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GROUND SURFACE TEMPERATURE PART II GRASS - COVERED GROUND

by

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Summary : *Temperature of grass - covered ground surface and at 10 cm above it are examined herein, for the city of Thessaloniki (Greece) and for the period between 1.1. 1931 - 31.10.1940 and 1.1.1954 - 31.12.1960. Normal temperature values are given (annual, monthly, and daily ones), as well as the extreme values recorded during the period examined.*

There is proof of a temperature inversion between ground surfaee and air - temperature (inside the meteorological screen), as well as between grass - covered ground surface and 10 cm above it, during the cold season.

In a previous paper the authors studied the bare - soil surface temperature (Livadas - Goutsidou 1972 [1]); in the present paper we examine the grass - covered ground surface temperature in Thessaloniki.

The couple of grass thermometers (Max. and Min.) was horizontally exposed within a small plot of 2 - 3 m^2, covered by thick grass, in a manner that while they were touching the ground they were also covered by grass which was maintained at a height of about 10 cm.

It should be noted that because of climatological conditions in the area of Thessaloniki (the type of its climate, according to Köppen's classification, is «Csa») the maintainance of a grass plot is a continuous problem : During the summer season it has to be watered (by sprinkling irrigation) and this was done just after the morning observation at 06.00 GMT (08.00 local time). On the other hand the extremely low winter temperatures (ground frosts) often kill the grass. The only successful way for facing these difficulties in summer as well as in winter, is the use of «double plots», meaning that we cultivated grass in two adjoining plots, alternatively, so that there was a difference in the «age» of the grass in each plot; thus it was possible to place instruments under and above grass, which was some 10 cm high. It should be noted however that, traditional lawn - grass doesn't thrive in the climate of Thes-

saloniki, dry and hot in summer and extremely cold in winter.

Measurements of temperature on grass - covered ground hold two periods : a) from 1.1.1931 till 31.10.1940. b) they were resumed on 1.1.1954.

The met. station of the Institute of Meteorology has been functioning in the garden of the old building of the University from 1930 till 1958; then it was moved on 1.1.1959 to its new position, some 220 m from the old one, near the new building of the Institute (LIVADAS 1973 [2]).

A large part of the material used herein has been published in the series «Observations Météorologiques de Thessaloniki» (MARIOLOPOULOS [3], KYRIAZOPOULOS [4], LIVADAS [5]), while the rest has been taken from the records of the Institute of Meteorology and Climatology.

A. GRASS - COVERED GROUND SURFACE.

a. Annual Mean.

The annual mean as well as the warmest and coldest year at the grass covered ground surface, for the 27 full years of the period examined, (1931 - 1940 and 1954 - 1970), are given in the following Table I.

TABLE I

Warmest year	18.96°C(1958)
Annual mean	17.05 ± 1.09
Coldest year	15.50°C(1934)

From the above Table I and from the following Table II, containing frequencies of annnal values, we find that the range of the mean annual temperature is ~3,50° C.

TABLE II

Frequency of mean annual temperature values of grass covered ground surface.

19,00 - 18,51	5 years	17,00 - 16,51	3 years
18,50 - 18,01	1 »	16,50 - 16,01	8 »
18,00 - 17,51	0 »	16,00 - 15,51	4 »
17,50 - 17,01	5 »	15,50 - 15,00	1 »

b. Monthly mean

Mean monthly values of the period examined, as well as extreme monthly temperature values of grass covered ground snrface, are included in Table III and illustrated in Graph 1. From the above mentioned Table and Graph we find that grass - covered ground surface

