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SUNSHINE DURATION IN ATHENS (II)

by

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Abstract: *Sunshine duration is examined from data of the National Observatory of Athens (φ=37° 58' N, λ=23° 43' E, elev. 107 m) which is situated at the center of Athens, that is the center of the largest urban complex in Greece (inhabitants ~2.500.000).*

We use for this study records of the N.O.A. sunshine recorder for the period 1897-1973, that is a span of 77 years. Special emphasis is given to the behaviour of sunshine duration (mean and extreme valucs) in each month and season (warm or cold). We also examine the particular contribution of each season to the annual duration in every year.

INTRODUCTION

The authors, in a previous paper, examine the annual sunshine duration in Athens, based on data from the sunshine recorder of the National Observatory of Athens for the period 1897-1973, that is a span of 77 years. (Livadas-Karakostas)[4].

The annual mean value resultant from the study of the above records is:

$$2779{,}0 \pm 118{,}9 \text{ hours}$$

and this is the highest value ever mentioned for the city of Athens (N.O.A). It should be mentioned that sunshine duration in Athens has been studied in the past by quite a few scientists, either in specific studies or in general studies of the climate of Athens or the area of Greece (Aeginitis[1], Mariolopoulos[8 9 10 11], Livathinos[5], Macris[6 7], Biel[2], and others).

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We, in our previous paper[4], discussed mainly the particularities appearing in the variation of annual values, especially if there are taken as 5 and 10 years running mean. In the present paper we examine sunshine duration from the classical climatological point of view.

Annual value. Monthy mean values.

The annual mean value of sunshine duration for the 77 years (1897-1973) as well as values of the years with the longest and the shortest sunshine duration of the same period, are given in Table I. In the same Table are given monthly mean values and monthly maxima and minima of the period examined.

TABLE I

Annual and monthly sunshine duration at the National Observatory of Athens (in hours)
period: 1897 - 1973

	Absolute maximum		Mean	$\pm \sigma$	Absolute minimum	
J	187.0	1967	128.4	29.0	64.6	1942
F	220.2	1958	144.6	29.8	77.4	1942
M	248.5	1912	185.3	31.5	71.0	1932
A	300.8	1924	236.0	30.5	157.8	1923
M	371.7	1955	276.6	48.7	147.9	1902
J	397.2	1954	320.1	39.7	213.1	1939
J	428.2	1954	370.3	26.4	306.0	1903
A	403.2	1952	351.9	24.6	280.3	1939
S	322.7	1954	277.3	22.9	193.8	1929
O	290.4	1911	211.2	35.9	116.6	1927
N	233.1	1972	152.0	32.2	77.3	1924
D	205.4	1909	124.9	27.4	72.4	1940
Year	3216.8	1952	2779.0	188.9	2370.3	1931

As to the variation of sunshine duration during the year, we observe that as to monthly mean values the minimum belongs in the month of December, that is the month with the shortest theoretical sunshine duration. The monthly mean value increases from December to July when it acquires its maximum value and thence it starts decreasing till December.

The summer quarter from June to August has montbly mean values>300 hours, while the cold five months from November to March have values below 200 h..

As to extreme values, we observe that from April till September it is possible for maxima > 300 h. to occur, while during the main two summer months (July and August) maxima > 400 h have been recorded.

Also as to absolute minima, the only month with values > 300 h is July, while values < 100 h have been recorded in every one of the five months from November to March, with the smallest value in January.

In Table II, giving frequencies of monthly mean values, the distribution of sunshine duration per each month of the year is shown even more analytically.

In the November - February four-months there have been 37 months (4.0%) with sunshine duration > 100 h. Small sunshine durations have been recorded mainly in the two winter months: December (16) - January (14); while November and February have 3 cases each of such monthly values.

November however exceeds February in number of months with monthly sunshine duration< 200 h. To this is essentially due the small superiority of November, because as to absolute minimum values of sunshine duration, both months have the same value.

July, the month with the longest monthly sunshine duration, has at the same almost every case with montbly duration > 400 h (10 months out of 11). This is one more characteristic of the sunniest, as an average, month of the year.

