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# SUNSHINE DURATION IN ATHENS (III)

by

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**Abstract;** *Sunshine duration in the area of Athens is studied from sunshine records of the National Observatory of Athens (N.O.A.) ($\varphi$=37° 58′ N, $\lambda$ = 23° 58′ E, elev. 107 m) for 1931 - 1973, that is a span of 43 years. The main objective of this study is to examine sunshine duration on a day to day basis. Conclusions are drawn as to the length of runs of consecutive sunless or practically sunless days.*

## INTRODUCTION.

The study of sunshine duration in Athens has been the subject of quite a few research works, not only in the past but also very recently. The Institute of Meteorology and Climatology of the Aristotelian University of Thessaloniki, within the frame of a general project for the study of sunshine duration in Greece, examines sunshine duration in Athens, based on data of the National Observatory of Athens for the period 1931-1973.

This paper is the third in a series of studies on the same subject; in the former two, the team consisted of the first and third of the authors of the present paper.

In the present work, besides annual and monthly values, sunshine duration is examined on a day to day basis. The main object of study of daily values is to procure as safe as possible information for possible applications of solar energy in everyday household uses at the city of Athens.

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It should be mentioned that the urban complex occupying the area of Greater Athens-Attica, is inhabited today by almost 1/4 of Greece's population. As a consequence, the possibility of puting to use solar energy for the needs of its inhabitants, should be a great relief for the passive Greek trade-balance.

In this study we use data of the 1931-1973 period, although the records of NOA extend back to 1897, because only after the year 1930 sunshine recorders began operating in other areas of Greece, and consequently only the period after 1930 lends itself for comparative studies of sunshine duration in the Greek area.

## SUNSHINE DURATION

α. The mean annual sunshine duration in the National Observatory of Athens for the 1931-1973 period, and also the absolute maximum and minimum annual duration, are given in Table I.

*TABLE I.*

*Annual sunshine duration in National Observatory of Athens (in hours)*

| | | |
|---|---|---|
| Maximum | 3216.8 | 1952 |
| Mean | 2809.0±204.8 | |
| Minimum | 2370.3 | 1931 |

Comparison of mean and extreme annual values shows that the annual sunshine duration may vary from +14.5% (+407.8 hours) to —15.6% (—438.7 hours). It must also be mentioned that the absolute minimum of the year 1931 is a very small annual value for the whole area of Greece.

We also note that the same absolute annual maximum and minimum are also met in a previous study of ours based on data of the 1897-1973 period.

However, the annual mean value of the 1931-1973 period is by 30.0 hours higher than that of the 1897-1973 period; this is due to the fact that in the present work we have not included the period 1921-1930, which together with the 1931-1945 interval are periods of reduced annual sunshine duration values, as compared with those of the 25-years from 1946 to 1970 (Livadas-Karakostas[1]), where values are higher.

*TABLE II*

*Mean and extreme monthly values of sunshine duration (in hours) at the National Observatory of Athens.*

| | Period: 1931-1973 | | | | | | Period: 1897-1973* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Abs. Max. | | Mean ± | | Abs. Min. | | Abs. Max. | | Mean ± | | Abs. Min. | |
| J | 187.0 | 1967 | 123.5 | 28.4 | 64.6 | 1942 | identical | | 128.4 | 29.0 | identical | |
| F | 220.2 | 1958 | 147.1 | 31.2 | 77.4 | 1943 | » | | 144.6 | 29.8 | » | |
| M | 226.6 | 1961 | 179.0 | 34.3 | 71.0 | 1932 | 248.5 | 1912 | 185.3 | 31.5 | » | |
| A | 297.9 | 1952 | 236.6 | 30.2 | 172.0 | 1960 | 300.8 | 1924 | 236.0 | 30.5 | 157.8 | 1923 |
| M | 371.7 | 1955 | 289.2 | 46.2 | 155.9 | 1940 | identical | | 276.6 | 48.7 | 147.9 | 1902 |
| J | 397.2 | 1954 | 327.1 | 37.2 | 213.1 | 1939 | » | | 320.1 | 39.7 | identical | |
| J | 428.2 | 1954 | 373.2 | 28.7 | 311.7 | 1933 | » | | 370.4 | 26.4 | 306.0 | 1904 |
| A | 403.2 | 1952 | 360.1 | 26.2 | 280.3 | 1939 | » | | 351.9 | 24.6 | identical | |
| S | 322.7 | 1954 | 280.2 | 19.5 | 245.1 | 1960 | » | | 277.4 | 22.9 | 193.8 | 1929 |
| O | 281.1 | 1956 | 212.1 | 33.2 | 151.9 | 1957 | 290.4 | 1911 | 211.2 | 35.9 | 116.6 | 1927 |
| N | 233.1 | 1972 | 155.3 | 30.8 | 85.1 | 1945 | identical | | 152.0 | 32.2 | 77.3 | 1924 |
| D | 193.3 | 1971 | 125.6 | 27.2 | 72.4 | 1940 | 205.4 | 1909 | 124.9 | 27.4 | identical | |
| Year | 3216.8 | 1952 | 2809.0 | ± 204.8 | 2370.3 | 1931 | identical | | 2779.0 | ± 188.9 | identical | |