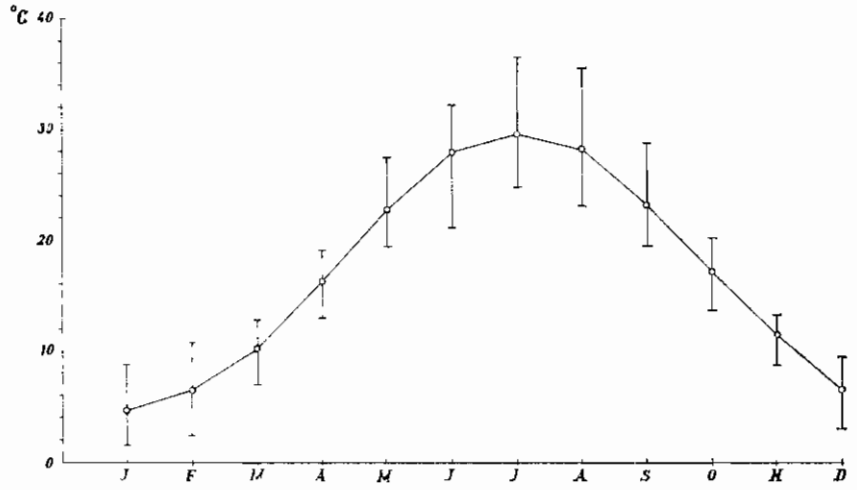
temperatures, like those of bare ground surface, have their smallest values in the month of January (mean and extreme monthly values as well), while July has the highest corresponding values.

TABLE III

Mean and extreme monthly temperature values of grass covered ground surface

(1930 - 1940 & 1954 - 1970)

	Warmest month		*Mean*	± σ	*Coef. of variation*	*Coldest month*		*Δ(range)*
J	8.96	1955	4.67	1.87	40.04%	1.61	1964	7.35
F	10.90	1955	6.53	2.31	35.38	2.37	1932	8.53
M	12.91	1936	10.29	1.54	14.97	6.97	1956	5.94
A	19.02	1957	16.32	1.96	12.01	13.00	1931	6.02
M	27.57	1962	22.85	2.33	10.20	19.51	1930	8.06
J	32.20	1930	27.99	2.44	8.72	21.19	1939	11.01
J	36.45	1958	29.59	2.57	8.69	24.82	1934	11.63
A	35.50	1956	28.25	3.30	11.68	23.21	1967	12.29
S	28.94	1954	23.24	2.35	10.11	19.41	1966	9.53
O	20.28	1961	17.21	1.53	8.89	13.76	1968	6.52
N	13.22	1962 1963	11.53	1.09	9.45	8.89	1967	4.33
D	9.41	1960	6.52	1.48	22.70	3.05	1931	6.36



GRAPH I

TABLE IV

Frequency of monthly-mean temperature values of grass covered ground surface in Thessaloniki

	J	F	M	A	M	J	J	A	S	O	N	D
37 - 38												
36 - 37							1					
35 - 36								1				
34 - 35								2				
33 - 34							1	1				
32 - 33						2	2	1				
31 - 32						1	4					
30 - 31						1	7	2				
29 - 30						8	1	3				
28 - 29						2	3	4	1			
27 - 28					2	5	3	3	1			
26 - 27						4	4	2	3			
25 - 26					5	2	1	3	2			
24 - 25					3	1	1	5	2			
23 - 24					1	1		1	3			
22 - 23					5				8			
21 - 22					5	1			2			
20 - 21					3				5	1		
19 - 20				1	4				1	2		
18 - 19				2						2		
17 - 18				6						14		
16 - 17				8						3		
15 - 16				6						4		
14 - 15				3						1		
13 - 14				2						1	3	
12 - 13			5								7	
11 - 12			4								9	
10 - 11		3	7								5	
9 - 10		1	5								2	1
8 - 9	1	2	5								1	4
7 - 8	3	5										3
6 - 7	2	6	1									12
5 - 6	4	4										3
4 - 5	4	1										3
3 - 4	8	3										1
2 - 3	4	2										
1 - 2	1											
	27	27	27	28	28	28	28	28	28	28	27	27

The mean annual range of grass - covered ground surface temperatures is : 24,92° C.

