random: i.e. extreme values for the month of May have been recorded in two consecutive years, and the same has happened for extreme values in July, while extreme values of November have been recorded one in 1930

and the other in 1968, that is at the beginning and the end of the period examined.

A study of deviations from mean monthly values, shows that the standard deviation is smallest during the main two summer months of July and August, and also the coefficient of variation has the smallest percentages in the above two months. The maxima of standard deviation occur during the two transitive months of the winder semester: March $\pm$ 40.35, and October $\pm$ 39.39. The winter semester from October till March has also a coefficient of variation >20.0 %.

Out of the 396 months examined herewith, 207 (52.2 %) show positive deviations from the mean monthly values, and the remaining 189 months (47.7 %) have negative deviations; these deviations are distributed as per the following *Table V*.

TABLE V

$+2\sigma$	to	$+3\sigma$	6 months	0.015
$+\sigma$	to	$+2\sigma$	59 »	0.149
$+\sigma$	to	$-\sigma$	263 »	0.664
$-\sigma$	to	-2σ	59 »	0.149
-2σ	to	-3σ	8 »	0.020
	$>-3\sigma$		1 »	0.003
				1.000

In the case of October 1951, there has been a deviation $>-3\,\sigma$ (Mean for October: 179.53 h / October 1951: 52.42 h / = 127.11 h / $-3\,\sigma$ = 117.87). An examination of weather conditions that have prevailed during that month, shows that the weather was unusually heavy:
Rain - days 20, against 11,0 mean; cloud - covered days (c 8/10) 25, against 8,7 mean; normal monthly mean cloudines for October is 5.4 / 10, October 1951: 8.9 / 10 (ANGOURIDAKIS [1]).

It should be mentioned that in October 1951 the absolute minimum values of sunshine duration have been recorded also at the following stations:

a. At the meteorological Station of the Sindos Cotton Institute, near Thessaloniki (φ: 40°40′, λ: 22°49′, Hp : 13.10 m), where the October mean for the 1946 - 1966 (period) is 152.4h ($\pm$ 45.09), and the sunshine duration recorded on October 1951 has been 32.74h, with 21 sunless days, against the mean 6.5 ($\pm$ 4.73) (ABADJOGLOU [12]).

b. At the National Observatory of Athens where the October

normal mean is 208.5 h and the duration recorded on October 1951 has been 134.8h (LIVATHINOS [9], MARIOLOPOULOS [10,14] KARAPIPERIS [13]).

The fact that this absolute October minimum coincides with the minima of the neighboring Sindos station, enhances the conclusion that on this month unusual weather conditions have prevailed in the area of Thessaloniki; but its coincidence with the minimum of Athens, that is a station lying 300 km to the south, indicates that October 1951 should be considered a month with extremely heavy weather conditions for the whole area of Greece.

Moreover, from the following *Table VII*, *containing* frequencies' distribution of sunshine durations, we draw the conclusion that the case of October 1951 is an exception in this also: While frequencies for almost every month hold consecutive degrees of the scale, this October 1951 minimum stands in the last degree, while its next duration value differs by more than three degrees, that is 74.43h. *Table VI, Table VII.*

TABLE VI

Comparing the absolute minima of sunshine duration with the next to minimum (secondary minimum) values in Table VI, we observe that October has this very marked difference and November the smallest of all.

	Absolute minimum		Secondary minimum		D	D/Abs. Min.
J	57.79	(1955)	60.88	(1933)	3.09	5.34%
F	52.70	(1954)	77.30	(1963)	24.60	46.67
M	80.27	(1960)	85.24	(1932)	4.97	6.19
A	173.17	(1959)	175.06	(1965)	1.89	1.09
M	208.99	(1957)	224.55	(1964)	15.56	7.44
J	271.65	(1964)	273.90	(1968)	2.25	0.83
J	322.85	(1967)	327.88	(1959)	5.03	1.55
A	313.15	(1963)	314.68	(1947)	1.53	0.49
S	184.15	(1960)	198.02	(1959)	13.87	7.53
O	52.42	(1951)	126.85	(1962)	74.43	141.98
N	83.80	(1968)	84.47	(1955)	0.67	0.08
D	41.38	(1938)	47.94	(1946)	6.56	15.85

From the *Table VII* we find that every month of July and August (that is the main two summer months) have sunshine durations of more than 300 hours; also a large percentage (21 cases) belongs to June, and 8 out of 33 months of May also belong to this group. One hundred and eleven (111) months have sunshine durations between

TABLE VII

Distribution of monthly sunshine duration frequencies.

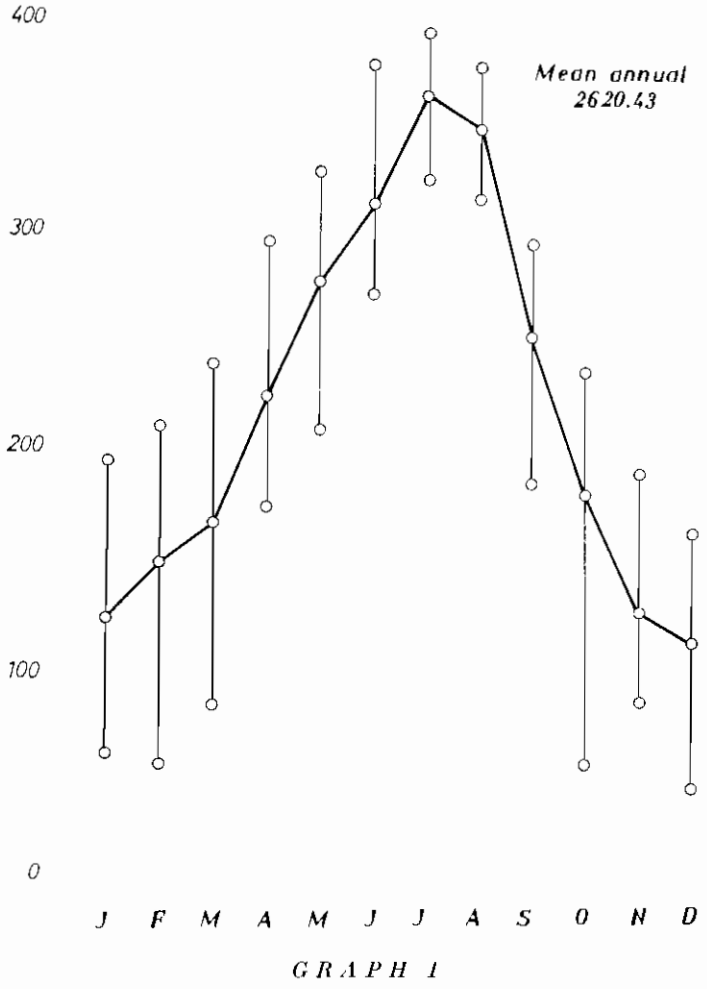
Duration in hours	J	F	M	A	M	J	J	A	S	O	N	D	Σ_1	Σ_2
381 - 400							6						6	
361 - 380						2	14	6					22	
341 - 360						4	7	16					27	
321 - 340					1	7	6	8					22	
301 - 320					7	8		3					18	95
281 - 300				1	8	8			5				22	
261 - 280				3	8	4			9				24	
241 - 260				7	4				11				22	
221 - 240			3	4	4				3	4			18	
201 - 220		2	5	7	1				3	7			25	111
181 - 200	2	7	2	9					2	7	2		31	
161 - 180	1	5	8	2						4		1	21	
141 - 160	5	5	7							5	6	6	34	
121 - 140	10	5	4							5	10	5	39	
101 - 120	5	5									8	7	25	150
81 - 100	7	2	3								6	7	25	
61 - 80	2	1	1								1	5	10	
41 - 60	1	1								1		2	5	40
Total													396	396

200 - 300 hours; this group includes the months of March, April, May, and September, and partly October with 11 out of 33 cases. Durations between 100-200 hours correspond to 150 months: in this group belong the months of the cold semester, from October till March, and some extremely short values of September and April. Finally we have 40 months (about 10 %) out of the 396 of the period examined, with durations between 40 and 100 hours. These months with extremely short sunshine durations, are all months of the cold October - March semester, with the greatest frequency in the main two winter months: December with 14 cases, and January 10.

From *Table III* and *IX* and the *Graph I* we draw the conclusion that the theoretical as well as the observed sunshine duration in Thessaloniki, increases as an average from December till July, and decreases from July till December.