If, instead of mean monthly values, we consider actual values, that is values which were actually recorded in each month of the period examined, we observe that it is possible for a sunny month to be followed by another with shorter sunshine duration, although this should be expected to have longer duration; or on the other hand while the next month should be expected to have shorter sunshine duration than its predecessor, it actually records a longer duration.

In Table III we give the variability of sunshine duration during the year, as it results from monthly mean values.

We observe that January slightly exceeds December and this is the main reason for January's superiority in 44 cases out of 77 observational years (57,1%) while in the remaining 33 cases (42.9%) December has longer sunshine duration. We note generally that out of the 924 months of the period examined, 141 months did not record their «normal» values, meaning that we have 15.3% of cases which do not follow the mode of monthly mean values.

TABLE II

Frequeney of monthly mean values of sunshine duration at the National Observatory of Athens period: 1897 - 1973

	J	F	M	A	M	J	J	A	S	O	N	D	Total	%
421 - 440							2						2	0.2
401 - 420							8	1					9	1.0
381 - 400						3	19	9					31	3.4
361 - 380					2	9	20	15					46	5.0
341 - 360					3	17	5	30					69	7.5
321 - 340					11	12	4	15	1				44	4.8
301 - 320				1	14	15		5	9				48	5.2
281 - 300				4	8	7		1	24	2			46	5.0
261 - 280				11	10	7		1	25	3			57	6.2
241 - 260			1	20	12	4			16	11			64	6.9
221 - 240			6	16	7	2				16	2		49	5.3
201 - 220		4	22	16	4	1			1	17	4	1	70	7.6
181 - 200	3	4	18	6	2				1	10	9	1	54	5.8
161 - 180	7	15	13	2	2					12	16	5	72	7.8
141 - 160	13	17	13	1	2					3	18	11	78	8.4
121 - 140	29	18	1							2	15	21	86	9.3
101 - 120	11	16	2							1	10	22	62	6.7
81 - 100	8	2									2	12	24	2.6
61 - 80	6	1									1	4	13	1.4
Total	77	77	77	77	77	77	77	77	77	77	77	77	924	100.1

TABLE III

Variability of sunshine duration throughout the year

	Mean variability of sunshine duration in hours (see Table I)	Number of cases Positive (+)	Percentages (%) of cases Positive (+)	Number of cases Negative (—)	Percentages (%) of cases Negative (—)
Jan. - Dec.	3.5	Jan. > Dec. 44	57.1	Jan. < Dec. 33	42.9
Feb. - Jan.	16.2	Feb. > Jan. 51	66.2	Feb. < Jan. 26	33.8
March - Feb.	40.7	March > Feb. 65	84.4	March < Feb. 12	15.6
April - March	50.7	April > March 72	93.5	April < March 5	6.5
May - April	40.6	May > April 60	77.9	May < April 17	22.1
June - May	43.5	June > May 70	90.9	June < May 7	9.1
July - June	50.2	July > June 74	96.1	July < June 3	3.9
Aug. - July	—18.4	Aug. < July 61	79.2	Aug. > July 16	20.8
Sept. - Aug.	—74.6	Sept. < Aug. 77	100.0	Sept. > Aug. Nil.	—
Oct. - Sept.	—66.1	Oct. < Sept. 75	98.7	Oct. < Sept. 2	1.3
Nov. - Oct.	—59.2	Nov. < Oct. 73	94.8	Nov. > Oct. 4	5.2
Dec. - Nov.	—27.1	Dec. < Nov. 61	79.2	Dec. > Nov. 16	20.8

In a considerable percentage of cases (33.8%) it is possible for February to have shorter sunshine duration than January, and for March to have shorter sunshine duration than February, although their mean values differ by 40.7 hours.

To the same it is possible that May records shorter sunshine duration than the previous month of April, although their mean values differ by 40.6 hours in favour of May. This is due to the fact that in May usually occurs a secondary maximum of rainfall in the area of the Aegean Sea, and thus sunshine duration is actually reduced in rainy months of May.

There is also a certain antagonism, as to sunshine duration maxima, between the main two summer months, July and August; the scales however seem to tilt towards the warmer mouth of July.