* (Livadas - Karakostas (II), 1976).

b. The mean monthly sunshine duration for the 1931-1973 period, that is 516 months in all, and also the absolute maxima and minima of every month have been included in Table II.

In this same Table II we give the corresponding values that resulted from the study of the period 1897-1973.

Comparing values of the two periods, we observe that:

1. As to monthly mean values, if we take

[Δ = Mean 1931/73 - Mean 1897/73].

we have a small decrease during the cold season, especially in March, and a considerable increase during the warm season (May-September).

*TABLE III*

*Differences between mean (1931-1973)-mean (1897-1973)*

| | | | | | |
|---|---|---|---|---|---|
| J | -4.9 | J | 2.8 | Cold Period | (N-M) -4.7 |
| F | 2.5 | A | 8.2 | | |
| M | -6.3 | S | 2.8 | Warm Period | (M-S) 33.4 |
| A | 0.6 | O | 0.9 | | |
| M | 12.6 | N | 3.3 | Year | 30.0 |

II. As to absolute monthly maxima we have (8) eight months with the same values in both periods. The maxima of the shorter period occur in four months. In March, during the longer observational period, were recorded values higher than the absolute maximum of the common period (1931-1973), as follows: 1912/248.5 h, 1906/235.5 h, 1922/235.0 h and 1927/229.4 h. April has a higher value only in 1924, October only in 1911 and December only in 1909. This fact partly accounts for the difference in the monthly mean value of March in the two periods. Although it is our belief that the subject should undergo further examination, because bad weather in March in the Greek area means lateness of winter.

III. As to absolute minimum values, we have six identical months in the two periods; minima occur in the remaining six months.

The main winter season has the same values because quite a few heavy winters occured during the period examined herein (i.e.1941-42 et al.).

April has only the value of 1923, May only the value of 1902, July only the value of 1904; September, in the longer period, had in five cases values smaller than the minimum of the 1931-1973 period:

(1929/193.8 h, 1912/217.4 h, 1924/240.7 h, 1915/240.8 h and 1916/243.7 h). October had twice values smaller than the minimum of 1931 - 73 (1927/116.6 h, 1920/126.2 h). Finally November had also twice values smaller than the minimum of 1931-73 (1924/77.3 h, and 1902/82.3 h).

From values in Table II it results that sushine duration increases from December till July and then from this month onwards continually decreases till December; in other words, it has a single fluctuation, with the minimum monthly mean value in January and the maximum monthly mean value in July.

The range of the month to month variation of sunshine duration through the year is given in the first column of Table IV. In the same Table we give the number of cases when the succession of monthly values agreed with the order of mean (normal) values, and also the maximum plus or minus differences recorded between two consecutive months.

From data in this Table it results that September is the only month which always has shorter sunshine duration than its predecessor. Also October only once had sunshine duration by 0.8 hours longer than September. This means that in the two autumnal months we always have less sunshine as we advance in season. These two are also the months with the greatest decreasing rate of sunshine duration. Every other month of the year may haved different sunshine duration than its order of succession.

These large differences from month to month are characteristic of the instability of weather in the area of Greece and especially in the Athens area.

c. Mean daily sunshine duration. The mean and extreme daily values of sunshine duration at the National Observatory of Athens, are given in Table V.

From data in Table V it results that the daily mean value is $> 8.50$ hours/day from May to September, that is throughout the warm season of the Greek area.

The daily mean value increases from December till July, and thence it decreases till December.

It is possibleto havequite high daily values (9 hours/day) even in December, the poorest month. On the other hand only the main two summer months, July and August, have bright sunshine, even short, in every day; sunless days occur only in the ten months from September to June.

