Hrvatski meteorološki časopis, 30, pp. 27-31, 1995.

UDK: 551.525.4
Izvorni znanstveni rad

SOME CHARACTERISTICS OF SOIL TEMPERATURE AND HEAT CONDUCTIVITY IN THE GROUND

Neke značajke temperature tla i provodljivosti topline u zemlji

DR. LIRI GJOKA (MUCAJ)

Hydrometeorological Institute
Durresi Street No-219
Tirana, Albanija

Primljeno: 15. kolovoza 1995, u konačnom obliku 20. listopada 1995.

Abstract — In this study, the main characteristics of soil temperature have been evidenced at some representative stations in Albania. By means of equation of regression, the correlation coefficients between mean air temperatures and mean soil temperatures have been calculated. The coefficients of the heat conductivity through soil for depths from 5 to 20 cm and from 5 to 80 cm have been calculated and explained as well.

Key words: soil temperature, coefficient of soil temperature conductivity, Albania.

Sažetak — U radu su analizirane osnovne značajke temperature tla na nekoliko reprezentativnih postaja u Albaniji. Pomoću jednadžbe regresije izračunati su koeficijenti korelacije između srednje temperature zraka i srednje temperature tla. Uz to su izračunati i komentirani koeficijenti provodljivosti topline u zemlji za dubine 5 do 20 cm i 5 do 80 cm.

Ključne riječi: temperatura tla, koeficijent provodljivosti topline u tlu, Albanija.

1. INTRODUCTION

Nowadays, studies on soil temperatures, such as the influence of its content and kind on its daily and annual course, the speed of penetration of the soil temperature wave into depth, are mainly experimental.

According to different works, regionalisation is of particular importance, especially climatic regionalisation.

To prepare this study, 25-year time series have been used. The time series have been controlled and homogenised by known statistical methods. The evaluation of data accuracy, the correlationship between soil temperatures at different stations and depths as well as the determination of the necessary length of the time series, give us the opportunity to determine the main peculiarities of the soil temperature regime.

2. SOME CHARACTERISTICS OF SOIL TEMPERATURE

Energy radiated by the sun is the main source of soil warming. A part of this energy is absorbed by the soil and then, by thermal conductivity, transmitted toward its lower layers. This paper deals with the soil temperature regime, which, in natural conditions is of particular importance in agriculture.

The soil temperature depends on soil composition, humidity, structure and the state of its surface (e.g. the presence or absence of snow cover). The complex action of these factors may result in a considerable difference in soil temperature even in places not far apart.

In order to present some of the main peculiarities of the soil temperature regime and distribution, the average values and amplitudes of soil

Table 1. The average soil temperature and its annual amplitude on the surface and at different depths at Vlora station.

Tablica 1. Srednja temperatura tla i njena godišnja amplituda na površini i na različitim dubinama na postaji Vlora.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	year	ampl
surface	7.8	9.2	11.8	16.5	23.0	28.8	31.1	29.8	24.4	18.0	18.8	9.3	18.6	23.3
at 5 cm	7.7	9.1	11.7	15.9	21.5	26.5	29.0	28.3	23.8	18.0	12.8	9.2	17.8	21.3
at 10 cm	7.8	9.1	11.5	15.7	20.9	24.8	28.2	27.7	22.9	18.3	13.1	9.4	17.4	20.4
at 15 cm	8.1	9.2	11.3	15.3	20.1	24.8	27.5	26.4	23.6	18.5	13.5	9.6	17.3	19.4
at 20 cm	8.3	9.1	11.3	15.1	19.7	24.3	26.9	26.7	24.3	18.5	13.7	9.9	17.3	18.6
at 40 cm	10.0	10.0	11.5	14.3	17.6	21.1	23.8	24.7	22.6	19.1	15.4	11.9	16.8	14.7
at 80 cm	11.3	11.2	12.0	14.1	16.7	18.9	22.0	23.4	22.5	20.0	17.0	14.1	17.0	12.1

temperature, on the surface and at different depths, for some representative stations are shown in Table 1.

From this table, it is possible to conclude that, apart from soil kind:

- The annual average temperature amplitude decreases with depth. This amplitude decreases about 8-9°C between 5 and 80 cm in depth.
- Down to 20 cm, the maximum has been recorded in July, but going further down, through the deeper layers, this maximum appears in August. The minimum temperature follows the same rule. Down to 20 cm, the minimum value appears in January, while in the deeper layers it has been observed in February.
- During the warm period of the year (mid March- mid September) the temperature with depth decreases by about 1-5°C. On the contrary, during the cold period, a temperature increase of 1-3°C can be observed.

In spite of the importance of soil temperature, limited observations of this parameter exist, especially in the mountainous zones. For this reason, the temperature regime for these zones can be assessed through air temperature, making use of a simple equation of linear regression.

$$y = a\,x + b. \tag{1}$$

where x=air temperature
y=soil temperature

For this purpose, the relationship between the average air temperature at 2 m height, and the soil temperature at 10, 20 and 40 cm depths have been determined.

