

ON THE EFFECT OF GROUND RELIEF  
UPON SUNSHINE DURATION ON MOUNT OLYMPUS-GREECE

By

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**Abstract :** *The effect of ground relief upon sunshine duration, is examined from data of a couple of meteorological stations on Mt Olympus: the Olympus Scientific Center (Ayios Antonios peak, elevation 2817 m) and the Skiing Center (inside the Ayios Antonios - Sparmos ravine, elevation 1.850 m) covering the summer seasons of 1966-1973.*

*The effect of the cloudiness factor, and the role this factor plays in the final results is defined.*

INTRODUCTION

The surrounding topography or ground relief may be a permanent and steady factor affecting sunshine duration. This factor becomes more important in a mountainous\* country, like Greece, whose lowlands are plains enclosed on two or three sides by mountains, more than 1.000 m high and in many cases 2.000 m high, while some peaks rise as high as 3.000 m. As a rule every work concerning sunshine duration or in any way related to this subject, mentions the effect of the ground relief (GEIGER <sup>4,5,6</sup>), while it is a prerequisite for works concerning the area of Greece.

Listed below are the principal works on sunshine duration in the area of Greece, which mainly relate to the two major cities: Athens and Thessaloniki.

I. D. AEGINITIS <sup>1</sup> in 1907, writing about the climate of Athens,

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\* The former of us thinks that one of the most accurate descriptions of the ground relief of Greece was given by Kenneth Matthews in «Memories of a Mountain War», Greece 1944-1949 (Longman Group Ltd, London 1972) : p. 28 . . . The plains so-called, are troughs in which the centuries' torrents have deposited some tribute of alluvial mud. All Greece is mountain, as relief map (or an aeroplane) shows - wave after wave of barren summits driving their children to the sea's edge . . . ».

calculated that the effect of the ground relief, in this case Mt Hymettus (elev. 1026), is to delay the sunrise by  $5^{\circ} 55'$ , while Mt Korydhallos (elev. 453 - 468 m) precipitates sunset by  $2^{\circ} 15'$ .

II. A. N. LIVATHINOS<sup>13</sup> in 1926, writing about insolation in Greece, accepts the influence of ground relief on the duration of sunshine, and mentions the same figures as Aeginitis.

III. E. G. MARIOLOPOULOS<sup>14</sup> in 1936, in the Chapter on Insolation, writes among others «. . . Even a small distance between two sites may result, if orographic conditions differ, in the increase or decrease of sunshine duration . . . .».

IV. The same author in 1938<sup>15</sup>, makes the same remark in his «Climate of Greece».

V. V. A. SAKALIS<sup>16</sup> in 1951, studying the climate of Athens assumes that the ground relief of the area (Mt Hymettus 1026 m to the east, and Aegaleo 468 m, Pikilon 453 m and Kithairon 1411 m to the west) results in the decrease of sunshine duration in the plain of Attica, by 115 hours yearly.

VI. PH. KARAPIPERIS<sup>7</sup> in 1965 mentions the effect of the ground relief in Attica on the course of the diurnal variation of sunshine duration.

VII & VIII. L. ALEXANDROU<sup>2,3</sup> in 1933, studying the climate of Thessaloniki also mentions the effect of the ground relief on sunshine duration. «. . . Mt Chortiates (elev. 1199 m) standing to the east of the city delays the sunrise by about  $20'$  in winter and about  $40'$  in the summer, while the range of Pieria mountains (elev. 1878 m, horizontal distance 60-70 km) extending to the west brings sunset in the city of Thessaloniki some 5 min earlier, in winter and summer as well...».

The same scientist in 1940<sup>3</sup>, writing about sunshine duration in Thessaloniki accepts the same figures, attributing the decrease of sunshine duration to the ground relief.

IX. B. KYRIAZOPOULOS<sup>8</sup>, in his work on «The Climate of Central Greek Macedonia» (1938) also admits the same figures.

X & XI. Similar statements about the effect of ground relief on sunshine duration are mentioned by LIVADAS - MALDOYANNIS - FLOCAS<sup>9</sup> 1970 and LIVADAS - FLOCAS<sup>10</sup> in 1972.