*TABLE IV*

*Variation of monthly mean values of sunshine duration at the National Observatory of Athens (period: 1931 - 1973)*

| | Mean Variation of Sunshine duration | Number of cases with differences (+) | Maximum differences in consecutive months (+) (in hours) | Nnmber of cases with differences (—) | Maximum differences in consecntive months (—) (in hours |
|---|---|---|---|---|---|
| J - D | —2.1 | Jan. < Dec. 20 | 109.5 | Jan. > Dec. 23 | 50.9 |
| F - J | 23.6 | Feb. > Jan. 33 | 95.2 | Feb > Jan. 10 | 38.1 |
| M - F | 31.9 | Mar. > Feb. 34 | 97.4 | Mar > Feb. 9 | 53.2 |
| A - M | 57.6 | Apr. > Mar. 40 | 138.4 | Apr > Mar. 3 | 23.3 |
| M - A | 52.6 | May > Apr. 37 | 143.5 | May > Apr. 6 | 45.3 |
| J - M | 37.9 | June > May 38 | 106.0 | June > May 5 | 33.0 |
| J - J | 46.1 | July > June 41 | 144.4 | Jnly > June 2 | 22.4 |
| A - J | —13.1 | Aug. < July 32 | 77.2 | Aug. > July 11 | 32.0 |
| S - A | —79.9 | Sept. < Aug. 43 | 140.3 | Sept.>Aug. None | — |
| O - S | —68.1 | Oct. < Sept. 42 | 150.7 | Oct. > Sept. 1 | 0.8 |
| N - O | —56.8 | Nov. < Oct. 39 | 147.5 | Nov > Oct. 4 | 47.0 |
| D - N | —29.7 | Dec. < Nov, 32 | 139.2 | D ec. > Nov. 10 | 26.6 |

*TABLE V*

*Mean and extreme values of daily sunshine duration at the National Observatory of Athens (in hours). Period: 1931 - 1973*

| | Abs. Maximum daily duration | Mean daily of sunniest month | | Mean | Mean daily of poorest month | | Abs. Mimimum daily duration |
|---|---|---|---|---|---|---|---|
| J | 9.6 | 6.03 | 1967 | 4.14 | 2.08 | 1942 | 0 |
| F | 10.6 | 7.86 | 1958 | 5.12 | 2.76 | 1942 | 0 |
| M | 11.7 | 8.02 | 1012 | 5.98 | 2.29 | 1932 | 0 |
| A | 13.6 | 10.03 | 1924 | 7.87 | 5.26 | 1923 | 0 |
| M | 14.2 | 11.99 | 1955 | 8.92 | 4.77 | 1902 | 0 |
| J | 14.4 | 13.24 | 1954 | 10.67 | 7.10 | 1939 | 0 |
| J | 14.4 | 13.81 | 1954 | 11.95 | 9.87 | 1903 | 2.0 |
| A | 13.7 | 13.01 | 1952 | 11.35 | 9.04 | 1939 | 0.5 |
| S | 12.5 | 10.76 | 1954 | 9.24 | 6.46 | 1929 | 0 |
| O | 10.8 | 9.37 | 1911 | 6.81 | 3.76 | 1927 | 0 |
| N | 9.8 | 7.77 | 1972 | 5.07 | 2.58 | 1924 | 0 |
| D | 9.2 | 6.63 | 1909 | 4.03 | 2.34 | 1940 | 0 |

Technological applications of solar energy for household uses, requires that the study of sunshine duration extends to a detailed and complete knoweledge of day to day changes.

The area of Athens-Attica, where the N.O.A. stands, in spite of its good reputation as one of the sunniest areas in Greece, yet has its abrupt changes of weather too. Thus it is possible for a sunny day, or a sequence of sunny days to be succeeded by one more cloudy days, and vice versa.

In Table VI we have included all the daily sunshine duration values recorded during the 43-years period examined herein, that is 15706 days in all, while in Table VII we give the occurence percentage of various sunshine duration values.

From these two Tables VI and VII we find that, the sunless days recorded, amount to 811, or 18.9 sunless days per year; in other words 5.2% of all the days of the period examined, were sunless ones.

If we add to these sunless days the «practically sunless» (duration of bright sunshine $\leq$0.4 hour), 463 days in all, the percentage increases to 8.1%.