November has the smallest range and August the largest.

The coefficient of variation at the grass - covered ground surface too has high values during the main winter season (Desember-February) with its maximum in January, while its smallest values appear in the warm season, from June to July, with their minimum in July.

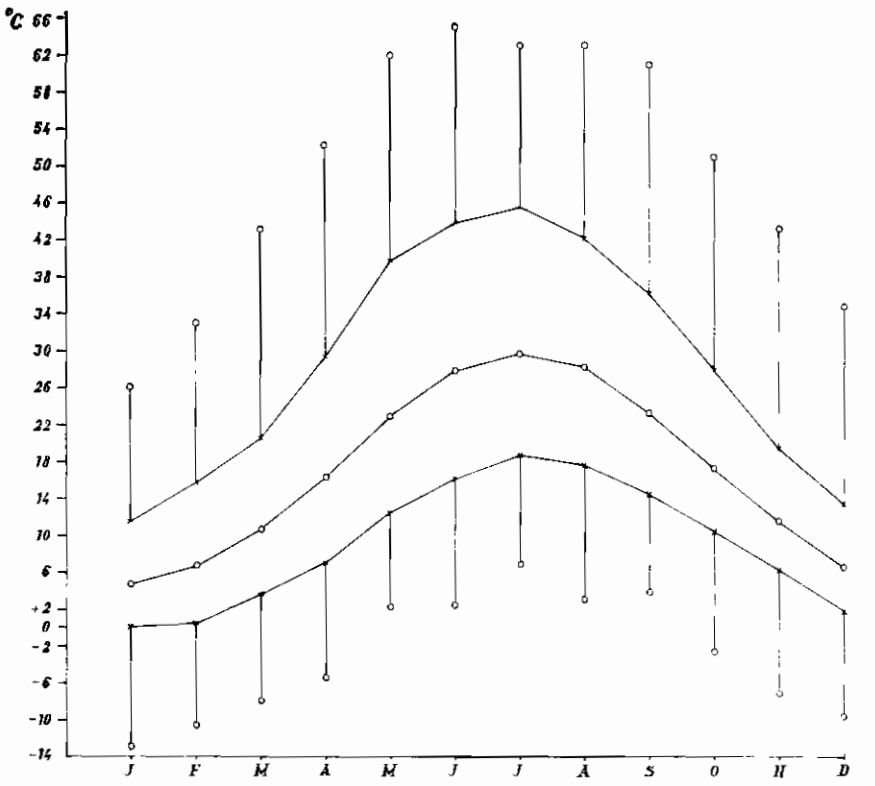
From the adjoined Table IV, containing frequencies of mean monthly values, we find that : as in the case of bare - soil surface, on grass - covered ground also the cold month of January holds the lowest grades of the thermometric scale as to the frequency of mean monthly values, the months of February and December come next in line; while the hot month of July holds the highest grades of this scale, outranking even the equally hot month of August, followed by the month of June.

c. Daily mean.

We have included monthly mean, and also mean and extreme maximum and minimum values of grass - covered ground - surface temperatures in the following Table V; The same are illustrated in G r a p h II.

TABLE V

	Maximum					*Minimum*		
	Abs		*Mean*	*Mean*	$\pm \sigma$	*Mean*	*Abs*	
J	26,1	1957	11,34	4,67	1,87	0,18	—12,8	1968
F	33,1	1957	15,72	6,53	2,31	0,39	— 10,5	1970
M	41,4	1957	20,43	10,29	1,54	3,53	—8,0	1968
A	52,2	1957	29,24	16,32	1,96	7,16	—5,6	1970
M	61,9	1956	37,60	22,85	2,33	12,21	2,2	1965
J	65,0	1970	41,70	27,99	2,44	16,09	2,4	1940
J	63,0	1970	43,46	29,59	2,57	18,49	6,8	1970
A	63,0	1957	42,11	28,25	3,30	17,70	3,0	1967
S	60,9	1962	36,09	23,24	2,35	14,55	3,8	1970
O	50,9	1956	27,70	17,21	1,53	10,40	—2,9	1958
N	41,0	1970	19,37	11,53	1,09	6,31	—7,2	1967
D	34,6	1970	13,25	6,52	1,48	1,80	—9,8	1967
			28,17	17,08	—	9.07		



GRAPH II

From the above Table V we find that the absolute range of temperature is : 77,8° C.