However a more detailed examination of sunshine duration per month, that is a comparison between consecutive months, shows that quite often the rule ensuing from the study of *mean monthly values*

according to which sunshine duration increases from month to month during the December - July period, and decreases from July to December



GRAPH 1

is not always valid (does not apply always). From *Table VIII* is clearly shown that hesides the transition from August to September, which is always normal, all other transitions might show increases instead of decreases, and vice - versa decreases instead of increases.

It is also quite possible that the sunshine duration of January be longer than that of February, or even March i. e.

TABLE VIII

Mean variation of sunshine duration (in hours)		No of Cases (in 33 months) Positive(+)		Negative(—)		Maximum Differences in Consecutive Months Hours (+)	Year	Hours (—)	Year
	Increase								
Jan-Dec	+12.07	Jan>Dec	21	Dec>Jan	12	+82.62	1939	—92.74	1932/33
Feb-Jan	25.56	Feb>Jan	23	Jan>Feb	10	+107.73	1946	—57.39	1932
March-Feb	16.83	March>Feb	20	Feb>March	13	+105.74	1947	—78.67	1959
Apr-March	58.91	Apr>March	30	March>Apr	3	+150.60	1964	—38.50	1948
May-Apr	54.23	May>Apr	28	Apr>May	5	+131.61	11958	—28.43	1947
June-May	37.02	June>May	24	May>June	9	+95.38	1946	—27.65	1966
Jul-June	+49.54	Jul>June	31	June>Jul	2	+97.68	1954	—4.23	1938
	Deerease								
Aug-Jul	—16.88	Aug<Jul	28	Jul>Aug	5			—21.65	1967
Sep-Aug	93.86	Sep<Aug	33	Sep>Aug	0	—139.61	1959	Never	
Oct-Sep	73.09	Oct<Sep	32	Oct>Sep	1	—204.08	1951	10.99	1960
Nov-Oct	55.24	Nov<Oct	30	Nov>Oct	3	—140.51	1956	63.66	1951
Dec-Nov	—15.09	Dec<Nov	21	Dec>Nov	12	— 78.37	1955	78.37	1956

1932	Jan.	193.65 (hours)	Feb.	136.26	March	85.24
1954	Jan.	90.66	Feb.	52.74	March	86.40
1964	Jan.	160.59	Feb.	134.74	March	97.40
1967	Jan.	191.30	Feb.	165.85	March	165.70

This fact can be attributed to the variability of weather conditions from year to year, and especially so from month to month. Moreover the lateness of winter in Northern Greece is proved once more.

As to the variability of weather in March, we should note that the sunshine duration of this month can be shorter even than that of December, during one and the same winter (6 cases in 33 winters).

Winter	1931/32	Dec.	128.50 (hours)	March	85.24 (hours)
»	1953/54	»	118.08	»	86.40
»	1955/56	»	162.84	»	129.00
»	1957/58	»	140.69	»	132.82
»	1959/60	»	99.21	»	80.27
»	1963/64	»	115.80	»	97.40

The same might happen even during a winter with reduced sunshine dnrations, such as the 1953/54 winter (374.88 hours), or in a winter with high sunshine durations, such as the 1957/58 winter (Dec. to March 597.86 hours, Normal Dec.-March duration 540.96 hours).

TABLE IX

Theoretieal sunshine duartion; observed duration (in hours); and per month fraetion.*

	Theoretical*	Mean observed duration (33 years)	Sunshine Fraction Maximum	Mean	Minimum
J	298.50	121.27	0.6487	0.4062	0.1935
F	297.85	146.83	0.7037	0.4929	0.1769
M	369.73	163.66	0.6465	0.4426	0.2171
A	398.77	222.57	0.7416	0.5581	0.4342
M	447.95	276.80	0.7336	0.6179	0.4665
J	451.33	313.82	0.8376	0.6953	0.6018
J	457.83	363.36	0.8587	0.7936	0.7051
A	427.13	346.48	0.8849	0.8111	0.7331
S	374.17	252.62	0.7870	0.6751	0.4921
O	345.15	179.53	0.6807	0.5201	0.1518
N	298.25	124.29	0.6337	0.4167	0.2809
D	289.02	109.20	0.5634	0.3778	0.1431
Year	4455.68	2620.43		0.5880	

* Theoretical sunshine values for Thessaloniki have been estimated by Alexandrou (2,3).

The prolongation of winter till March is also proven by the sunshine fraction, which is smaller in March than in February.

From *Table IX* we draw the conclusion that the sunshine fraction per month is >0.50 for the whole period from April to October, with its maximum in August (0.81), becoming <0.50 during the winter five months, from November till March, with its minimum in December (0.33).

The mean annual fraction is 0.5880.

The absolute maximum sunshine fraction has been recorded in August and it is 0.8849, and the absolute in December. It should be noted that in the city of Thessaloniki is at —5 min. for the whole year, because of the Pieria mountains, while the *retardation of sunrise* varies between 20 - 40 min. because of the neighbourhood of the mountain mass of Chortiates - Kissos, which reduces the sunshine duration by some 230 hours per year.

c. Mean daily sunshine duration: Besides the comparatively high variability of sunshine duration in the monthly values, the exact knowledge of the variation of its values from day to day, as well as its daily variation are also of interest, mainly in technological applications.

In the area examined, freequent and sudden changes of the weather are quite usual: it is possible for a sunny day, or a sequence of sunny days to be succeeded by one or more cloudy days, and vice versa. This is due to the fact of Thessaloniki being situated in the contact area between the warm East Mediterranean and the comparatively cold southeastern Europe, and the western projection of Asia (Asia Minor), that is the activity area of the Mediterranean - Polar front.

Table X contains all the daily values for the period examined, that is for 12.414 days; only three days with no data have been excluded, together with two days of solar eclipses (the 15.2.1961 and 20.5. 1966) which although they should have been sunny, nevertheless and their sunshine obstructed from astronomical causes.

From *Tables X* and *XI* we find that sunless days are 1.436 (11.6%), while for the same period, days with sunshine duration $\geqq 12.50$ hours are also 1.434, and days with sunshine duration $\geqq 8.50$ hours are 6.088 (49.0%). The period between April to September seems to have a considerable percentage of daily sunshine durations $\geqq 11.50$ hours. The months from May to August seem to assemble most of the sunny days, while sunless days (duration $= 0$), the «practically sunless» (duration $\leqq 0.49$) and the almost sunless (sunshine duration $\leqq 1.49$, but >0.49) hold a very small percentage.

TABLE X

Distribution of daily sunshine duration values

Duration in hours	I	F	M	A	M	J	J	A	S	O	N	D	Σ	
13.50 - 14.49	—	—	—	—	10	36	23	2	—	—	—	—	71	0.0057
12.50 - 13.49	—	—	—	25	196	328	579	235	—	—	—	—	1363	0.1098
11.50 - 12.49	—	—	—	124	153	177	164	455	72	—	—	—	1145	0.0922
10.50 - 11.49	—	11	20	150	138	121	106	147	97	4	—	—	794	0.0640
9.50 - 10.49	1	171	187	122	111	99	50	72	375	217	28	—	1433	0.1154
8.50 - 9.49	177	125	120	96	73	44	40	40	140	175	157	95	1282	0.1033
7.50 - 8.49	94	73	86	90	63	42	24	26	80	84	98	123	883	0.0711
6.50 - 7.49	68	72	73	59	45	40	16	20	63	81	51	82	670	0.0540
5.50 - 6.49	65	56	70	50	53	32	16	12	39	57	67	56	573	0.0462
4.50 - 5.49	66	30	48	39	36	17	11	11	26	48	66	67	465	0.0375
3.50 - 4.49	59	49	56	36	38	22	7	17	24	59	65	71	503	0.0405
2.50 - 3.49	58	42	31	36	35	9	7	5	10	52	55	66	406	0.0327
1.50 - 2.49	46	62	61	39	30	18	3	4	17	45	62	46	433	0.0349
0.50 - 1.49	80	57	72	45	28	14	7	4	22	66	87	63	545	0.0439
0.01 - 0.49	63	44	52	27	14	5	1	2	19	46	69	70	412	0.0332
0	277	167	178	82	30	15	—	2	36	119	215	315	1436	0.1157
	1054	959	1054	1020	1053	1019	1054	1054	1020	1053	1020	1054	12414	1.0000

Notice: The above Table does not include three days, for which no data exist, and two days of solar eclipses, the 15.2.1961, and the 20.5.1966.

TABLE XI

Occurence percentage of various sunshine duration values.