After August, which is the last month of summer, sunshine duration goes on decreasing at a rapid pace untill November. September, the warm autumnal month never had longer sunshine duration than the summer month of August. Also the percentage of cases of autumnal months or even the first winter month with longer sunshine duration than the preceding one, is very small (2 cases in October against September and 4 cases in November against October). While it is quite often possible for December to have longer sunshine duration than November. This happens if the winter rains produced by depressions of the polar-mediterranean front are more frequent in November than in Decemher.

If we examine positive and negative deviation from the average value of sunshine duration, we may observe quite high deviation values.

We have included maximum values of positive or negative deviations in Table IV. There, we observe that it is possible to have positive differences up to 192.4 hours (year 1928: May 173.3 h to June 365.7 h), as well as negative ones up to 160.7 hours (year 1907: Octoher 270.4 h to November 109.7 h).

These maximum differences give a measure of the variability of sunshine duration in the area of Athens.

It is also possible to have greater anomalies in the picture produced by monthly mean values i.e., it is possible for December to have longer sunshine duration than January and February or even March, or to have longer sunshine duration than February but not longer than January.

TABLE IV

Maximum differences (in hours) in eonsecutive months. National Observatory of Athens, period 1897-1973

Mean Variability		(+)		(—)	
Jan. — Dec.	3.5	96.5	1926/27	-99.9	1923/24
Feb. — Jan.	16.2	105.2	1966	-70.0	1902
March — Feb.	40.7	122.0	1927	-55.2	1958
April — March	50.7	168.7	1932	-45.2	1923
May - April	40.6	163.3	1907	-74.9	1928
June - May	43.5	192.4	1928	-38.9	1921
July - June	50.2	150.9	1921	-22.7	1916
Aug. - July	-18.4	38.0	1903	-77.2	1939
Sept. - Aug.	-74.6	Never		-150.3	1929
Oct. - Sept.	-66.1	2.9	1929	-152.5	1927
Nov. - Oct.	-59.2	48.6	1927	-160.7	1907
Dec. - Nov.	-27.1	26.7	1945	-142.0	1926

It is also possible for November to have shorter sunshine duration than the next two winter months of December and January.

It is interesting to study sunshine duration per season:

In the area of Greece we consider as «summer» the June-August quarter, while the five-months from May to September should be considered as «warm period».

«Winter» is the December-February quarter, while the five-months from November to March should be considered as «cool season».

The months of April and October are considered as «transitive months» between the two principal seasons.

In Table V we give the total duration of bright sunshine per season of the year, and also the maximum positive and negative deviations from normal values.

TABLE V

Winters with considerable anomalies of sunshine duration at the National Observatory of Athens

Dec. Jan. and Febr.	10	1900/01 1912/13 1921/22 1922/23 1923/24 1925/26 1932/33 1953/54 1970/71 1971/72
Dec. Jan. and Febr. and March	3	1909/10 1941/42 1955/56
Dec. Febr. but no Jan.	4	1901/02 1905/06 1908/09 1967/68
Nov. Dec. and Jan.	4	1902/03 1912/13 1924/25 1945/56
Nov. Dec., Jan., Feb. and March	2	1930/31 1931/32

From data given in Table VI it results that, it is possible to have an extremely sunny winter, such as that of 1909/10 with 558.1 hours of bright sunshine, which means 187.3% of the normal value, or even to have a very poor winter: 1930/31 with only 285.8 hours of bright sunshine, or 71.8% of the normal deviation.

TABLE VI

Total sunshine duration at the National Observatory of Athens, per season of the year.

Period	Total duration in hours	+	—	Maximum positive		Maximum negative	
Dec., Jan., Feb.	397.9	39	36	+160.1 187.3%	1909/10	-112.1 71.8%	1930/31
Nov. - March	735.2	35	41	+200.0 127.2%	1909/10	-229.9 68.7%	1931/32
June, July, Aug.	1042.3	37	40	+181.4 117.4%	1954	-191.4 81.6%	1939
May - Sept.	1596.2	38	39	+258.5 116.2%	1954	-318.2 80.1%	1939

Besides, there have been cold seasons, like that of 1909/10, with 935.2 hours of total sunshine duration, that is 200 hours more or 127.2% of the normal value; and also very poor cold seasons, as that of 1931/32 with 505.3 hours of total sunshine duration, that is 229.9 hours less or 68.7% of the normal value for the cold season.