From Tables III and V we also find that, the coldest month of the year (January) has the smallest temperature values in all the columns of both Tables, for the period examined; while the hottest month of the year (July) has the highest values of grass - covered ground - surface temperature in almost every column of the same two Tables, except for the absolute maximum which belongs in June.

From Table V we also find that ground frosts (temperatures $<0°$ C) have been recorded on grass - covered ground from October till April, the earliest date of these ground frosts being : October 20, 10, 1967 and the batest April 10, 4, 1956, meaning that we have a frost - free period of 185 days on grass - covered ground.

TABLE VI

Frequency of daily minima on grass covered ground surface

	J	F	M	A	M	J	J	A	S	O	N	D			
—16,1 - (—18)															
—14,1 - (—16)															
—12,1 - (—14)	1												1		
—10,1 - (—12)	6	1											7		
—8,1 - (—10)	10	2										7	19		
—6,1 - (—8)	24	28	4								1	20	77		
—4,1 - (—6)	85	50	19	1							8	32	195		
—2,1 - (—4)	116	98	31	4						1	16	97	363		
—0 - (—2)	173	152	83	10						1	40	118	577	1.239	12.66%
0 - 2	185	170	138	34					1	16	81	161	786		
2,1 - 4	103	114	172	88	7			2	3	44	79	136	748		
4,1 - 6	73	105	179	155	23	1		1	3	72	115	126	853		
6,1 - 8	47	38	136	197	51	3	2	2	15	108	155	64	818		
8,1 - 10	13	2	64	187	120	8	2	11	47	127	120	30	731	3.936	40.23%
10.1 - 12		1	11	97	175	48	13	18	122	161	105	13	764		
12,1 - 14				33	216	127	30	47	160	170	53	1	837		
14,1 - 16				3	163	220	81	126	201	100	6		900		
16,1 - 18				1	59	180	184	214	164	33	1		836		
18,1 - 20					16	139	310	258	72	3			798	4.135	42.23%
20,1 - 22					2	68	163	138	21				392		
22,1 - 24						12	43	13	1				69		
24,1 - 26						3	2	5					10		
26,1 - 28															
28,1 - 30							1						1	472	4.82%
30,1 - 32							1						1	1	
	836	761	837	810	832	809	832	835	810	836	780	805		9.783	99.94%

From the adjoined T a b l e V I , containing frequencies of daily minima on grass - covered ground, we find that :

a) Temperatures<-10.0° C have been recorded in the two - months of January and February.

b) Temperatures<0° C have been recorded during the seven - month period from October to April. While the probability of ground - frost increases from October till January, and then it decreases untill April.

TABLE VII

Probability of ground - frost on grass - covered ground surface

	Days of observations	*Days with ground frost*	%
October	836	2	0.24
November	780	65	8.33
December	805	274	34.04
January	836	415	49.64
February	761	331	43.50
March	837	137	16.37
April	810	15	1.85

Conclusively out of 9783 days, on which minimum temperatures were taken by minimum thermometers :

—1239 days, that is a percentage of 12.66 %, had values<0.0° C

—3936 days, that is a percentage of 40,23 %, had daily minima between 0.0 and 10.0° C.

—4135 days, that is a percentage of 41,35 %, had daily minima between 10.1° and 20.0° C.

—472 days, that is a pereentage of 4,82 %, had daily minima between 20.1° and 30.0° C.