If we considered, something acceptable by Greek standards, as «almost sunless» those days on which sunshine duration has been between 0.5-1.4 hours, and these days (737 in all) are considered useless for applications of solar energy in household uses, the total percentage

*TABLE VI*

*Distribution of daily sunshine duration values at the National Observatory of Athens.*

| Duration in hours | J | F | M | A | M | J | J | A | S | O | N | D | $S_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ⩾ 13.5 | 0 | 0 | 0 | 2 | 36 | 151 | 212 | 22 | 1 | 0 | 0 | 0 | 424 |
| 12.5 - 13.4 | 0 | 0 | 1 | 43 | 208 | 296 | 456 | 392 | 5 | 0 | 0 | 0 | 1401 |
| 11.5 - 12.4 | 0 | 0 | 6 | 147 | 261 | 312 | 351 | 526 | 98 | 0 | 0 | 0 | 1701 |
| 10.5 - 11.4 | 0 | 6 | 96 | 236 | 178 | 151 | 147 | 221 | 418 | 35 | 0 | 0 | 1488 |
| 9.5 - 10.4 | 11 | 147 | 193 | 174 | 112 | 97 | 60 | 65 | 349 | 340 | 46 | 0 | 1594 |
| 8.5 - 9.4 | 137 | 157 | 130 | 111 | 103 | 70 | 39 | 39 | 132 | 227 | 238 | 116 | 1499 |
| 7.5 - 8.4 | 128 | 101 | 123 | 95 | 73 | 53 | 26 | 22 | 77 | 45 | 166 | 161 | 1170 |
| 6.5 - 7.4 | 106 | 115 | 113 | 97 | 84 | 38 | 15 | 11 | 55 | 90 | 112 | 102 | 918 |
| 5.5 - 6.4 | 98 | 85 | 93 | 66 | 58 | 34 | 14 | 9 | 34 | 87 | 01 | 125 | 804 |
| 4.5 - 5.4 | 120 | 89 | 82 | 66 | 48 | 21 | 6 | 9 | 33 | 78 | 109 | 112 | 773 |
| 3.5 - 4.4 | 93 | 93 | 65 | 58 | 43 | 23 | 3 | 6 | 32 | 61 | 90 | 113 | 680 |
| 2.5 - 3.4 | 104 | 73 | 82 | 45 | 34 | 14 | 1 | 7 | 19 | 74 | 79 | 103 | 635 |
| 1.5 - 2.4 | 106 | 83 | 78 | 40 | 33 | 14 | 5 | 2 | 11 | 53 | 87 | 96 | 608 |
| 0.5 - 1.4 | 164 | 81 | 101 | 48 | 23 | 8 | 0 | 2 | 14 | 64 | 97 | 135 | 737 |
| 0.1 - 0.4 | 92 | 63 | 49 | 32 | 20 | 5 | 0 | 0 | 2 | 35 | 69 | 96 | 463 |
| 0 | 174 | 122 | 121 | 48 | 19 | 3 | 0 | 0 | 10 | 44 | 96 | 174 | 811 |
| | 1333 | 1215 | 1333 | 1290 | 1333 | 1290 | 1333 | 1333 | 1290 | 1333 | 1290 | 1333 | 15706 |

*TABLE VII*

*Occurence percentage of various sunshine duration values at the National Observatory of Athens.*