XII. LIVADAS - PENNAS<sup>11</sup> in 1973 studying sunshine duration in Neos Marmaras, Chalkidiki, also mention the effect of the ground relief; this is also the first Greek work that makes use of «horizontiograms».

XIII. Finally the authors of the present paper in a previous stu-

dy of sunshine duration in Upper Olympus (LIVADAS - SEMERTZIDIS<sup>12</sup>), examined systematically the effect of the local ground relief.

The problem of the effect of ground relief on sunshine duration becomes more acute, but also far more interesting in studies of mountainous areas.

We, for the study of this problem, have selected two met. stations that function during the summer season in the area of Upper Olympus:

- a. The met. station of Olympus Scientific Center (O.S.C. - elevation 2817 m).
- b. The met. station of the Skiing Center (Sk. C. elev. 1850 m) (See Fig. 1).

The first of these two stations stands on the Ayios Antonios peak, which is the third highest peak of Mt Olympus and of Greece at the same time; while the second is situated inside a deep valley with a north-south axis and is surrounded by the mountain masses of Upper Olympus (see Horizontal diagram, Fig. 11), especially on the north and east side.

The data examined herein, are those of the 1966-1973 summer seasons when Campbell-Stokes sunshine recorders worked simultaneously in both stations.

#### *A. Sunshine Duration in Olympus Scientific Center and in the Skiing Center.*

As we mentioned in a previous paper (LIVADAS - SEMERTZIDIS<sup>12</sup>): «The elevation of Olympus Scientific Center (O.S.C.) is the highest of all meteorological stations around the Mediterranean and one of the highest in Europe, while, as far as we know, it holds a very good place among the twenty most elevated meteorological stations of this planet. Met. stations like that of Ayios Antonios peak, have an entirely free horizon, where all natural obstacles stand at negative elevations as to the level of the peak and can consequently be considered as reference points.

On the contrary, the Skiing Center (Sk. C.) is situated inside a deep valley, or rather a wide ravine surrounded by the mountaintops Dhia-koptis - Pyrgos to the west, Trypes - Ayios Antonios (Kastron) to the north, and Pighes - Kakavrakas to the east, and as a consequence undergoes the effect of the local relief. It could be maintained that one of the main factors diminishing sunshine duration in this station, are the natural obstacles of the ground relief.