B. TEMPERATURES AT 10 CM ABOVE GRASS - COVERED GROUND.

Measurements of temperature at the level of 10 cm above grass - covered ground cover the period between the years 1954 - 1970.

In Table VIII we observe that, the coldest month at 10 cm above grass - covered ground is January, and August the warmest, while the mean annual range is 22.29° C. The frost season, that is temperatures <0° C, is wider here, covering eight months (September - April). Absolute minima <-10.0° C are recorded in the December to February three - months.

TABLE VIII

Monthly mean and extreme values of air temperature at 10 cm above grass - covered ground

(period : 1954 - 1970)

	Mean	*Mean Minimum*	*Absol. Minimum*
J	4.23	—2.31	—13.8
F	5.95	—0.40	—12.5
M	8.98	1.64	—9.5
A	14.49	4.16	—5.4
M	20.22	8.89	0.0
J	24.32	12.32	2.6
J	26.40	14.99	2.2
A	26.52	14.83	3.6
S	21.41	11.37	—0.3
O	15.78	7.19	—4.5
N	10.91	4.12	—8.5
D	6.23	—0.28	—10.4

From Table IX we find that the percentage of daily minima $<0^{o}$ C, is 20,0 % above grass - covered ground.

Conclusions

From the study of grass - covered ground temperatures, we draw the following conclusions :

a) The smallest mean and extreme temperature values of grass - covered ground - surface are recorded mostly during the coldest month of the year (January : mean monthly air temperature $+5.86^{o}$ C); while almost all the highest values are recorded during the warmest month of the year (July : mean monthly air temperature $+26.47^{o}$ C).

It should be noted that the authors came to a similar conclusion, in the study of bare - soil surface temperatures (LIVADAS - GOUTSIDOU 1972 [1]).

b) At the level of 10 cm above grass - covered ground (grass - top), the month of January has the smallest temperatures :

Absol. minimum	-13.80^{o} C
Mean minimum	-2.31^{o} C
Mean	4.23^{o} C

On the other hand July only has the absolute minimum of the warm season, while for the minimum June has 14.99^{o} C against 14.83^{o} of July,

TABLE IX

Frequency of temperature minima at 10 cm above grass - covered ground.

	J	F	M	A	M	J	J	A	S	O	N	D			
—16,1 - (—18)															
—14,1 - (—16)	1												1		
—12,1 - (—14)	11	2											13		
—10,1 - (—12)	16	7										2	25	39	
—8,1 - (—10)	35	9	2								2	11	59		
—6,1 - (—8)	58	41	10								5	38	152		
—4,1 - (—6)	60	47	14	2						2	11	55	191		
—2,1 - (—4)	86	80	43	12						6	29	61	317		
—0 - (—2)	101	105	78	30					1	11	51	97	474	1193	
														1.232	19.99% 20.0%
0 - 2	67	93	129	99	10				4	24	68	96	590		
2,1 - 4	41	56	95	105	23	6	3		6	72	64	78	549		
4,1 - 6	33	34	93	111	80	8	3		20	91	105	52	630		
6,1 - 8	13	5	48	93	96	27	13	9	54	87	67	19	531		
8,1 - 10	5	1	13	40	106	51	19	20	80	102	63	11	511	2.811	45.38% 45.4%
10,1 - 12			2	15	109	124	47	42	115	71	37	5	567		
12,1 - 14				1	65	128	106	108	103	46	8		565		
14,1 - 16				1	27	98	142	176	89	12			545		
16,1 - 18					6	49	117	118	25	1			316		
18,1 - 20					1	14	64	40	11				130	2.123	34.28% 34.3%
20,1 - 22						1	11	11					23		
22,1 - 24							1						1		
24,1 - 26						2		1					3	27	00.43% 00.4%
															100.18
															100%
	527	480	527	509	523	508	526	525	508	525	510	525	6.193	6.193	

and for the monthly mean August has 26.52° C against 26.40° C of July.