Duration in hours	J	F	M	A	M	J	J	A	S	O	N	D
13.50 - 14.49	—	—	—	—	0.95	3.53	2.18	0.19	—	—	—	—
12.50 - 13.49	—	—	—	2.45	18.61	32.19	54.93	22.30	—	—	—	—
11.50 - 12.49	—	—	—	12.16	14.53	17.37	15.56	43.17	7.05	—	—	—
10.50 - 11.49	—	4.15	1.90	14.71	13.10	11.87	10.06	13.95	9.51	0.38	—	—
9.50 - 10.49	0.10	17.83	17.74	11.96	10.54	9.72	4.74	6.83	36.76	20.61	2.75	—
8.50 - 9.49	16.79	13.03	11.38	9.41	6.93	4.32	3.80	3.80	13.73	16.62	15.39	9.01
7.50 - 8.49	8.92	7.61	8.16	8.82	5.98	4.12	2.28	2.47	7.84	7.98	9.61	11.67
6.50 - 7.49	6.45	7.51	6.92	5.78	4.27	3.93	1.52	1.90	6.18	7.69	5.00	7.78
5.50 - 6.49	6.17	5.84	6.64	4.90	5.03	3.14	1.52	1.14	3.82	5.41	6.57	5.31
4.50 - 5.49	6.26	3.13	4.55	3.82	3.42	1.67	1.04	1.04	2.55	4.56	6.47	6.36
3.50 - 4.49	5.60	5.11	5.31	3.53	3.61	2.16	0.66	1.61	2.35	5.60	6.37	6.74
2.50 - 3.49	5.50	4.38	2.94	3.53	3.32	0.88	0.66	0.47	0.98	4.94	5.39	6.26
1.50 - 2.49	4.36	6.47	5.79	3.82	2.85	1.77	0.28	0.38	1.67	4.27	6.08	4.36
0.50 - 1.49	7.59	5.94	6.83	4.41	2.66	1.37	0.66	0.38	2.16	6.27	8.53	5.98
0.01 - 0.49	5.98	4.59	4.93	2.65	1.33	0.49	0.09	0.19	1.86	4.37	6.76	6.64
0	26.28	17.41	16.89	8.04	2.85	1.47	—	0.19	3.53	11.30	21.08	29.89
	100.00	100.00	99.98	99.99	99.98	100.00	99.98	100.01	99.99	100.00	100.00	100.00

TABLE XII

Percentage of days with various sunshine-durations during the April-September semester.

Daily duration (in hours)	A	M	J	J	A	S
⩾ 11.50	14.61%	34.09%	53.09%	72.67%	65.66%	7.05%
< 1.50	15.10%	6.84%	3.33%	0.75%	0.76%	7.55%
< 0.49	10.69%	4.18%	1.96%	0.09%	0.19%	5.39%
= 0	8.04%	2.85%	1.47%	0	0.19%	3.53%

Days with sunshine outnumber sunless ones, from February till October, while sunless days predominate during the November - January trimester only, with their maximum in December (315 days/29,89%). The percentage of sunless or almost sunless days (Table XII) becomes <1 during the main two summer months of July and August.

d. Duration of groups of sunless days.

The problem of whether sunless days occur at random, alternating with sunny ones, or if the appear as groups of consecutive sunless days, is of paramount importance from the meteorological point of view, and also from that of technological applications (utilization of sun - power).

TABLE XIII

Mean and extreme per month occurences of sunless days in Thessaloniki (1960 - 1968).

	Maximum	Mean	$\pm\sigma$	Minimum
J	18 (1946)	8.15	±4.39	1 (1932)
F	17 (1954)	4.91	±3.99	0 (1938, 1953, 1966)
M	14 (1959)	5.24	±3.33	0 (1938)
A	7 (1931, 1959)	2.41	±1.95	0 frequently
M	3 (1950)	0.88	± 0.72	0 »
J	2 (4 years)	0.44	±0.69	0 »
J	—	0		—
A	1 (1955, 1966)	0.06	±0.23	0 frequently
S	5 (1960)	1.06	± 1.31	0 »
O	16 (1951)	3.50	±3.06	0 (1935, 1967)
N	10 (1946, 1956, 1962)	6.32	±2.42	0 (1950)
D	19 (1946)	9.26	± 3.70	2 (1951)
Year		42.24		

We give *Table XIII*, in which we have included data of sunless days, as a climatological feature.

Data of the above Table prove once more the conclusions we have come to previously, that is:

a. That the main two summer months of July and August practically have no sunless days.

b. March outnumbers February in sunless days, while December has the highest values, extreme and monthly average as well.

In Tables XIV and *XV* we have included groups of consecutive sunless days (sunshine duration = 0) and groups of consecutive «actually or practically» sunless days (sunshine duration 0.49 hours).

TABLE XIV

Distribution of groups of consecutive sunless days in Thessaloniki.

	2	3	4	5	6	7	8	9	Total of groups Σ_1	Total of days Σ_2	Σ_1/Σ_2 %
J	26	13	3	5	2	3	—	2	179	277	64.6
F	20	8	2	1	2	—	—	—	89	167	53.3
M	17	8	2	1	2	—	—	—	83	178	46.6
A	8	2	2	—	—	—	—	—	30	82	36.6
M	3	—	—	—	—	—	—	—	6	30	20.0
J	2	—	—	—	—	—	—	—	4	15	
J		—	—	—	—	—	—	—	—	—	—
A	—	—	—	—	—	—	—	—	—	2	—
S	3	1	—	—	—	—	—	—	9	36	25.0
O	10	4	3	—	—	1	—	—	51	119	42.9
N	24	10	2	2	—	1	—	—	103	215	47.9
D	31	18	9	3	1	1	—	—	180	315	57.1
Total of cases	144	64	23	12	7	6	—	2		1436	
Total of days	288	192	92	60	42	42	—	18	734		

In the above *Table XIV* the 1.436 sunless days of the period examined, are studied as to the duration of groups of consecutive sunless days; this examination leads to the following conclusions:

a. Half of the sunless days (51.1%) appear in Thessaloniki in groups of consecutive days.

b. Sunless days appear in groups during the whole October - March

semester, in a percentage of more than 40%, while in the main three winter months, December, January, and February, the percentage is above 50%.

c. Almost half of these groups of sunless days consist of two consecutive days (144 case out of 258).

The longest period of sunless days belongs in January, with two cases of 9 consecutive days (21 - 29/1/1946 and 16 - 24/1/1962)

Besides the really sunless days (sunshine duration = 0), we consider as actually or practically sunless days those with daily sunshine duration of less than 0.50 hours, since the incoming solar radiation in a day when the sun shone for only 30′ or less, is so insignificant as to be practically useless for any application.

In the *Table XV* are classified groups of consecutive «practically or actually» sunless days for the period examined. These groups total 1.848 days, and their study leads to the following conclusions:

a. Consecutive sunless days come in groups at a percentage of 63.6%, meaning that if to the sum of actually sunless days we should add the 412 practically sunless ones (with sunshine durations from 0.01 to 0.49 hours) the percentage of grouped consecutive sunless days increases by about 12%. This means that practically sunless days largely intermingle with actually sunless days, thus emphasizing even more the impression of long intervals with overcast skies in Thessaloniki.

b. The October - March semester has a percentage of 60% of sunless days in groups; while December and January have such days in groups at more than 70%. Also the percentage of grouped actually sunless days is larger in March than in February.

Finally the two purely summer months of July and August, remain free of such groups of days with bad weather.

c. The percentage of groups with two consecutive days decreases from 144:258 = 0.56% (with durations = 0), to 213:399 = 0.53%; as to the percentage of days this class instead of 288:734 = 0.39%, becomes 426:1175 days = 0.36%.

Moreover the longest durations of groups of sunless days now amount to one case of 10 consecutive days (10 - 19/1/1963), and one case of 12 consecutive days (9 - 20/12/1968).

e. Daily variation of sunshine - Hourly values.

The period of daylight changes continuously, and accordingly also changes the theoretical duration of sunshine from day to day,

TABLE XV

Distribution of groups of «practically or actually» sunless consecutive days in Thessaloniki.