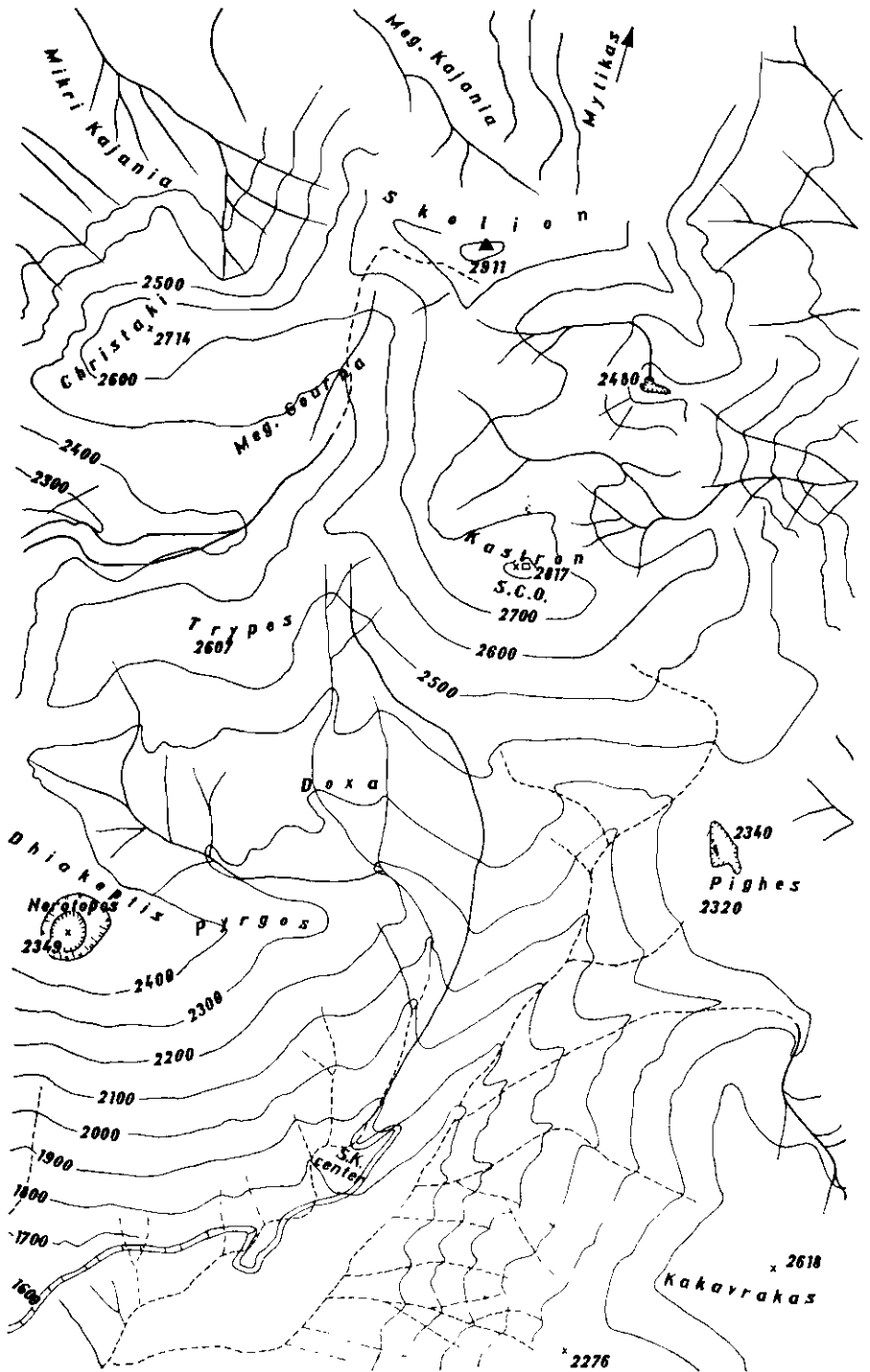


Fig. I. Contour map of the area

I. Comparing the recorded mean sunshine duration values for all the observational days (736 in all) in both met. stations, for the 1966 - 1973 period, we observe a considerable and steady difference in sunshine duration in the early morning hours between 04:00 - 08:00.