TABLE X

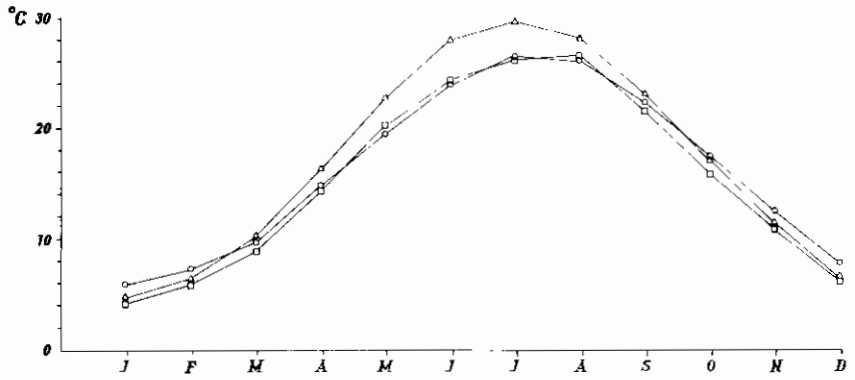
	January	*July*
Absol. Maximum	26.10 (1957)	63.0* (1970)
Mean »	11.34	43.46
Warmest month	8.96 (1955)	36.45 (1958)
Monthly mean	4.67±1.87	29.59±2.57
Goldest month	1.61 (1964)	24.82 (1934)
Mean Minimum	0.18	18.49
Absol. »	—12.80 (1968)	6.80 (1970)
Annual temp. range	24.92	
Absol. » »	77.8*	

*Absolute maximum : 65.0° C June 1970.

c) Comparing values of temperature at the following levels : grass - covered ground surface, 10 cm above grass - covered ground, and air temperature at 1,5 m (inside the Stevenson screen), we observe that :

TABLE XI

	(1) *Air Temp.*	*(2)* *Grass-covered ground*	*(3)* *10cm above grass-covered ground*	Δ 1-2	Δ 1-3	Δ 2-3
J	5.86	4.67	4.23	1.09	1.63	0.44
F	7.30	6.53	5.95	0.77	1.35	0.58
M	9.92	10.29	8.98	—0.37	0.94	1.31
A	14.69	16.32	14.49	—1.53	0.20	1.83
M	19.58	22.85	20.22	—3.27	—0.64	2.63
J	23.86	27.99	24.32	—4.13	—0.46	3.67
J	26.47	29.59	26.40	—3.12	0.07	3.19
A	26.28	28.25	26.52	—1.97	—0.24	1.73
S	22.32	23.24	21.41	—0.92	0.91	1.83
O	17.31	17.21	15.78	0.10	1.43	1.43
N	12.49	11.53	10.91	0.96	1.58	0.62
D	7.95	6.52	6.23	1.43	1.72	0.29
Y	16.17	17.08	15.45	—0.91	0.72	1.63



GRAPH III

I. There exists, as an average throughout the whole year, a permanent temperature inversion in the layer between grass - covered ground - surface and the level at 10 cm above it. The magnitude of this inversion (see columns Δ 2 - 3, Table XI) is extremely small in December and remains $<1^{o}$ C during the cold season (November - February); then it becomes $>2^{o}$ C during the warm season (May - July), with its maximum in June.

II. There is, as an average during the October - February period, a permanent temperature inversion in the layer between grass - covered ground surface and the height of 1,5 m above it (air temperature inside the met. screen).

III. The period of inversion increases from September to April, if we compare the levels of 10 cm above grass - covered ground and 1,5 m above it.

The above three conclusions, prove that in Thessaloniki there is a strong temperature inversion at the lowest almosperic layer. This is due to the strong nocturnal radiation of this are.

The authors have come to similar conclusions (Livadas - Goutsidou, 1972 [1]), studying temperatures of bare - soil surface and above it in the same area (Thessaloniki - Greece) for a period including the one examined herein.