	2	3	4	5	6	7	8	9	10	11	12	Total of groups Σ_1	Total of days Σ_2	Σ_1/Σ_2 %
J	37	19	8	5	2	3	—	2	1	—	—	249	340	73.2
F	26	11	2	3	2	1	—	—	—	—	—	127	211	60.2
M	29	15	3	1	4	1	—	—	—	—	—	151	230	65.7
A	12	4	3	—	—	—	—	—	—	—	—	48	109	44.0
M	4	1	—	—	—	—	—	—	—	—	—	11	44	25.0
J	2	—	—	—	—	—	—	—	—	—	—	4	20	20.0
J	—	—	—	—	—	—	—	—	—	—	—	0	1	—
A	—	—	—	—	—	—	—	—	—	—	—	0	4	—
S	6	2	—	—	—	—	—	—	—	—	—	18	55	32.7
O	19	10	5	—	1	1	—	—	—	—	—	101	165	61.2
N	37	13	5	6	—	2	—	—	—	—	—	177	284	62.3
D	41	25	14	3	3	1	3	—	—	—	—	289	385	75.1
Total of cases	213	100	40	18	12	9	3	2	1	—	1			
Total of Days	426	300	160	90	71	63	24	18	10	—	12	1175	1848	

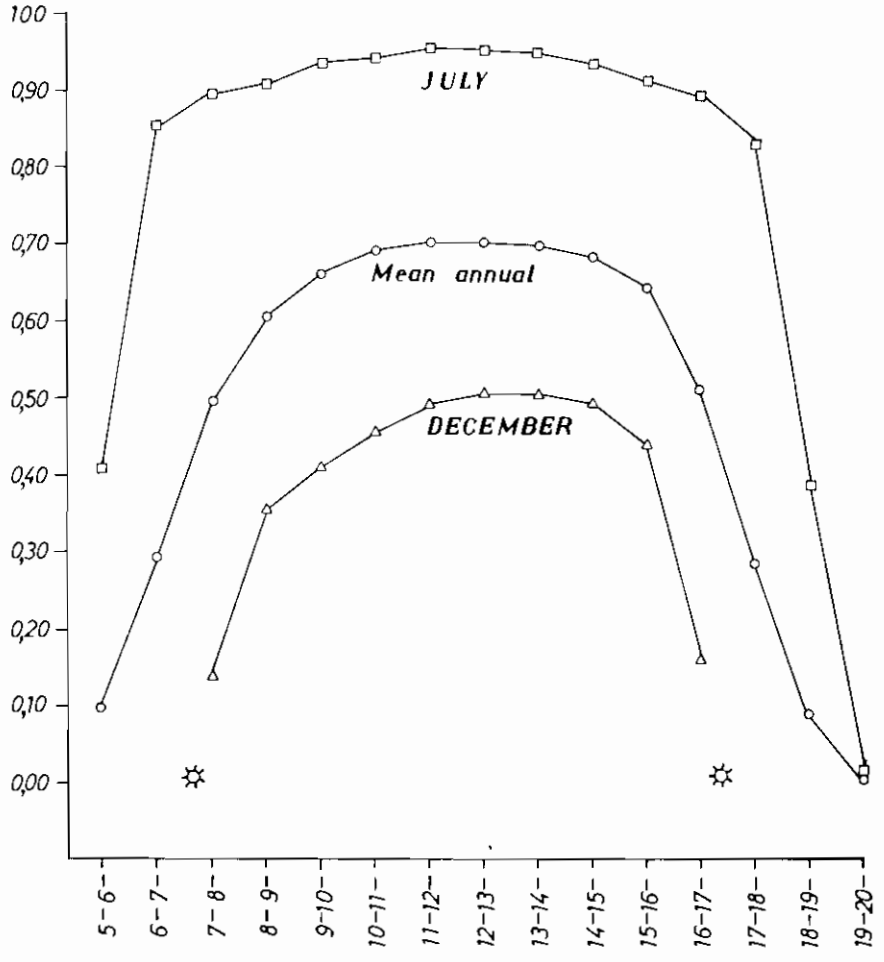
TABLE XVI

Mean hourly values of sunshine duration, per hour and per month, in Thessaloniki (in hours)
(1930 - 1968)

	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	Observed	Theoret.
J			0.13	0.36	0.41	0.45	0.49	0.50	0.50	0.49	0.44	0.16				3.93	9.63
F		0.01	0.35	0.49	0.54	0.57	0.59	0.60	0.59	0.56	0.53	0.38	0.03			5.24	10.54
M		0.02	0.34	0.47	0.54	0.58	0.59	0.60	0.59	0.55	0.52	0.41	0.04			5.25	11.93
A	0.04	0.33	0.57	0.65	0.68	0.72	0.73	0.72	0.71	0.69	0.65	0.56	0.32	0.04	0.00	7.41	13.29
M	0.23	0.62	0.69	0.73	0.77	0.78	0.79	0.78	0.76	0.74	0.71	0.65	0.54	0.20	0.00	8.98	14.45
J	0.39	0.73	0.80	0.85	0.86	0.87	0.88	0.87	0.86	0.83	0.80	0.74	0.65	0.31	0.04	10.48	15.04
J	0.41	0.85	0.89	0.91	0.93	0.94	0.95	0.95	0.95	0.93	0.91	0.89	0.83	0.37	0.00	11.71	14.77
A	0.17	0.82	0.89	0.91	0.92	0.94	0.94	0.95	0.95	0.94	0.92	0.89	0.80	0.16	0.00	11.20	13.78
S	0.00	0.16	0.66	0.77	0.82	0.84	0.86	0.85	0.85	0.84	0.82	0.72	0.18	0.00		8.37	12.47
O		0.01	0.38	0.55	0.59	0.63	0.65	0.65	0.65	0.64	0.60	0.45	0.01			5.81	11.13
N		0.00	0.17	0.34	0.43	0.46	0.50	0.51	0.51	0.49	0.45	0.22	0.01			4.09	9.94
D			0.08	0.32	0.39	0.43	0.45	0.47	0.46	0.44	0.38	0.09				3.51	9.23
year	0.103	0.296	0.496	0.613	0.657	0.684	0.702	0.705	0.698	0.678	0.644	0.513	0.284	0.090	0.003	7.166	

from month to month, during the evolvement of the year. In the adjoined *Table XVI* we observe that the length of actual daylight, as it ensues from the sunshine duration recorded, changes: thus it has its minimum (10 hours) during the two winter months of December and January, while the preceding two autumnal months of October and November, and the two following of February and March (although from the weather point of view, they too can be considered as winter months) they all have sunshine durations of 12 hours.

GRAPH II



Daily variation of sunshine in Thessaloniki.

The actual - possible sunshine duration is 15 hours from April till August.

The largest values appear around midday, although one cannot really talk about a daily variation of sunshine, since the mean sunshine value rises sharply shortly after sunrise, and from then on remains almost stable, with very slight variations during the whole day; thus between 09:00 and 16:00 during the whole year, variations are $\leq$0.10h, that is almost invariable. A study of *Graph II* leads to similar conclusions.

Furthermore we have examined the probability of recording hourly sunshine values = Xi (where i = 0, 1, 2, 3, 4, 5), that is:

X_0 =	sunshine	duration	= 0		
X_1 =	»	»	between	0,01 - 0,09	hours
X_2 =	»	»	»	0,10 - 0,29	»
X_3 =	»	»	»	0,30 - 0,69	»
X_4 =	»	»	»	0,70 - 0,99	»
X_5 =	»	»	»	1 hour	»

We believe that this knowledge is important for technological applications.

Data of the adjoined *Tables XVII - XXII* show that:

a. The minimum frequency of hours with «0» sunshine duration, during the day and for all months, is between 11:00 to 14:00 hours, while maxima appear at the hours of sunrise and sunset.

The same applies for the «practically sunless» hours (with sunshine duration: 0,01 - 0,09h).

b. On the other hand the maximum frequency of sunlit hours (sunshine duration: 1h per hour) appears between 10:00 to 14:00 hours. This frequency is 37,0% in December, increasing to 89,5% and 89,6% respectively in the main two summer months of July and August.

c. Sunshine duration between 0,10 - 0,99h per hour (see *Tables XIX - XXI*) have smaller percentages, comparatively higher during the early morning and late afternoon hours.

Conclusions.

Most of these conclusions have been already mentioned in the previous sections of this paper. However, in summing up, we can mention that, from the detailed study of sunshine duration in Thessaloniki for the 1930 - 1968 period, we have come to the following conclusions:

a. The annual mean sunshine duration is: 2621.43 hours ± 93.3 (TABLE 11); meaning that from the point of view of sunshine, at the northern recess of Thermaikos Gulf on the north coast of the Aegean Sea, we have the climatic type of the Mediterranean Riviera. Moreover, by comparing the data of Thessaloniki with data of various other mediterranean stations on the northern coast of the Mediterranean, we observe that even the macedonian coast exceeds other world famous coasts as to sunshine durations.