| Duration in hours | J | F | M | A | M | J | J | A | S | O | N | D | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ⩾ 13.5 | — | — | — | 0.2 | 2.7 | 11.7 | 15.9 | 1.6 | 0.1 | — | — | — | 2.69 |
| 12.5 - 13.4 | — | — | 0.1 | 3.3 | 15.6 | 22.9 | 34.2 | 29.4 | 0.4 | — | — | — | 8.94 |
| 11.5 - 12.4 | — | — | 0.4 | 11.4 | 19.6 | 24.2 | 26.3 | 39.5 | 7.6 | — | — | — | 10.83 |
| 10.5 - 11.4 | — | 0.5 | 7.2 | 18.3 | 13.4 | 11.7 | 11.0 | 16.6 | 32.4 | 2.6 | — | — | 9.47 |
| 9.5 - 10.4 | 0.8 | 12.1 | 14.5 | 13.5 | 8.4 | 7.5 | 4.5 | 4.9 | 27.0 | 25.5 | 3.6 | — | 10.14 |
| 8.5 - 9.4 | 10.3 | 12.9 | 9.8 | 8.6 | 7.7 | 5.4 | 2.9 | 2.9 | 10.2 | 17.0 | 18.4 | 8.7 | 9.54 |
| 7.5 - 8.4 | 9.6 | 8.3 | 9.2 | 7.4 | 5.5 | 4.1 | 2.0 | 1.7 | 6.0 | 10.9 | 12.9 | 12.1 | 7.44 |
| 6.5 - 7.4 | 8.0 | 9.5 | 8.5 | 6.1 | 6.3 | 3.0 | 1.0 | 0.8 | 4.3 | 6.8 | 8.7 | 7.6 | 5.84 |
| 5.5 - 6.4 | 7.3 | 7.0 | 7.0 | 5.1 | 4.4 | 2.6 | 1.1 | 0.7 | 2.6 | 6.5 | 7.8 | 9.4 | 5.14 |
| 4.5 - 5.4 | 9.0 | 7.3 | 6.1 | 5.1 | 3.6 | 1.6 | 0.4 | 0.7 | 2.6 | 5.9 | 8.5 | 8.4 | 4.92 |
| 3.5 - 4.4 | 7.0 | 7.7 | 4.9 | 4.5 | 3.2 | 1.8 | 0.2 | 0.5 | 2.5 | 4.6 | 7.0 | 8.5 | 4.32 |
| 2.5 - 3.4 | 7.8 | 6.0 | 6.1 | 3.5 | 2.5 | 1.1 | 0.1 | 0.5 | 1.5 | 5.5 | 6.1 | 7.7 | 4.04 |
| 1.5 - 2.4 | 8.0 | 6.8 | 5.8 | 3.1 | 2.5 | 1.1 | 0.4 | 0.1 | 0.8 | 4.0 | 6.7 | 7.2 | 3.87 |
| 0.5 - 1.4 | 12.3 | 6.7 | 7.6 | 3.7 | 1.7 | 0.6 | — | 0.1 | 1.1 | 4.8 | 7.5 | 10.1 | 4.69 |
| 0.1 - 0.4 | 6.9 | 5.2 | 3.7 | 2.5 | 1.5 | 0.4 | — | — | 0.2 | 2.6 | 5.3 | 7.2 | 2.95 |
| 0 | 13.1 | 10.0 | 9.1 | 3.7 | 1.4 | 0.2 | — | — | 0.8 | 3.3 | 7.4 | 13.1 | 5.19 |
| | 100.1 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.00 |

of «poor» days in the Athens area during the period examined, amounts to 12.8%.

This percentage is higher in the main winter months, rapidly decreasing as we advance towards the warm season; becomes nil in July, and then starts increasing from the month of August onwards till it reaches its maximum in January.

*TABLE VIII*

*Percentage of days with various sunshine duration: almost sunless - practically sunless - sunless (0.0 - 1.4)*

| | Sunless (d=0) | Practically sunless (d=0.0-0.4h) | Almost sunless (d=0.5-1.4h) | Σ1+2+3 |
|---|---|---|---|---|
| J | 13.1 | 6.9 | 12.3 | 32.3 |
| F | 10.0 | 5.2 | 6.7 | 21.9 |
| M | 9.1 | 3.7 | 7.6 | 20.4 |
| A | 3.7 | 2.5 | 3.7 | 9.9 |
| M | 1.4 | 1.5 | 1.7 | 4.6 |
| J | 0.2 | 0.4 | 0.6 | 1.2 |
| J | — | — | — | — |
| A | — | — | 0.1 | 0.1 |
| S | 0.8 | 0.2 | 1.1 | 2.1 |
| O | 3.3 | 2.6 | 4.8 | 10.7 |
| N | 7.4 | 5.3 | 7.5 | 20.2 |
| D | 13.1 | 7.2 | 10.1 | 30.4 |
| Year | 5.2 | 2.9 | 4.7 | 12.8 |

The five-months from November to March are rightly considered the cold season, while the five months from May to September are respectively the warm season. July justifies its good reputation for not having, at least in the Athens area, days with sunshine duration $<1.5$ hours.

Days with sunshine duration $\geq 8.5$ hours are to be found in every month of the year.

We consider the limit of 8.5 hours as the minimum required for the operation, at a satisfactory rate, of sunshine energy collectors.

In Table IX we give the occurence percentage of days with sunshine duration $\geq 8.5$ hours in each month

We observe here that all tbe months in the cold season hold small percentages of long daily durations, with the smallest values belonging to December; on the other hand, percentages are very high in every month of the warm season, with the maximum in July, the sunniest month of the year.