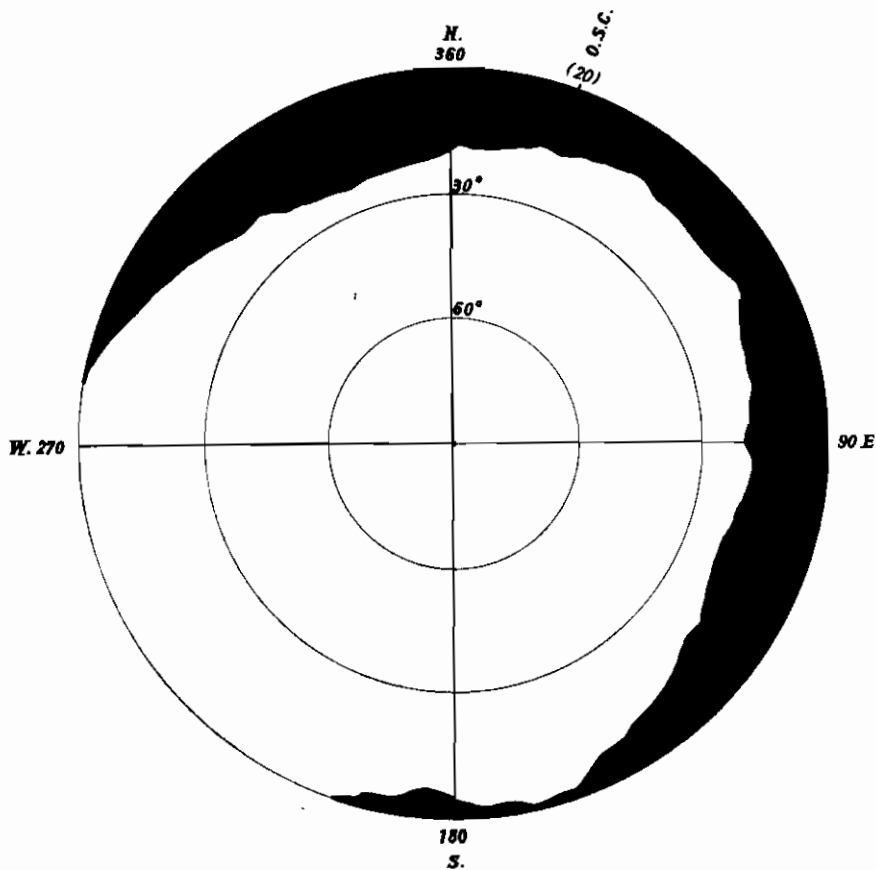


Fig. II.

a. In July we observe from 04:00 - 07:00 hours a small superiority of the O.S.C. over the Sk. C., amounting to 0.78 hours; this however is succeeded during the next three hours (07:00-10:00 hours) by a superiority of the Sk. C. by 0.10 hours.

b. In August, during the first three hours of daylight (04:00-07:00) the sunshine duration in O.S.C. is longer than that of the Sk. C. by 0.95 hours, while during the next three hours (07:00-10:00) this difference becomes only 0.1 hour, the two stations having practically the same sunshine duration.

TABLE I

Sunshine duration in Olympus Scientific Center (O.S.C.) and in Skiing Center (Sk. C.) during the warm season (1966 - 1973).

	4-5	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	Total hours/day	
O.S.C.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
J.	0.08	0.56	0.68	0.72	0.73	0.71	0.71	0.72	0.73	0.72	0.70	0.68	0.65	0.58	0.42	0.02	9.41	
A.	0.00	0.43	0.77	0.81	0.83	0.80	0.76	0.75	0.73	0.73	0.73	0.73	0.70	0.63	0.35	0.00	9.75	
S.	—	0.02	0.40	0.68	0.71	0.71	0.71	0.70	0.66	0.67	0.66	0.63	0.56	0.31	0.03	—	7.45	
Sk. C.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
J.	—	0.01	0.53	0.76	0.77	0.73	0.69	0.67	0.68	0.67	0.67	0.62	0.60	0.55	0.24	0.00	8.19	
A.	—	—	0.25	0.80	0.83	0.80	0.75	0.70	0.68	0.66	0.62	0.62	0.58	0.49	0.16	0.00	7.94	
S.	—	—	0.00	0.31	0.67	0.66	0.60	0.55	0.57	0.59	0.56	0.52	0.42	0.18	0.00	—	5.63	
Δ.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
J.	0.08	0.55	0.15	-0.04	-0.04	-0.02	0.02	0.05	0.05	0.05	0.05	0.03	0.06	0.05	0.03	0.18	0.02	1.22
A.	0.00	0.43	0.52	0.01	0.00	0.00	0.01	0.05	0.05	0.07	0.11	0.11	0.12	0.14	0.14	0.19	0.00	1.81
S.	—	0.02	0.40	0.37	0.04	0.05	0.11	0.15	0.09	0.08	0.10	0.11	0.14	0.13	0.03	—	—	1.82

c. In September, the O.S.C. again exceeds the values of the Sk. C. by 0.79 hours during the first three hours of the day (05:00-08:00); this superiority lasts throughout the day.

A similar, although not so pronounced, difference is recorded again during the last three hours of daylight.

July	:	0.23 hour
August	:	0.33 »
September	:	0.30 »