TABLE XXIII

Sunshine duration (in hours) of Balkan's meteorological Stations.

	Thessaloniki	Trieste	Split	Avar	Cetinje	Sulina
J	121	94	148	132	86	71
F	147	137	158	204	144	87
M	164	155	195	198	154	110
A	226	170	206	259	236	190
M	277	228	255	282	245	290
J	314	256	323	319	357	308
J	363	315	354	339	366	338
A	346	294	345	356	329	319
S	253	212	246	249	226	222
O	180	140	185	203	191	157
N	124	108	128	141	98	87
D	109	96	115	87	41	67
Year	2624	2205	2658	2769	2473	2246

b. The mean monthly sunshine durations has a simple variation, with a minimum in December with 109.20 hours ± 31.58, and a maximum in July with 363.36 hours ± 18.31 *(Table III)*.

The monthly values of sunshine duration from May till December are >200 hours, while values <100 hours are assembled in the cold period, with their maximum in December (14 cases out of 33 months).

c. As an average sunshine duration increases from December till July, and decreases from July till December. However, because of particular weather conditions, it is possible for March to have shortest sunshine durations than February, and also for December to have longest durations than January (see *Table VIII*). This fact is characteristic of the weather instability in the area examined, from year to year and also from month to month.

Month	Hours	05 00 06 00	06 00 07 00	07 00 08 00	08 00 09 00	09 00 10 00	10 00 11 00	11 00 12 00
J				21.15 ±*4.18*	16.76 ±*3.94*	14.88 ±*4.07*	13.35 ±*4.29*	12.79 ±*4.03*
F			19.50 ±*10.09*	13.53 ±*4.86*	11.29 ±*4.44*	10.50 ±*4.25*	9.50 ±*4.53*	8.71 ±*4.85*
M			26.91 ±*3.23*	15.76 ±*4.27*	12.68 ±*3.77*	10.71 ±*3.57*	9.62 ±*4.09*	9.18 ±*3.96*
A		24.38 ±*3.14*	13.71 ±*2.70*	8.97 ±*2.86*	7.29 ±*2.50*	6.41 ±*2.68*	5.62 ±*2.62*	5.24 ±*2.74*
M		13.24 ±*4.63*	7.50 ±*3.33*	5.74 ±*2.88*	4.79 ±*2.28*	4.21 ±*1.97*	3.74 ±*1.65*	3.44 ±*1.70*
J		8.41 ±*5.01*	4.41 ±*3.18*	3.21 ±*2.10*	2.44 ±*1.54*	2.12 ±*1.23*	1.74 ±*1.14*	1.82 ±*1.27*
J		5.41 ±*3.41*	2.03 ±*1.74*	1.38 ±*1.43*	1.15 ±*1.11*	0.94 ±*1.05*	0.85 ±*0.91*	0.68 ±*0.79*
A		11.86 ±*4.33*	2.40 ±*1.68*	1.46 ±*1.25*	1.11 ±*1.03*	0.86 ±*0.83*	0.94 ±*1.04*	0.74 ±*0.77*
S		10.31 ±*13.45*	18.37 ±*4.64*	5.46 ±*3.04*	3.66 ±*2.39*	3.06 ±*2.05*	2.89 ±*1.94*	2.66 ±*2.04*
O			17.89 ±*13.09*	13.11 ±*4.93*	10.14 ±*4.75*	8.89 ±*4.44*	8.03 ±*4.16*	7.26 ±*3.62*
N				17.91 ±*4.71*	14.65 ±*3.17*	13.35 ±*3.11*	12.35 ±*2.91*	11.24 ±*2.87*
D				22.29 ±*4.04*	17.56 ±*3.66*	15.38 ±*3.97*	14.68 ±*3.50*	13.47 ±*4.05*

«Ο»

12 00 13 00	13 00 14 00	14 00 15 00	15 00 16 00	16 00 17 00	17 00 18 00	18 00 19 00	19 00 20 00
12.18 ±4.02	12.15 ±3.94	12.68 ±3.80	13.79 ±3.72	17.82 ±3.83			
8.59 ±4.41	8.41 ±3.99	8.94 ±4.06	10.06 ±4.17	12.24 ±4.31	21.12 ±6.91		
9.00 ±4.08	9.15 ±4.30	9.71 ±4.58	10.76 ±4.98	13.38 ±4.55	24.26 ±3.41	*	
5.26 ±2.37	5.62 ±2.56	5.79 ±2.43	6.29 ±2.55	8.21 ±2.96	13.65 ±3.73	25.44 ±2.51	0.85 ±4.90
3.76 ±1.93	3.62 ±2.04	4.21 ±2.42	4.53 ±2.03	5.88 ±2.11	8.71 ±2.67	14.97 ±3.91	4.21 ±10.15
1.71 ±1.15	1.97 ±1.20	2.26 ±1.22	3.35 ±1.69	4.06 ±1.91	5.38 ±2.40	10.26 ±3.64	3.91 ±9.47
0.53 ±0.65	0.59 ±0.73	0.65 ±0.80	1.06 ±0.91	1.26 ±1.01	2.29 ±1.77	6.12 ±2.94	7.79 ±12.99
0.57 ±0.73	0.51 ±0.77	0.66 ±0.75	0.80 ±1.01	1.09 ±1.16	1.91 ±1.78	12.80 ±3.83	1.60 ±6.52
2.77 ±1.84	2.74 ±1.96	2.89 ±2.05	3.11 ±2.16	4.40 ±2.68	15.11 ±5.72	6.49 ±11.92	
7.17 ±3.51	7.63 ±3.91	7.51 ±3.83	9.03 ±3.97	10.80 ±4.51	19.14 ±11.51		
10.94 ±3.21	10.79 ±2.79	11.38 ±3.13	12.79 ±3.43	16.15 ±3.63			
13.26 ±4.00	13.50 ±4.22	14.53 ±4.61	16.00 ±4.17	20.85 ±3.93			

X_1

Month \ Hours	05 00 06 00	06 00 07 00	07 00 08 00	08 00 09 00	09 00 10 00	10 00 11 00	11 00 12 00
J			0.65 ±*0.24*	0.41 ±*0.19*	0.82 ±*0.28*	0.76 ±*0.29*	0.62 ±*0.24*
F		1.03 ±*1.00*	0.47 ±*0.65*	0.79 ±*0.83*	0.38 ±*0.54*	0.50 ±*0.65*	0.53 ±*0.70*
M		1.15 ±*1.40*	0.50 ±*0.69*	0.65 ±*0.87*	0.85 ±*0.94*	0.53 ±*0.74*	0.65 ±*0.80*
A	0.00 *0.00*	5.00 ±*2.73*	12.85 ±*3.16*	15.79 ±*2.74*	17.09 ±*3.10*	18.06 ±*3.34*	18.21 ±*3.16*
M	1.00 ±*1.06*	0.71 ±*0.86*	0.62 ±*0.77*	0.76 ±*1.00*	0.53 ±*0.69*	0.53 ±*0.74*	0.62 ±*0.73*
J	0.56 ±*0.73*	0.59 ±*0.81*	0.41 ±*0.60*	0.38 ±*0.54*	0.35 ±*0.48*	0.35 ±*0.53*	0.18 ±*0.38*
J	0.53 ±*0.85*	0.35 ±*0.54*	0.38 ±*0.81*	0.29 ±*0.52*	0.03 ±*0.17*	0.12 ±*0.10*	0.09 ±*0.28*
A	2.23 ±*1.69*	0.46 ±*0.60*	0.31 ±*0.62*	0.14 ±*0.35*	0.20 ±*0.40*	0.06 ±*0.23*	0 09 ±*0.28*
S	0.46 ±*0.80*	2.29 ±*2.18*	0.83 ±*1.03*	0.54 ±*0.99*	0.37 ±*0.54*	0.26 ±*0.50*	0.20 ±*0.40*
O		1.20 ±*1.35*	0.71 ±*0.70*	0.77 ±*0.87*	0.66 ±*0.83*	0.60 ±*0.76*	0.54 ±*0.65*
N			1.00 ±*0.77*	1.03 ±*1.04*	0.88 ±*0.72*	0.71 ±*0.89*	0.88 ±*0.79*
D			0.91 ±*0.89*	0.56 ±*0.81*	0.65 ±*0.93*	0.62 ±*0.94*	0.76 ±*0.84*

ΠΙΝΑΞ XVIII

«0.01 - 0.09»