But the warm season has also its anomalies as to sunshine duration. It should however be mentioned that although the maximum positive or negative anomalies have higher values yet they are smaller as percentages than those of the cold season.

This means that however poor a summer might be as to sunshine duration, yet its anomalies are never quite important, at least in the Athens area.

On the other hand, weather contrasts are much more vivid during the season of intense cyclonic activity in the Eastern Mediterranean area.

If we draw a table (TABLE VII) with positive and negative deviations from mean seasonal values we observe that the «winter» and «summer» seasons have a smaller dispersion than the corresponding «cold» and «warm» periods. we attribute this basically to the fact that the «border» months of both periods sometimes are very rich

TABLE VII

Frequency of positive and negative deviations from mean seasonal values of sunshine duration at N.O.A. (76 winters, 77 years)

	Dec., Jan., Feb.	Nov. - March	June, July, Aug.	May - Sept.
251 - 300				1
201 - 250				1
151 - 200	1	2	2	7
101 - 150	3	7	6	7
51 - 100	11	14	13	10
1 - 50	24	12	16	12
— 49 - 0	21	20	19	11
— 99 - — 50	11	14	14	12
—149 - —100	5	4	5	10
—199 - —150		1	2	3
—249 - —200		2		2
—299 - —250				
—349 - —300				1
	76	76	77	77

in sunshine duration and sometimes very poor. Usually however, they both have abundant bright sunshine or they both have considerably reduced bright sunshine.

It is our belief that, the study of the «contribution» of each particular season to the annual duration of bright sunshine, is of some importance.

Here, the combinations possible are 14 in all (as per the adjoined Table VIII).

As we can see from Table VIII, first place is held by the combination of: sunny winter, sunny cold season, summer rich in bright sunshine and plenty of sunshine in the warm season (W++ S++).

The most unfavored place is held by the combination of: poor winter, little bright sunshine through out the cold season, little bright sunshine in the summer as well as in all the warm season (W— —S — —).

The above two types hold 43.4% of the years in the period examined ((17+16) = 33 years out of 76). Another considerable percentage is held by characteristic opposites of sunny winters with sunny cold period (10 years or 13.2%) combined with little bright sunshine in the summer and in the whole warm period (11 years or 14.5%).

The remaining 22 years (28.9%) cover the more infrequent com-

TABLE VIII

Classification of years according to the combination of sunshine duration of season.

	W	S	Dec., Jan., Feb. winter	Nov.-March cold period	Jun, July, Aug. summer	May-Sept. warm period	Number of years
a.	++	++	+	+	+	+	17
b.	++	+−	+	+	+	−	1
c.	++	−+	+	+	−	+	1
d.	−+	++	−	+	+	+	1
e.	+−	++	+	−	+	+	5
f.	++	−−	+	+	−	−	10
g.	−−	++	−	−	+	+	11
h.	+−	−+	+	−	−	+	1
i.	−+	−+	−	+	−	+	1
j.	+−	−−	+	−	−	−	6
k.	−+	−−	−	+	−	−	3
l.	−−	+−	−	−	+	−	2
m.	−−	−+	−	−	−	+	1
n.	−−	−−	−	−	−	−	16

binations; half of them is taken up by combinations of (+ − + +) and (+ − − −).

If we consider amnual values of sunshine duration recorded during the 1897-1973 period-examined, out of 77 years, 52 have values within the normal 2.7790 ± 118.8^h (that is between 2967.9 - 2590.1 hours).

From the remaining 25 years, 13 have values>2779.0+1 σ and 12 years have values < 276719.0 - 1σ Out of the former 13 years, 10 had the combination [W+ +S+ +); this same combination produced the maximum values of the 77-years period, in 1952 with 3216.8 hours. In the remaining three years, the combination [W + − S + +] occurs twice and combination (W − − S + +) once (1909).