### JULY

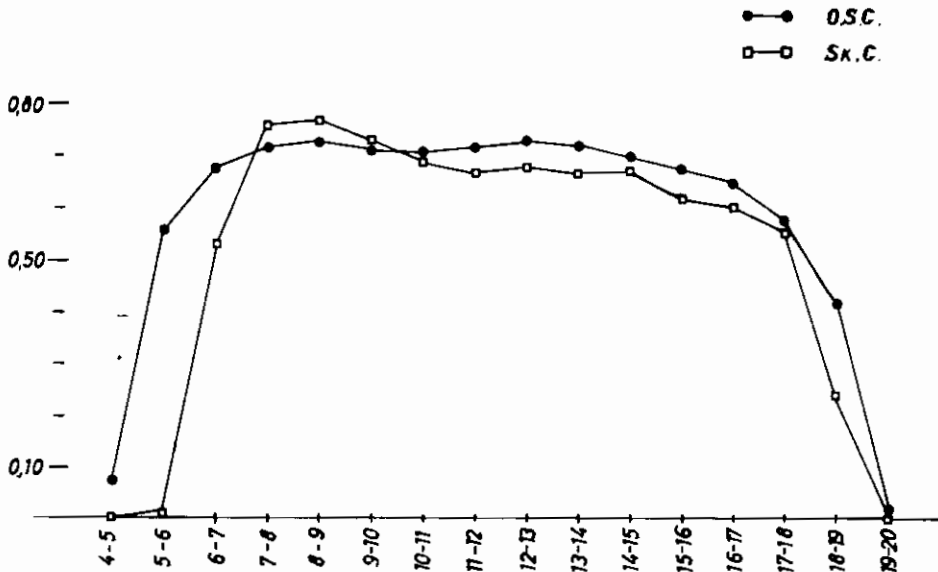


Fig. III.

This so pronounced superiority of the O.S.C., during the first three hours of the day is actually due to the ground relief, which also causes the diminishment of sunshine duration in the second station during the last three hours of daylight.

II. Comparing sunshine duration values on sunny days alone in both stations (97 days in all: 34 in July, 36 in August, 27 in September). (Table II), we observe:

a. In clear days of July and August, the difference of sunshine

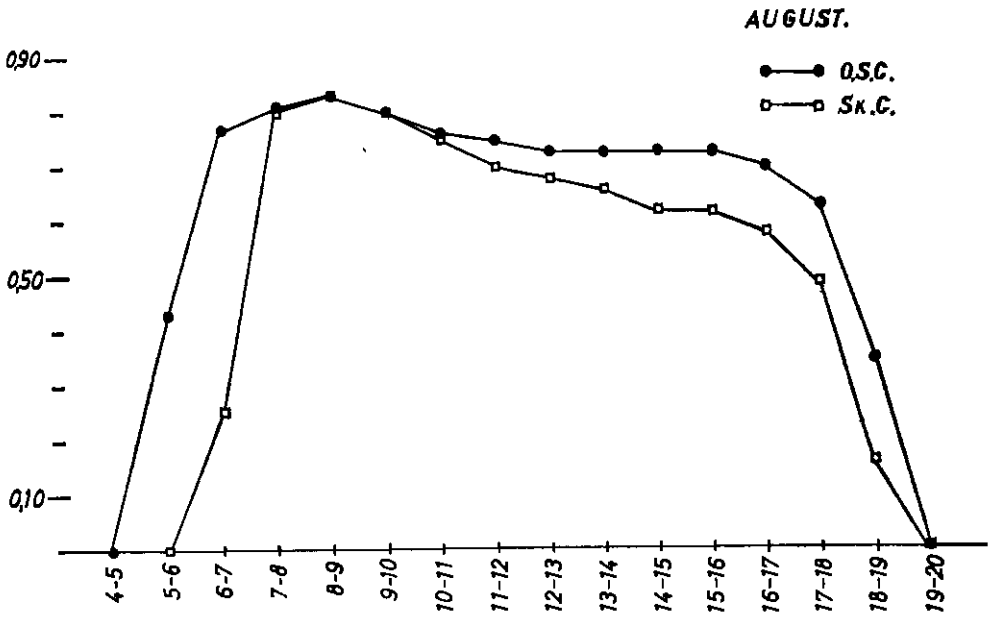


Fig. IV.