12 00 13 00	13 00 14 00	14 00 15 00	15 00 16 00	16 00 17 00	17 00 18 00	18 00 19 00	19 00 20 00
0.53 ±*0.21*	0.91 ±*1.01*	0.76 ±*1.00*	0.68 ±*0.26*	1.12 ±*1.25*			
0.41 ±*0.69*	0.47 ±*0.65*	0.53 ±*0.74*	0.62 ±*0.81*	0.53 ±*0.98*	1.38 ±*1.39*		
0.71 ±*0.82*	0.68 ±*0.79*	0.74 ±*0.98*	0.59 ±*0.69*	0.71 ±*0.96*	1.65 ±*1.19*		
18.29 ±*3.37*	17.47 ±*3.11*	16.71 ±*3.22*	14.82 ±*3.10*	11.71 ±*3.46*	3.74 ±*2.35*	0.03 ±*0.17*	0.00 *0.00*
0.44 ±*0.74*	0.47 ±*0.61*	0.65 ±*0.84*	0.65 ±*0.72*	1.00 ±*0.84*	0.82 ±*1.01*	1.50 ±*1.12*	0.12 ±*0.32*
0.35 ±*0.53*	0.12 ±*0.32*	0.18 ±*0.45*	0.41 ±*0.77*	0.38 ±*0.64*	0.76 ±*1.00*	1.18 ±*1.04*	0.12 ±*0.40*
0.12 ±*0.32*	0.12 ±*0.32*	0.21 ±*0.40*	0.24 ±*0.49*	0.24 ±*0.49*	0.32 ±*0.47*	1.06 ±*1.08*	0.18 ±*0.38*
0.11 ±*0.32*	0.11 ±*0.32*	0.14 ±*0.35*	0.14 ±*0.35*	0.23 ±*0.42*	0.51 ±*0.65*	2.60 ±*1.73*	0.03 ±*0.17*
0.17 ±*0.38*	0.34 ±*0.53*	0.26 ±*0.44*	0.29 ±*0.51*	0.40 ±*0.59*	2.43 ±*1.89*	0.06 ±*0.23*	
0.57 ±*0.64*	0.46 ±*0.69*	0.60 ±*0.76*	0.57 ±*0.77*	0.74 ±*0.81*	1.80 ±*1.85*		
1.12 ±*1.03*	0.74 ±*1.07*	0.91 ±*1.01*	0.79 ±*0.93*	0.85 ±*0.88*			
0.50 ±*0.74*	0.50 ±*0.70*	0.62 ±*0.73*	0.44 ±*0.74*	1.00 ±*1.16*			

X_2

Month \ Hours	05 00 06 00	06 00 07 00	07 00 08 00	08 00 09 00	09 00 10 00	10 00 11 00	11 00 12 00
J			2.88 ±*1.79*	1.50 ±*0.30*	1.62 ±*1.05*	1.38 ±*1.06*	1.18 ±*1.01*
F		1.65 ±*1.43*	2.00 ±*1.91*	1.35 ±*0.86*	0.91 ±*1.07*	0.97 ±*1.04*	1.06 ±*0.91*
M		2.24 ±*2.17*	1.79 ±*1.08*	1.88 ±*1.25*	1.50 ±*1.09*	1.53 ±*1.27*	1.44 ±*1.31*
A	3.47 ±*2.28*	3.26 ±*1.91*	1.76 ±*1.31*	1.18 ±*1.17*	1.47 ±*1.40*	1.38 ±*1.28*	1.09 ±*0.86*
M	4.38 ±*1.97*	1.71 ±*1.36*	1.44 ±*1.06*	1.32 ±*1.08*	1.03 ±*1.15*	1.35 ±*1.45*	1.21 ±*1.28*
J	2.85 ±*1.63*	1.26 ±*0.98*	1.29 ±*1.01*	0.82 ±*0.75*	0.85 ±*0.84*	0.82 ±*1.07*	0 68 ±*0.79*
J	3.21 ±*2.64*	0.88 ±*1.30*	0.68 ±*0.76*	0.53 ±*0.81*	0.41 ±*0.60*	0.24 ±*0.43*	0.29 ±*0.52*
A	0.74 ±*2.98*	0.80 ±*0.89*	0.86 ±*0.93*	0.57 ±*0.73*	0.63 ±*0.80*	0.31 ±*0.52*	0.43 ±*0.55*
S	0.37 ±*0.96*	3.51 ±*2.81*	1.40 ±*1.02*	1.23 ±*0.90*	0.97 ±*0.94*	0.60 ±*0.80*	0.46 ±*0.65*
O		1.23 ±*1.74*	2.31 ±*1.77*	1.60 ±*1.02*	1.63 ±*1.15*	1.43 ±*1.20*	1.54 ±*1.18*
N			2.38 ±*1.33*	1.79 ±*1.23*	1.44 ±*1.21*	1.79 ±*0.96*	1.56 ±*1.19*
D			3.12 ±*2.02*	2.12 ±*1.33*	1.76 ±*1.24*	1.41 ±*1.09*	1.76 ±*1.16*

ΠΙΝΑΞ XIX

«0.10 - 0.29»

12 00 13 00	13 00 14 00	14 00 15 00	15 00 16 00	16 00 17 00	17 00 18 00	18 00 19 00	19 00 20 00
1.41 ±*1.07*	1.50 ±*1.33*	1.38 ±*1.14*	1.59 ±*1.60*	2.97 ±*1.89*			
1.35 ±*1.16*	1.41 ±*1.17*	1.65 ±*1.49*	1.35 ±*1.02*	2.24 ±*1.68*	2.68 ±*1.79*		
1.56 ±*1.35*	1.41 ±*1.29*	2.03 ±*1.38*	1.79 ±*1.32*	2.12 ±*1.13*	4.00 ±*2.83*		
1.62 ±*1.33*	1.21 ±*1.39*	1.82 ±*1.40*	2.03 ±*1.29*	2.03 ±*1.65*	2.82 ±*1.69*	2.06 ±*1.53*	0.00 *0.00*
1.15 ±*1.29*	1.62 ±*1.35*	1.50 ±*0.98*	1.65 ±*1.16*	1.97 ±*1.25*	2.24 ±*1.41*	4.68 ±*2.19*	0.12 ±*0.47*
0.71 ±*0.92*	0.88 ±*1.05*	1.00 ±*1.08*	1.12 ±*1.05*	1.65 ±*1.30*	2.18 ±*1.27*	4.09 ±*2.12*	0.26 ±*0.81*
0.18 ±*0.45*	0.35 ±*0.64*	0.47 ±*0.65*	0.47 ±*0.77*	0.85 ±*1.09*	0.88 ±*1.02*	4.44 ±*2.90*	0.15 ±*0.49*
0.23 ±*0.48*	0.26 ±*0.50*	0.43 ±*0.64*	0.43 ±*0.60*	0.89 ±*0.98*	1.57 ±*1.54*	8.66 ±*3.01*	0.09 ±*0.50*
0.60 ±*0.69*	0.51 ±*0.60*	0.74 ±*0.73*	0.83 ±*0.74*	1.37 ±*1.15*	5.83 ±*3.38*	0.29 ±*0.66*	
1.49 ±*1.10*	1.37 ±*0.93*	1.57 ±*1.25*	1.11 ±*1.16*	2.43 ±*1.64*	1.83 ±*2.21*		
1.41 ±*1.35*	1.59 ±*1.26*	1.59 ±*1.17*	1.56 ±*1.19*	2.91 ±*1.42*			
1.32 ±*1.13*	1.12 ±*1.02*	1.03 ±*1.01*	1.44 ±*1.24*	4.59 ±*2.74*			