By combining the data of the present and previous work of ours, we can examine the frost - free and frost - periods in the lowest, next-to the-ground, layer of the atmosphere.

TABLE XII

	Frost free period (days)						*Frost period (days)*					
	Mean	± σ	*Maximum*		*Minimum*		*Mean*	± σ	*Maximum*		*Minimum*	
Air temperature (met. screen)	309.67	28.67	361	1935/36	250	1931	53.63	31.51	104	1955 - 56	1	1951
Bare soil. surf.	250.21	18.98	298	1959	212	1956	114.24	19.16	149	1948 - 49	86	1933 - 34
Grass - covered ground surf.	256.23	25.60	308	1934	209	1967	107.73	32.75	164	1967 - 68	34	1930 - 31
10 cm above bare soil surf.	229.82	18.90	265	1964	196	1969	136.18	17.81	166	1952 - 53	102	1963 - 64
10 cm above grass - covered ground	210.06	24.71	250	1968	153	1954	154.19	22.03	208	1954 - 55	117	1957 - 58

TABLE XIIa

	First frost	*Latest frost*	*Absol maximum (possible duration)*	
Air temperature (met. screen)	25 - 11 - 1948	28 - 3 - 1931	124	Days
Bare soil surf.	4 - 11 - 1969	12 - 4 - 1969	159	»
Grass - covered ground surf.	20 - 10 - 1967	10 - 4 - 1956	182	»
10 cm above bare soil surf.	3 - 11 - 1969	25 - 4 - 1967	173	»
10 cm above grass - covered graund	26 - 9 - 1954	25 - 4 - 1967	216	»

From Table XII and XIIa we come to same very interesting conclusions :

a. The frost - free period is considerably reduced between ground surface and 10 cm above it, for bare ground as for grass - covered as well, while it increases a great deal at the level of 1,5 m.

b. On the other hand, the frost - period increases from the ground - surface to the level of 10 cm above it (again for bare grouud and grass - covered as well), while the level of 1,5 m has a much shorster frost - period.

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ΠΕΡΙΛΗΨΙΣ

Η ΘΕΡΜΟΚΡΑΣΙΑ ΤΗΣ ΕΠΙΦΑΝΕΙΑΣ ΤΟΥ ΕΔΑΦΟΥΣ ΜΕΡΟΣ ΙΙ. ΕΠΙΦΑΝΕΙΑ ΧΛΟΕΡΟΥ ΕΔΑΦΟΥΣ

Ὑπὸ

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Μελετᾶται ἡ θερμοκρασία τῆς ἐπιφανείας τοῦ χλοεροῦ ἐδάφους, ὡς καὶ εἰς ὕψος 10 ἑκ. ὑπεράνω αὐτοῦ, εἰς τὴν πόλιν τῆς Θεσσαλονίκης, διὰ τὴν χρονικὴν περίοδον 1.1.1931 - 31.10.1940 καὶ 1.1.1954 - 31.12.1970. Δίδονται δὲ τόσον αἱ μέσαι κανονικαὶ τιμαὶ τῆς θερμοκρασίας (ἐτήσιαι, μηνιαῖαι, ἡμερήσιαι), ὅσον καὶ αἱ ἄκραι τιμαὶ αἱ ὁποῖαι ἐσημειώθησαν κατὰ τὴν ὑπὸ μελέτην περίοδον.

Ἐπίσης προκύπτει ὅτι, ὑφίστανται ἀναστροφαὶ τῆς θερμοκρασίας, τόσον μεταξὺ ἐπιφανείας χλοεροῦ ἐδάφους - θερμοκρασίας ἀέρος (μετεωρολογικοῦ κλωβοῦ), ὅσον καὶ μεταξὺ ἐπιφανείας χλοεροῦ ἐδάφους καὶ 10 ἑκ. ὑπεράνω αὐτοῦ, κατὰ τὴν ψυχρὰν περίοδον.