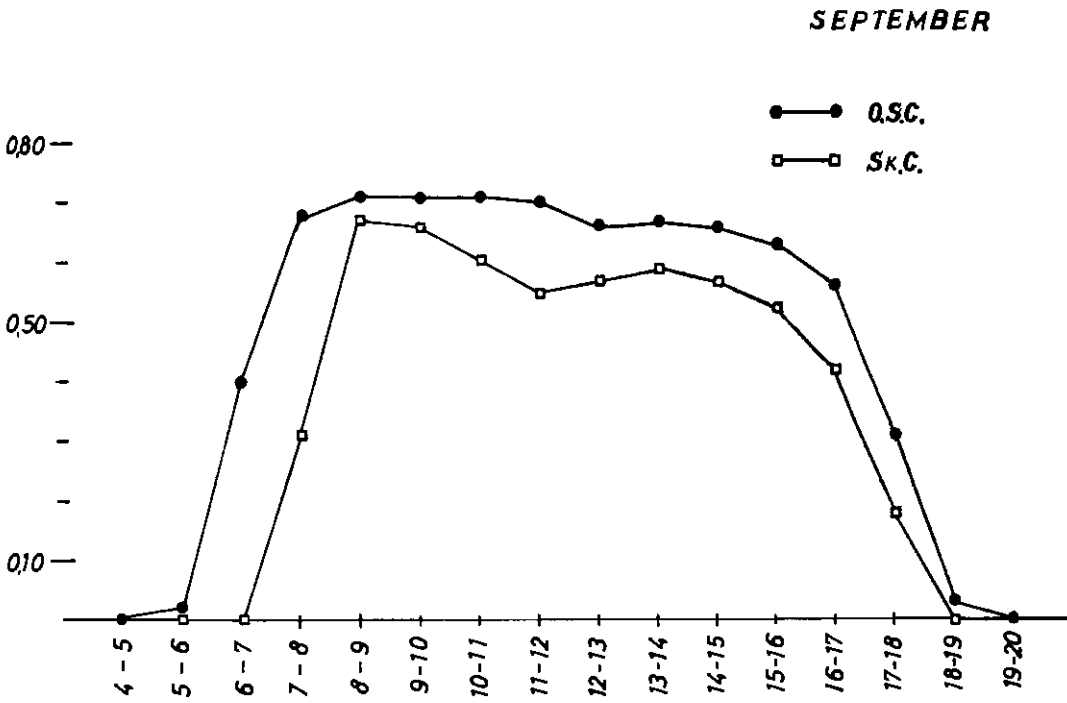


Fig. V.



TABLE II

*Sunshine duration in Olympus Scientific Center (O.S.C.) and in Skiing Center (Sk. C.)  
on clear days only (Period 1966 - 1973). (In hours).*

S.C.O.	4-5	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	Total hours/day	
J.	8.20	32.75	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	34.00	27.49	1.55	477.99
A.	0.15	24.05	35.95	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	35.90	34.85	21.30	0.20	—	476.40
S.	—	0.45	19.10	27.00	26.90	27.00	27.00	27.00	27.00	27.00	26.95	26.95	27.00	15.15	0.50	—	—	305.00
Sk. C.																		
J.	—	1.65	27.40	34.00	34.00	34.00	34.00	33.95	34.00	34.00	34.00	34.00	33.90	31.70	15.75	—	—	416.35
A.	—	—	11.45	35.35	36.00	36.00	36.00	35.85	35.90	35.50	35.80	36.00	35.80	28.00	12.05	—	—	409.70
S.	—	—	0.15	14.15	27.00	27.00	26.65	27.00	27.00	27.00	27.00	26.50	23.85	11.05	—	—	—	264.35
Δ.																		
J.	8.20	31.10	6.60	00.00	00.00	00.00	00.00	00.00	0.05	00.00	00.00	00.00	0.10	2.30	11.74	1.55	—	61.64
A.	0.15	24.05	24.50	0.65	00.00	00.00	00.00	0.15	0.10	0.05	0.20	00.00	0.10	6.85	9.25	0.20	—	66.70
S.	—	0.45	18.95	12.85	-0.10	00.00	0.35	00.00	00.00	00.00	-0.05	0.45	3.15	4.10	0.50	—	—	40.65

duration between the above two stations during the ten-hours period from 07:00 to 17:00, is almost «0», while the O.S.C. has higher values at sunrise and sunset time

	Sunrise	Sunset
July	45.90 (hours)	15.59
August	48.70 »	16.30

meaning that as an average for the main warm season, on clear days, sunshine duration is longer in the O.S.C. (elev. 2817 m) by 1.78 hours in July and 1.80 hours in August. The diminishment of sunshine duration in the station with the lower elevation (Sk. C. elev. 1850 m) is due to the obstruction of sunrise and sunset caused by the local relief alone.

b. In September, when the time of daylight decreases, the duration of the day at the Skiing Center is limited to 8 hours (08:00-16:00). In this month too, the ground relief plays an important role in the decrease of sunshine duration, as follows:

September: Sunrise 32.25 hours less; sunset 7.75 hours less, meaning that in September, daily sunshine duration is diminished as an average by 1.48 hours, because of the ground relief.