X_3

Month \ Hours	05 00 06 00	06 00 07 00	07 00 08 00	08 00 09 00	09 00 10 00	10 00 11 00	11 00 12 00
J			5.74 ±3.13	2.91 ±2.15	2.41 ±1.52	3.06 ±1.51	2.21 ±1.28
F		0.21 ±0.47	3.76 ±1.66	1.97 ±1.20	2.38 ±1.35	1.82 ±1.49	2.09 ±1.69
M		0.71 ±1.40	3.94 ±2.42	2.50 ±1.59	2.44 ±1.52	2.68 ±1.32	2.47 ±1.27
A	1.24 ±1.54	4.59 ±2.02	3.06 ±1.19	2.47 ±1.44	2.21 ±1.37	1.91 ±1.54	2.24 ±1.46
M	11.47 ±4.13	3.71 ±2.16	3.29 ±1.74	2.53 ±1.58	2.41 ±1.59	2.32 ±1.37	2.21 ±1.67
J	13.15 ±4.57	3.29 ±2.24	1.91 ±1.38	1.24 ±0.84	1.41 ±1.22	1.47 ±1.01	1.35 ±1.21
J	18.03 ±4.66	2.35 ±1.41	1.35 ±1.00	1.35 ±1.02	1.00 ±1.21	0.88 ±0.93	0.50 ±0.61
A	8.03 ±4.02	2.94 ±2.29	1.40 ±1.50	1.29 ±1.11	0.74 ±0.69	0.97 ±0.94	0.83 ±0.88
S	0.00 0.00	2.34 ±2.51	3.69 ±2.05	2.31 ±1.57	1.77 ±1.44	1.49 ±1.20	1.29 ±1.08
O		0.06 ±0.33	5.06 ±2.82	2.71 ±1.73	2.43 ±1.40	2.63 ±1.41	2.43 ±1.38
N			5.85 ±2.30	2.79 ±2.36	2.91 ±1.42	2.32 ±1.62	2.44 ±1.67
D			4.65 ±3.44	2.03 ±1.63	2.03 ±1.25	1.97 ±1.52	1.94 ±1.33

ΠΙΝΑΞ XX

«0.30 - 0.69»

12 00 13 00	13 00 14 00	14 00 15 00	15 00 16 00	16 00 17 00	17 00 18 00	18 00 19 00	19 00 20 00
2.44 ±*1.42*	1.91 ±*1.48*	1.94 ±*1.16*	2.44 ±*1.12*	8.38 ±*3.96*			
1.82 *1.41*	2.15 ±*1.44*	2.47 ±*1.59*	2.71 ±*1.65*	4.24 ±*1.83*	0.53 ±*0.74*		
2.68 ±*1.71*	2.79 ±*1.79*	2.56 ±*1.52*	3.26 ±*2.16*	3.44 ±*1.88*	1.06 ±*1.23*		
1.85 ±*1.22*	2.59 ±*1.26*	2.65 ±*1.37*	2.94 ±*1.64*	3.44 ±*1.48*	5.26 ±*2.65*	1.53 ±*1.65*	0.03 ±*0.17*
2.65 ±*1.35*	3.15 ±*1.85*	2.94 ±*1.57*	3.65 ±*1.33*	3.50 ±*1.59*	4.65 ±*1.97*	8.38 ±*3.15*	0.09 ±*0.37*
1.53 ±*1.14*	1.91 ±*1.36*	2.62 ±*1.91*	1.94 ±*1.37*	2.94 ±*1.43*	3.56 ±*1.93*	11.09 ±*4.23*	0.12 ±*0.53*
0.65 ±*0.84*	0.82 ±*0.95*	1.32 ±*1.21*	1.56 ±*1.31*	1.68 ±*1.10*	2.56 ±*1.35*	16.82 ±*4.61*	0.09 ±*0.37*
0.86 ±*0.87*	1.14 ±*1.10*	0.83 ±*0.94*	1.57 ±*1.38*	1.83 ±*1.18*	3.09 ±*1.89*	6.37 ±*3.62*	0.03 ±*0.17*
1.40 ±*0.99*	1.60 ±*1.27*	1.54 ±*1.13*	1.91 ±*1.56*	3.17 ±*2.10*	3.34 ±*2.33*	0.03 ±*0.17*	
2.91 ±*1.52*	2.13 ±*1.50*	2.89 ±*1.74*	2.77 ±*1.60*	4.63 ±*2.82*	0.23 ±*0.48*		
2.32 ±*1.73*	2.65 ±*1.49*	2.24 ±*1.39*	2.62 ±*1.30*	6.85 ±*2.76*			
2.32 ±*1.67*	2.71 ±*1.42*	2.06 ±*1.30*	2.38 ±*1.37*	4.53 ±*2.96*			

X_4

Month \ Hours	05 00 06 00	06 00 07 00	07 00 08 00	08 00 09 00	09 00 10 00	10 00 11 00	11 00 12 00
J			0.59 ±*1.06*	1.65 ±*1.45*	2.00 ±*1.75*	1.74 ±*1.31*	2.62 ±*1.73*
F		0.00 *0.00*	5.47 ±*2.58*	2.35 ±*1.55*	1.76 ±*1.54*	2.18 ±*1.36*	1.97 ±*1.60*
M		0.00 *0.00*	4.56 ±*2.46*	1.79 ±*1.05*	2.47 ±*1.17*	2.18 ±*1.36*	2.74 ±*1.65*
A	0.00 *0.00*	2.62 ±*1.59*	2.74 ±*1.29*	2.50 ±*1.31*	2.35 ±*1.17*	2.68 ±*1.55*	2.62 ±*1.30*
M	0.85 ±*1.19*	3.53 ±*1.59*	2.88 ±*1.87*	2.71 ±*2.02*	2.29 ±*1.56*	2.59 ±*1.70*	2.88 ±*1.47*
J	4.97 ±*3.86*	2.85 ±*1.66*	2.79 ±*1.73*	2.85 ±*1.54*	1.79 ±*1.35*	2.24 ±*1.63*	2.18 ±*1.29*
J	3 79 ±*1.05*	2.85 ±*1.83*	2.21 ±*1.18*	1.68 ±*1.16*	1.50 ±*1.29*	1.53 ±*1.21*	1.71 ±*1.48*
A	0.14 ±*0.68*	5.09 ±*2.61*	2.06 ±*1.37*	1.94 ±*1.58*	2.31 ±*4.71*	1.46 ±*1.05*	1.31 ±*1.09*
S	0.00 *0.00*	2.31 ±*2.24*	7.06 ±*3.11*	2.63 ±*1.41*	2.20 ±*1.43*	2.43 ±*1.50*	2.26 ±*1.25*
O		0.00 *0.00*	6.51 ±*3.35*	2.54 ±*1.57*	2.29 ±*1.67*	2.17 ±*1.52*	2.57 ±*1.38*
N			1.94 ±*2.17*	2.32 ±*1.49*	2.06 ±*1.57*	2.44 ±*1.46*	2.44 ±*1.54*
D			0.03 ±*0.17*	2.53 ±*1.63*	2.06 ±*1.37*	1.76 ±*1.37*	2.06 ±*1.26*

ΠΙΝΑΞ XXI

«0.70 - 0.99»

12 00 13 00	13 00 14 00	14 00 15 00	15 00 16 00	16 00 17 00	17 00 18 00	18 00 19 00	19 00 20 00
2.26 ±*1.61*	2.09 ±*1.36*	2.06 ±*1.49*	2.35 ±*1.49*	0.65 ±*1.13*			
2.09 ±*1.46*	2.56 ±*1.50*	2.09 ±*1.29*	2.03 ±*1.34*	4.44 ±*2.55*	0.03 ±*0.17*		
2.62 ±*1.46*	2.88 ±*1.71*	2.76 ±*1.75*	2.94 ±*1.80*	4.85 ±*2.40*	0.03 ±*0.17*		
2.44 ±*1.50*	2.62 ±*1.71*	2.62 ±*1.41*	3.38 ±*1.71*	3.76 ±*1.83*	3.41 ±*2.29*	0.09 ±*0.28*	0.00 *0.00*
3.29 ±*1.64*	3.94 ±*3.60*	3.35 ±*1.84*	4.53 ±*1.85*	4.59 ±*2.06*	4.56 ±*2.07*	1.12 ±*1.52*	0.03 ±*0.17*
2.15 ±*1.31*	2.62 ±*1.76*	2.29 ±*1.38*	3.12 ±*1.66*	3.18 ±*1.74*	4.00 ±*1.94*	2.79 ±*2.51*	0.00 *0.00*
2.09 ±*1.95*	2.15 ±*1.63*	2.00 ±*1.61*	2.29 ±*1.67*	2.82 ±*1.98*	3.56 ±*2.17*	2.09 ±*2.24*	0.00 *0.00*
1.46 ±*1.36*	1.29 ±*1.30*	1.86 ±*1.57*	2.14 ±*1.38*	2.40 ±*1.40*	5.63 ±*3.15*	0.54 ±*1.32*	0.00 *0.00*
2.00 ±*1.33*	1.86 ±*1.80*	2.09 ±*1.54*	2.60 ±*1.64*	6.74 ±*3.89*	2.63 ±*1.99*	0.00 *0.00*	
2.31 ±*1.30*	2.60 ±*1.42*	2.57 ±*1.57*	2.89 ±*1.4η*	7.83 ±*3.99*	0.03 ±*0.17*		
2.65 ±*1.68*	2.88 ±*1.74*	2.97 ±*1.79*	2.59 ±*1.52*	2.88 ±*2.23*			
2.12 ±*2.05*	2.29 ±*2.20*	2.29 ±*1.29*	2.53 ±*1.65*	0.03 ±*0.17*			