*TABLE IX*

*Percentage of days with sunshine duration ⩾ 8.5 hours at the National Observatory of Athens. Period: 1931 - 1973*

| | Duration 8.5 - 10.4h | Duration 10.5 - 12.4h | Duration 12.5 13.5h | Duration 8.5 13.5 |
|---|---|---|---|---|
| J | 11.3 | — | — | 11.3 |
| F | 25.0 | 0.5 | — | 25.5 |
| M | 24.3 | 7.6 | 0.1 | 32.0 |
| A | 22.1 | 29.7 | 3.5 | 55.3 |
| M | 16.1 | 33.0 | 18.3 | 67.4 |
| J | 12.9 | 35.9 | 34.6 | 83.4 |
| J | 7.4 | 37.3 | 50.1 | 94.8 |
| A | 7.8 | 56.1 | 21.0 | 84.9 |
| S | 37.2 | 40.0 | 0.5 | 77.7 |
| O | 42.5 | 2.6 | — | 45.1 |
| N | 22.0 | — | — | 22.0 |
| D | 8.7 | — | — | 8.7 |
| Year | 19.7 | 20.3 | 11.6 | 51.6 |

DURATION OF SEQUENCES OF SUNLESS DAYS

The problem of whether sunless days occur at random, alternating with sunny ones, or if they occur in sequences of consecutive sunless days, is of paramount importance from the meteorological point of view-as to the speed of alternation or the persistence of various weather types-and also from the technological viewpoint, as to solar energy conversion and applications in everyday household uses.

In Table X we have included mean and extreme values of per month occurence of sunless days, as they resulted from the study of the 1931-1973 period.

From data in Table X we draw the following conclusions:

a. It is possible to have, in months of the cold season, 10 or even more sunless days, as it is also possible for a whole month to go by without even one sunless day. January is the only month that always has at least one sunless day, March and February have the same mean number of sunless days; yet it is possible for March to have up to 13 sunless days, and this fact bespeaks the lateness of greek winters, especially in the south of the area of Greece.

b. On the other hand, one can not speak about sunless days during the five-months warm period, while a sunless day has never been

*TABLE X*

*Mean and extreme values of per month occurence of sunless days at the National Observatory of Athens*
*Period: 1931 - 1973*

| Month | Maximum | Year | Mean | ± σ | Minimum | Year |
|---|---|---|---|---|---|---|
| J | 12 | 1933 | 4.1 | 2.4 | 1 | frequently |
| F | 11 | 1942 | 2.8 | 2.5 | 0 | » |
| M | 13 | 1932 | 2.8 | 2.2 | 0 | » |
| A | 4 | 1931 | 1.1 | 1.2 | 0 | » |
| M | 3 | 1939,1941 | 0.5 | 0.8 | 0 | » |
| J | 1 | 1939,1942,1944 | 0.1 | 0.3 | 0 | » |
| J | — | | — | — | | |
| A | — | | — | — | | |
| S | 1 | frequently | 0.2 | 0.4 | 0 | frequently |
| O | 4 | 1940, 1957 | 1.2 | 1.2 | 0 | » |
| N | 9 | 1932 | 2.2 | 2.3 | 0 | » |
| D | 10 | 1933 | 4.1 | 2.1 | 0 | » |

recorded during the two months of July and August. This last is a characteristic of leeward areas when etesian winds blow in the southern Greek area.

In Table XI we have included the total number of sunless days per month (total $\Sigma^2$) and also sequences of consecutive sunless days.

A study of data in Table XI leads to the following conclusions:

a. 36.3% of sunless days (294/811) occur in sequences.

b. During the cold five-months from November to March, the percentage of sunless days occuring in sequences is as an average >30.0% and it reaches 50.0% in February.

c. Almost 60.0% of these consecutive days, occur in sequences of two. But there have also been recorded, one sequence of five days (in January) and one of eight consecutive sunless days (in March).

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 even less, is so insignificant as to be practically useless for any application.

In Table XII are classified runs of consecutive «practically or actually» sunless days for the period examined. These runs total 1274 days, and their study leads to the following conclusions:

a. 45.1% of sunless and «practicaly or actually» sunless days, occur in sequences (575/1274).

*TABLE XI*

*Distribution of runs of consecutive sunless days at the National Observatory of Athens.*

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total of runs $S_1$ | Total of days $S_2$ | $S_1$ $S_2$ % |
|---|---|---|---|---|---|---|---|---|---|---|
| J | 20 | 7 | 4 | 1 | — | — | — | 82 | 174 | 47.1 |
| F | 21 | 5 | 1 | — | — | — | — | 61 | 122 | 50.0 |
| M | 12 | 1 | 1 | — | — | — | 1 | 39 | 121 | 32.2 |
| A | 4 | — | — | — | — | — | — | 8 | 48 | 16.7 |
| M | 2 | — | — | — | — | — | — | 4 | 19 | 21.1 |
| J | — | — | — | — | — | — | — | — | 3 | — |
| J | — | — | — | — | — | — | — | — | 0 | — |
| A | — | — | — | — | — | — | — | — | 0 | — |
| S | — | — | — | — | — | — | — | — | 10 | — |
| O | 3 | — | 1 | — | — | — | — | 10 | 44 | 22.7 |
| N | 9 | 3 | 1 | — | — | — | — | 31 | 96 | 32.3 |
| D | 17 | 7 | 1 | — | — | — | — | 59 | 174 | 33.9 |
| Total of cases | 88 | 23 | 9 | 1 | — | — | 1 | | | |
| Total of days | 176 | 69 | 36 | 5 | — | — | 8 | 294 | 811 | 36.3 |