Also out of the 12 very poor in bright sunshine years, 9 years had the most adverse combination [W − − S − −); this same combination resulted in the year with the shortest sunshine duration in the 77-years period, 1931 with 2370.3 hours. In the remaining three years, the combination (W + − S − −) occurs twice, and combination (W + + S − −) once (1901).

It should be mentioned here that a winter poor in bright sunshine with an equally poor cold period, may well be counterbalanced by a summer with plenty of bright sunshine and an equally rich warm season,

thus resulting in a high annual value of sunshine duration as, for instauce, has been the case of 1909. On the other hand, a sunny winter and an equally sunny cold period can not compensate for a very poor in bright sunshine summer and an equally poor warm period.

CONCLUSIONS

Besides what we have already mentioned in this study, we can sum up the following conclusions:

a. The mean annual variation of sunshine duration has a single fluctuation throughout the year with a minimum in December and a maximum in June.

b. From November till Fehruary it is possihle to record monthly duration values< 100 hours (percentage of 4.0%). It is also possible to have monthly values >400 hours (percentage of 1.2%) during the two warm months of July and August.

c. It is possible to have considerable anomalies in the transition from one month to another, as to the expected value of sunshine duration (Tables III, IV, V). Such anomalies occur in winter and the cold season as well as in summer and the warm season.

The principal causes of such anomalies are:

For the cold period, the activities of the mediterranean-polar front and depressions moving along the great axis of the Mediterranean during this season.

For the warm period the irregularity as to the exact time when the «etesian winds», characteristic of the Greek summer, will prevail.

c. Research scientists who intend to undertake, in the near future, applications of solar energy in this favored by the Sun area of Attica, should always bear in mind the ahove mentioned anomalies.

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ΠΕΡΙΛΗΨΗ

Η ΔΙΑΡΚΕΙΑ ΤΗΣ ΗΛΙΟΦΑΝΕΙΑΣ ΣΤΗΝ ΑΘΗΝΑ

Ὑπὸ

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Στὴν ἐργασία αὐτή, δεύτερη στὴν σειρὰ τῆς ἔρευνάς μας «Ἡ Ἡλιοφάνεια στὴν Ἀθήνα», μελετοῦμε τὰ στοιχεῖα τῆς διάρκειας τῆς ἡλιοφάνειας τοῦ Ἐθνικοῦ Ἀστεροσκοπείου Ἀθηνῶν (Ε.Α.Α.) (φ=37° 48′ Ν, λ=23° 43′ Ε, ὑψομ. 107 μ.). Τὸ Ε.Α.Α. εἶναι ἐγκαταστημένο στὸ κέντρο σχεδὸν τοῦ πολεοδομικοῦ συγκροτήματος τῆς Μείζονος Ἀθήνας - Ἀττικῆς, δηλαδὴ στὴν περιοχὴ ὅπου κατοικεῖ τὸ 1/4 τοῦ πληθυσμοῦ τῆς χώρας μας.

Χρησιμοποιοῦμε τὰ ἐγγραφήματα τοῦ ἡλιογράφου τοῦ Ε.Α.Α. γιὰ τὴν χρονικὴ περίοδο 1897-1973, δηλαδὴ γιὰ μιὰ σημαντικὴ διάρκεια στὴν Ἑλληνικὴ μετεωρολογικὴ πραγματικότητα.

Στὴν μελέτη μας, στὶς μέσες καὶ ἄκρες τιμὲς τῆς διαρκείας τῆς ἡλιοφάνειας, δίνουμε ἔμφαση στὴν μεταβλητότητα τῶν τιμῶν αὐτῶν, ὅπως ἐπίσης καὶ στὴν ἐπὶ μέρους συμβολή τους στὴν ἐτήσια διάρκεια, γιὰ κάθε χρόνου.

Ἐπίσης μελετοῦμε τὴν δυνατότητα ὁμαλῆς ἢ ὄχι ὁμαλῆς διαδοχῆς τῶν μηνῶν, ὡς πρὸς τὴν διάρκεια τῆς ἡλιοφάνειας καὶ δίνουμε τὴν ἀναλογία τῶν ἀνωμαλιῶν ποὺ παρατηροῦνται.