X_5

Month \ Hours	05 00 06 00	06 00 07 00	07 00 08 00	08 00 09 00	09 00 10 00	10 00 11 00	11 00 12 00
J			0.00 *0.00*	7.76 ±*3.58*	9.26 ±*3.73*	10.71 ±*3.62*	11.59 ±*3.84*
F		0.00 *0.00*	3.00 ±*2.38*	10.47 ±*3.71*	12.29 ±*4.18*	13.26 ±*4.55*	13.85 ±*4.52*
M		0.00 *0.00*	4.44 ±*3.35*	11.50 ±*3.80*	13.03 ±*4.29*	14.47 ±*4.59*	14.53 ±*4.41*
A	0.00 *0.00*	5.00 ±*2.73*	12.85 ±*3.16*	15.79 ±*2.74*	17.09 ±*4.10*	18.06 ±*3.34*	18.21 ±*3.16*
M	0.06 ±*0.23*	13.62 ±*4.62*	16.50 ±*4.79*	18.18 ±*4.75*	19.94 ±*4.32*	19.85 ±*4.68*	20.32 ±*3.89*
J	0.06 ±*0.24*	17.60 ±*5.22*	20.38 ±*3.22*	22.26 ±*2.90*	23.47 ±*2.19*	23.38 ±*2.09*	23.79 ±*2.37*
J	0.03 ±*0.17*	22.53 ±*2.91*	25.00 ±*2.56*	26.00 ±*2.42*	27.12 ±*2.34*	27.38 ±*1.98*	27.74 ±*2.13*
A	0.00 *0.00*	19.31 ±*4.11*	24.91 ±*3.05*	25.94 ±*2.74*	26.26 ±*5.04*	27.26 ±*1.89*	27.60 ±*1.71*
S	0.00 *0.00*	1.17 ±*1.71*	11.57 ±*3.99*	19.63 ±*3.79*	21.63 ±*3.46*	22.34 ±*3.35*	23.14 ±*3.05*
O		0.00 *0.00*	3.17 ±*3.06*	13.20 ±*4.37*	15.03 ±*4.36*	16.00 ±*4.45*	16.66 ±*4.37*
N			0.03 ±*0.17*	7.41 ±*3.34*	9.35 ±*3.20*	10.38 ±*3.58*	11.44 ±*3.61*
D			0.00 *0.00*	6.21 ±*3.82*	9.12 ±*3.67*	10.56 ±*3.75*	11.00 ±*3.98*

«1.00»

12 00 13 00	13 00 14 00	14 00 15 00	15 00 16 00	16 00 17 00	17 00 18 00	18 00 19 00	19 00 20 00
12.18 ±3.46	12.44 ±3.39	12.18 ±3.91	10.15 ±3.35	0.06 ±0.24			
13.97 ±3.88	13.24 ±4.31	12.53 ±4.02	11.53 ±3.90	4.56 ±2.70	0.00 0.00		
14.44 ±4.50	14.09 ±4.53	13.21 ±4.78	11.65 ±4.24	6.50 ±3.19	0.00 0.00		
18.29 ±3.37	17.47 ±3.41	16.71 ±3.14	14.82 ±2.79	11.71 ±3.76	3.74 ±2.36	0.03 ±0.17	0.00 0.00
19.26 ±3.81	17.88 ±4.96	17.88 ±4.03	15.71 ±3.40	13.71 ±3.50	9.91 ±2.99	0.38 ±0.08	0.00 0.00
23.56 ±2.67	22.50 ±2.90	21.65 ±2.86	20.06 ±2.96	17.79 ±3.57	14.12 ±4.09	0.59 ±0.65	0.00 0.00
27.44 ±2.23	26.97 ±2.20	26.35 ±2.59	25.35 ±2.54	24.15 ±3.43	21.41 ±3.54	0.47 ±1.01	0.00 0.00
27.77 ±1.71	27.69 ±2.07	27.09 ±2.41	25.91 ±2.77	24.57 ±3.23	18.14 ±4.19	0.17 ±0.84	0.03 ±0.17
23.06 ±3.19	22.94 ±3.45	22.49 ±3.25	21.26 ±3.53	13.91 ±5.43	0.66 ±1.04	0.00 0.00	
16.54 ±4.43	16.51 ±4.43	15.94 ±4.55	14.69 ±4.44	4.77 ±3.41	0.00 0.00		
11.56 ±3.52	11.35 ±3.16	10.91 ±3.02	9.65 ±3.00	0.35 ±0.72			
11.47 ±4.31	10.88 ±4.32	10.47 ±3.97	8.21 ±3.76	0.00 0.00			

d. The daily mean of sunshine duration increases according to the monthly mean. Maximums appear during the main two summer months of July and August (when totally overcast days are null).

The totally sunless days (sunshine duration = 0) are 42,24 per year (Table XIII), with a maximum of 9.26 in December. It should be noted that March outnumbers February in sunless days (5.24 cases against 4.91), a fact that enhances the notion of late winters in the area of Northern Greece.

We believe also that the detailed examination of groups of consecutive sunless days, should be the basis for research upon the possibility of technological applications and exploitation of solar energy in the area of Northern Greece.

e. The percentage of practically sunless hours (duration 0 - 0,09h) is very small during the whole year for the 10:00 - 14:00h interval *(Table XVII)*. On the other hand a large percentage of sunlit hours (duration 1,00h) is characteristically grouped in this same interval *(Table XXII)*.

As it should be expected, percentages of the remaining degrees of sunshine duration (0,10 - 0,99h) are quite high for the remaining hours.

f. As an average there is no real daily variation of sunshine duration in Thessaloniki (Table XVI, Graph II). One or two hours after sunrise, the mean hourly duration rises to a high degree, and remains almost stable for 7 - 11 hours (according to season), without any noteworthy variations.

Karapiperis [16] comes to similar conclusions for sunshine durations in the city of Athens, studying the 1959 - 1963 period.

In Thessaloniki, at first glance, cloudiness should not play an important role as to the development of the average sunshine duration, because as a rule it is almost the same at 08:00h (5,39 tenths) and at 14:00h (5,53 tenths) (*Angouridakis*) [1]. But since cloudiness should have the same influence upon sunshine, one is led to believe that we should look elsewhere for cause and effect.

In our opinion, although cloudiness is the basic for the daily average of sunshine duration, is should however be examined in correlation with the geographic position and the relief of the area, at the meteorological station of the University of Thessaloniki as well as in the met. station of the National Observatory of Athens.

The two stations have characteristic similarities as to geographic position and relief:

— They are both situated at the northern coasts, of Thermaikos Gulf the first, and Saronikos Gulf the second; both gulfs facing southwards, that is open to the southern horizons (same orientation).

— Sunrise is retarded for a 30 - 40 period by mountains: Mt Chortiates (elev. 1201 m[17] in Thessaloniki, and Mt Hymettus (elev. 1026 m)[17] in Athens.

— Also the horizon to the west and north is obstructed by mountains in both cases.

— Both stations are situated at the same longitude, meaning that the sun is at zenith on almost the same instant, and they have the same period of daylight.

The neighbohood of land with sea, causes, almost during the whole year, sea breezes, which in turn give rise to orographic cumuli upon the surrounding mountain tops, which however do not obstruct the sun's trajectory. Thus, cloudiness remains the same, but changingplaces upon the sky, it leaves the sun's path free.

ΠΕΡΙΛΗΨΙΣ

Μελετᾶται ἡ διάρκεια τῆς ἡλιοφανείας ἐν Θεσσαλονίκῃ, διὰ τὴν χρονικὴν περίοδον 1930 - 1968, τόσον ἡ ἐτησία (2621,03 ὧραι = 93,3) ὅσον καὶ ἡ μηνιαία καὶ ἡμερησία, ὡς καὶ αἱ ὡριαῖαι τιμαί. Δίδονται Πίνακες ὡριαίων τιμῶν τῆς ἡλιοφανείας διὰ τεχνολογικὰς ἐφαρμογὰς καὶ χρησιμοποίησιν τῆς ἡλιακῆς ἐνεργείας εἰς τὴν βορείαν ταύτην Ἑλληνικὴν Περιοχήν.

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