*TABLE XII*

*Distribution of runs of «sunless» and «partically or actually sunless» consecutive days at the National Observatory of Athens.*

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Total of runs $S_1$ | Total of days $S_2$ | $S_1$ $S_2$ % |
|---|---|---|---|---|---|---|---|---|---|---|
| J | 31 | 15 | 3 | — | 2 | 1 | — | 138 | 266 | 51.9 |
| F | 32 | 5 | 4 | 1 | 1 | — | — | 106 | 185 | 57.3 |
| M | 19 | 4 | 2 | — | — | — | 1 | 66 | 170 | 38.8 |
| A | 10 | 1 | — | — | — | — | — | 23 | 80 | 28.8 |
| M | 3 | — | — | — | — | — | — | 6 | 39 | 15.4 |
| J | — | — | — | — | — | — | — | — | 8 | — |
| J | — | — | — | — | — | — | — | — | — | — |
| A | — | — | — | — | — | — | — | — | — | — |
| S | — | — | — | — | — | — | — | — | 12 | — |
| O | 8 | 2 | 1 | — | — | — | — | 26 | 79 | 32.9 |
| N | 20 | 4 | 1 | — | 1 | — | — | 62 | 165 | 37.6 |
| D | 42 | 13 | 2 | 2 | — | 1 | — | 148 | 270 | 54.8 |
| Total of cases | 165 | 44 | 13 | 3 | 4 | 2 | 1 | | | |
| Total of days | 330 | 132 | 52 | 15 | 24 | 14 | 8 | 575 | 1274 | 45.1 |

b. During the main winter season, the percentage of sunless and «practically or actually» sunless days occuring in sequences, is 50%, while the highest percentage belongs again in the sunless days of February.

c. 57.4% of sunless and «practically or actually» sunless days (330/575) occur in sequences of two. There have, however, been recorded during the cold five-months period from November to March, rare cases with sequences of 5 up to 8 consecutive days. The longest sequence of consecutive sunless days is again that of 1-8/3/1932.

## CONCLUSIONS

In addition to remarks made in the various sections of this paper, we note the following:

a. The annual mean value of 2809 hours is a quite satisfactory value for the northern Mediterranean coasts, although it represents a period of more abundant bright sunshine in the Athens area.

The coefficient of variation for the annual mean value rose to 7.3% during the period examined herein, against 6.8% of the 1897-1973 period. This should be attributed to the fact that extreme annual values were recorded in the period 1931-1973.

b. Monthly mean values of the 1931-1973 period have in ten months higher values than the corresponding ones of the longer period (1897-1973).

The difference of 30.4 hours per year, is due to the increase of sunshine duration by 33.4 hours during the warm season (May-September).

c. Monthly mean values of December and January slightly differ from each other (J-D= —2.1 hours). That is why in 20 cases December had longer sunshine duration than January, while January exceeded December in 23 cases.

The greatest pre-eminence of December over January was recorded during the 1970-71 winter, when December had sunshine duration of 193.3 hours while January had only 83.8. This means that the sunniest December of the whole 1931-73 period was succeeded by a January poor in sunshine.

On the other hand the greatest pre-eminence of January over December was recorded during the 1947-48 winter, when December had 113.7 hours of bright sunshine while January had 164.6 hours,

Table IV is characteristic of the instability of Greek weather, and

it proves that a month with fair or bad weather may, by chance, be succeeded by another month with reversed weather conditions or by one with similar weather conditions; in this last case, the sequence of two or more months with fair or bad weather, characterizes the whole season.

d. The mean per year value of daily sunsbine duration is 7.60 hours. This value has a single fluctuation, with a maximum in July and a minimum in December.

July is the only month when the absolute minimum recorded was 2.0 hours. During the ten months from September to June, it is possible to have nil (0) sunshine duration.

e. Studying the mean per cent (%) values of «sunless», «practically sunless», and «almost sunless» days (Table VIII) in correlation with values of Table IX, we arrive at the conclusion that during the eight months from March to October we have sunshine duration of more than 30%.