#### DISCUSSION

Comparing the diurnal variation of sunshine duration in the examined two met. stations of Mt Olympus, for the summer season (July-September) of the years 1966 - 1973, we notice the following:

a. Sunshine duration in the valley station (Skiing Center-elevation 1850 m) is always shorter than on the peak (Olympus Scientific Center - elevation 2.820 m).

As we can see in Table I, this difference is as an average, for the sum of observational days examined here (736 days in all): July: 1.22 hours, August 1.81 hours, September 1.82 hours.

The above difference is finally the result of two factors:

I. The ground relief is a permanent and steady factor that affects the duration of daylight at sunrise and sunset, and

II. The variable factor of cloudiness.

b. In order to define the role of the relief, comparison should be made between cloudy days and clear days or days with traces of clouds only. We have selected 97 days with none or traces of clouds out of the amount of 736 days examined herein, and we observe that the effect of ground relief is more clearly defined.

TABLE III

*Role of the relief factor and cloudiness factor on days of none or traces of clouds.*

	Relief - factor		Cloudiness - factor
	sunrise	sunset	
July	1.35 <sup>h</sup>	0.46 <sup>h</sup>	0.004
August	1.35 <sup>h</sup>	0.45 <sup>h</sup>	0.034
September	1.19 <sup>h</sup>	0.30 <sup>h</sup>	0.022

On the contrary, from the amount of observational days, on which the present research has been based, we observe that the relief factor is restrained from the coexisting cloudiness factor.

TABLE IV

*Role of the relief-factor and cloudiness-factor on the amount of 736 days of the 1966-1973 summers.*

	Relief - factor		Cloudiness - factor	total
	sunrise	sunset		
July	0,78	0,23	0,21	1.21
Aug.	0,95	0,33	0,53	1.81
Sept.	0,79	0,30	0,73	1.82

The cloudiness-factor overlaps the obscuring of sunshine duration that is caused by the local relief of the ravine station, because of the increased cloudiness at the Skiing Center. This is made clear if we compare the figures of the cloudiness factor in Tables III and IV: While on the 97 selected days with none or traces of clouds, it varies between 0.00 - 0.03 hours, on the amount of days examined (736 observational days) it becomes 0.21-0.73 hours.

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## ΠΕΡΙΛΗΨΙΣ

### Η ΕΠΙΔΡΑΣΙΣ ΤΟΥ ΑΝΑΓΛΥΦΟΥ ΕΙΣ ΤΗΝ ΔΙΑΡΚΕΙΑΝ ΤΗΣ ΗΛΙΟΦΑΝΕΙΑΣ ΕΝ ΟΛΥΜΠΩ

Ὑπὸ

ΓΕΩΡΓΙΟΥ Κ. ΛΙΒΑΔΑ καὶ ΒΛΑΔΙΜΗΡΟΥ Α. ΣΕΜΕΡΤΖΙΑΗ

(Ἐργαστήριον Μετεωρολογίας καὶ Κλιματολογίας)