Consequently during these eight months it should be possible to employ systems operating with solar energy in the Attica basin.

f. The use of solar energy would be considerably impeded during the November - February four-months, mainly by sequences of poor in sunsbine days (Tables X1, and XII).

## REFERENCES

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ΠΕΡΙΛΗΨΗ

# Η ΔΙΑΡΚΕΙΑ ΤΗΣ ΗΛΙΟΦΑΝΕΙΑΣ ΣΤΗΝ ΑΘΗΝΑ (ΙΙΙ)

Ὑπὸ

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Ἡ ἐργασία αὐτὴ εἶναι τρίτη στὴν σειρὰ στὴν ἔρευνά μας «Ἡλιοφάνεια στὴν Ἀθήνα» καὶ δωδεκάτη στὴν σειρὰ τοῦ γενικωτέρου προγράμματος τοῦ Ἐργαστηρίου Μετεωρολογίας-Κλιματολογίας τοῦ Ἀριστοτελείου Πανεπιστημίου Θεσσαλονίκης «Ἡ Ἡλιοφάνεια στὴν Ἑλλάδα».

Μελετοῦμε τὰ στοιχεῖα τῆς διάρκειας τῆς ἡλιοφανείας ἀπὸ τὰ ἐγγραφήματα τοῦ ἡλιογράφου τοῦ Ἐθνικοῦ Ἀστεροσκοπείου Ἀθηνῶν (Ε.Α.Α.) (φ=37° 48′ Ν, λ=23° 43′ Ε, ὑψομ. 107 μ.).

Στὴν μελέτη μας χρησιμοποιοῦμε τὰ στοιχεῖα τῆς χρονικῆς περιόδου 1931-1973 δηλαδὴ περίοδο 43 ἐτῶν. Χρησιμοποιοῦμε τὴν περίοδο αὐτὴ γιατὶ μετὰ τὸ 1930 ἄρχισαν νὰ λειτουργοῦν καὶ σὲ ἄλλους μετεωρολογικοὺς σταθμοὺς ἡλιογράφοι. ἔτσι ἡ περίοδος αὐτὴ δίνει τὴν δυνατότητα νὰ γίνουν συγκρίσεις μὲ τὰ στοιχεῖα τῆς διάρκειας τῆς ἡλιοφανείας καὶ μὲ ἄλλους μετεωρολογικοὺς σταθμοὺς τῆς Ἑλληνικῆς περιοχῆς.

Στὸ πρῶτο μέρος, μελετοῦμε τὶς μέσες καὶ ἄκρες μηνιαῖες καὶ ἐτήσιες τιμὲς τῆς διάρκειας τῆς ἡλιοφάνειας καὶ τὴν συγκρίνουμε μὲ ἀποτελέσματα τῆς μελέτης μας ποὺ εἶχε περιλάβει τὴν χρονικὴ περίοδο 1897-1973, μὲ σκοπὸ νὰ δοῦμε τὴν ἀντιπροσωπευτικότητα τῆς βραχύτερης περιόδου, ποὺ χρησιμοποιοῦμε στὴν νέα ἔρευνά μας.

Ὁ κύριος ὅμως ἀντικειμενικὸς σκοπὸς τῆς μελέτης μας εἶναι νὰ μελετηθῆ ἡ συμπεριφορὰ τῆς διάρκειας τῆς ἡλιοφάνειας στὴ βάση, δηλαδὴ ἀπὸ μέρα σὲ μέρα.

Ἐξάγονται τελικὰ συμπεράσματα, ὡς πρὸς τὴν διάρκεια τῶν διαδοχικῶν ἀνήλιων καὶ πρακτικὰ ἀνήλιων διαδοχικῶν ἡμερῶν.

Ἡ σημασία τῶν συμπερασμάτων αὐτῶν εἶναι χρήσιμη γιὰ τὶς πρακτικὲς ἐφαρμογὲς τῆς ἡλιακῆς ἐνεργείας, τουλάχιστον στὴν περιοχὴ τῆς μείζονος Ἀθήνας-Ἀττικῆς μὲ ἄλλα λόγια μέσα στὸ μεγαλύτερο πολεοδομικὸ συγκρότημα τῆς Ἑλληνικῆς περιοχῆς, στὸ ὁποῖο κατοικεῖ τὸ 1/4 τοῦ πληθυσμοῦ τῆς χώρας μας (περίπου 2.500.000).