Μελετᾶται ἡ ἐπίδρασις τοῦ ἀναγλύφου ἐπὶ τῆς διάρκειας τῆς ἡλιοφανείας, εἰς ἓν ζεῦγος Μετεωρολογικῶν Σταθμῶν εἰς τὴν περιοχὴν τοῦ Ἄνω Ὀλύμπου. [Μ. Σταθμὸς Ἐπιστημονικοῦ Κέντρου Ὀλύμπου ὕψομ. 2817 μ. καὶ Μ. Σταθμὸς Κέντρου Ἐκπαιδεύσεως Ὀρεινοῦ Ἀγῶνος ὕψομ. 1850 μ.]. Τοῦτο ἔχει μεγάλην σημασίαν εἰς τὴν Ἑλληνικὴν περιοχὴν, διότι μὲ ἐξαιρέσιν τὴν δυτικὴν ἀκτὴν (Ἰόνιον Πέλαγος) εἰς οἷονδῆποτε ἄλλο σημεῖον τοῦ Ἑλλαδικοῦ χώρου, τὸ ἀνάγλυφον περιορίζει κατὰ τὸ μᾶλλον ἢ ἥττον τὴν διάρκειαν τῆς ἡμέρας (ἡλιοφανείας).

Ἡ μελέτη ἐστηρίχθη εἰς τὰς συγχρόνους παρατηρήσεις τὰς πραγματοποιηθείσας κατὰ τὴν διάρκειαν τῆς θερμῆς περιόδου (Ἰουλίου - Σεπτεμβρίου) τῶν ἐτῶν 1966 - 1973 (8 ἔτη), ἧτοι συνολικῶς ἐπὶ 736 ἡμέρας.

Τὰ προκύψαντα συμπεράσματα δύνανται νὰ συνοψισθοῦν ὡς κάτωθι:

α. Ἐὰν ληφθοῦν ὑπ' ὄψιν αἱ κοιναὶ αἰθρίαὶ ἡμέραι (97 ἡμέραι) εἰς τοὺς δύο Μ. Σταθμοὺς προκύπτει ὅτι τὸ ἀνάγλυφον περιορίζει τὴν διάρκειαν τῆς ἡλιοφανείας, κυρίως κατὰ τὴν ἀνατολὴν (πίναξ III α, Διαγρ. III - V). Ὁ περιορισμὸς αὐτὸς κυμαίνεται ἀπὸ 16 - 21 % διὰ τὴν ἡλιοφάνειαν τοῦ Κ.Ε.Ο.Α., ἐὰν δὲ προστεθῇ καὶ ὁ περιορισμὸς κατὰ τὴν δύσιν ποὺ κυμαίνεται μεταξὺ 5 % καὶ 6 %, τὸ ἀνάγλυφον εἰς τὴν χαράδραν τοῦ Ἀγ. Ἀντωνίου - Σπαρμοῦ περιορίζει τὴν διάρκειαν τῆς ἡλιοφανείας κατὰ ποσοστὸν 21 - 27 %.

β. Ἐὰν ληφθῇ ὑπ' ὄψιν τὸ σύνολον τῶν ἡμερῶν παρατηρήσεων (736 ἡμέραι), τότε προκύπτει ἡ σημασία τοῦ δευτέρου ἢ μεταβλητοῦ παράγοντος περιορισμοῦ τῆς ἡλιοφανείας, ἧτοι τῆς νεφώσεως. Ὁ Μ. Σταθμὸς τοῦ Κ.Ε.Ο.Α. ἔχει ὀλιγωτέραν ἡλιοφάνειαν, κατὰ τὴν θερινὴν περίοδον, λόγῳ σχηματισμοῦ νεφῶν εἰς τὴν περιοχὴν τοῦ ὄρεινοῦ ὄγκου τοῦ Ἄνω Ὀλύμπου, ἡ ὁποία νέφωσις καὶ περιορίζει τὴν διάρκειαν τῆς ἡλιοφανείας εἰς τὸν χαμηλότε-

ρον εύρισκόμενον Μ. Σταθμόν, ό δέ περιορισμός αύξάνει όσον παρέρχεται ή έποχή: 8 % 'Ιούλιος - 13 % Σεπτέμβριος.

γ. Ούσιαστικώς προτείνεται μέθοδος: ότι διά νά μελετηθῆ ή επίδρασις τοῦ ανάγλυφου είς μίαν θέσιν (Μετ. Σταθμόν) θά πρέπει νά επιλέξωμεν μόνον αιθρίας ήμέρας, διότι ό παράγων νέφωσις συσκοτίζει λόγω υπερχαλύψεως τοῦ παράγοντος «ανάγλυφου» τά σχετικά άποτελέσματα.