Table 2 shows the correlation coefficients at 10, 20 and 40 cm depths for the spring, summer and autumn seasons. By analysing this table, two main conclusions may be drawn:

2.1. The correlation coefficient in summer (July) is greater than in September and April

This phenomenon could be explained by the fact that during summer the active layer of soil having high temperatures, produces an increase in air temperature. Penetrating to the depth, its impact becomes weaker, because of its low thermal conductivity and the lack of humidity. April and September, on the contrary, are rainy months, so that humidity is increased and conductivity becomes greater. For this reason, there is a stable relationship during spring and autumn.

2.2. The correlation coefficient decreases with depth

Almost all correlation coefficients given in Table 2 are significant at 95% level (higher then the critic limit 0.3494) with exception of those which belong to the second decades of April and July (0.3414, 0.2306) at 40 cm depth.

Figure 1 proves the relationship between air and soil temperatures. Their annual course is similar, particularly the soil temperature down to 20 cm in depth. The extreme values belong to January and

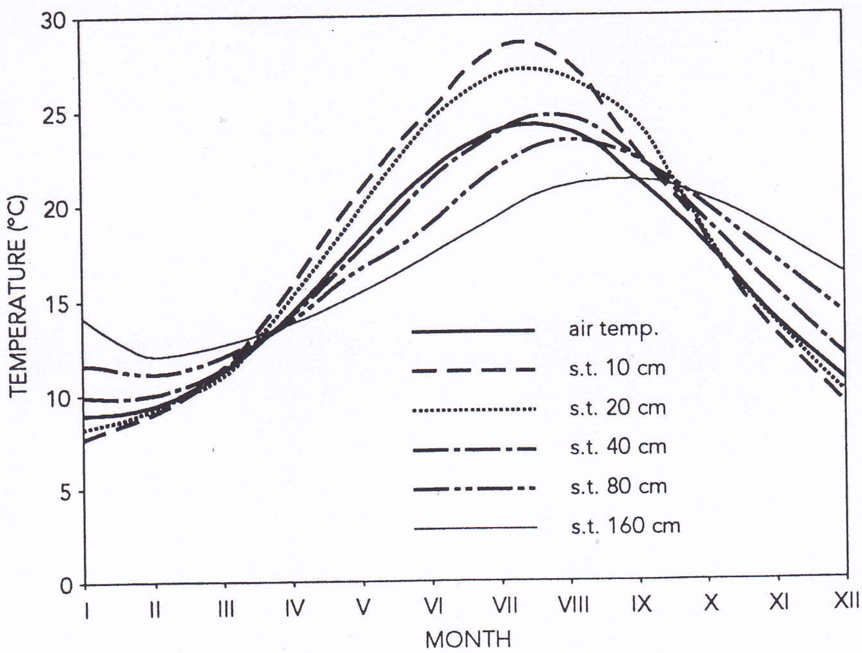

Figure 1. Annual courses of air and soil temperatures.

Slika 1. Godišnji hodovi temperature zraka i tla na različitim dubinama.

July. The minimum and maximum values, as well as the annual amplitude, change with depth. The extremes move toward February and August, and at the same time the amplitude gets lower.

The inflection points (mid September, mid March) appear in the case when the warm flux changes direction. This is accompanied by an equalisation of temperature at all mentioned depths.

Thus, the soil temperature regime, obeys the following rules:

- A gradual increase in soil temperature with depth during the cold period and its gradual decrease during the warm period.
- A movement of minimum temperature from January to February and of the maximum temperature from July to August.
- A change in the direction of the warm flux in mid September and March.

3. HEAT CONDUCTIVITY THROUGH SOIL

It is important to know about the distribution of heat with depth, which depends on the thermal quality of the soil, such as soil thermal permeability, soil thermal capacity, as well as heat conductivity through soil.

Heat conductivity depends on the physical qualities of the soil, such as its the mechanical composition and regime of humidity. High-density and wet soils have a high conductivity, while, dry soils have a low conductivity.

Different kinds of soils, such as grey brown pasture (GBP) soils, brown pasture (BP), pasture alluvial (PA) and torphic soils located in different regions have been taken into consideration (Tab. 3).

A great temperature amplitude on the surface and in the 15 - 20 cm layer has been observed. By penetrating to the depths, the amplitude decrease, while the extreme temperatures retard in time.

It is known (Nerpin and Cadnovski, 1967) that the change of amplitude of a temperature wave in relation to depth obeys the exponential law:

$$a_h = a\, exp[-h\, (\pi/KT)^{1/2}] \qquad (2)$$

and $t = h\, (\pi/KT)^{1/2}$

or $a_h/a = exp[-h\, (\pi/KT)^{1/2}]$

$log\, a_h - log\, a = -h(\pi/KT\, log\, e)^{1/2}$

So that,

$$K = \pi h^2/T(ln\, a/a_h)^2 \qquad (3)$$

$T = 1\ year$

Table 2. The correlation coefficients (*r*) between air temperature and soil temperature at 10, 20, 40, cm depths as well as the coefficient values *a* and *b* at Vlora station.

Tablica 2. Koeficijent korelacije (*r*) između temperature zraka i temperature tla na 10, 20 i 40 m dubine, te parametri *a* i *b* za postaju Vlora.

Month	April			July			September		
Decade	I	II	III	I	II	III	I	II	III
10 cm									
a	0.69	0.77	0.82	0.41	0.41	0.66	0.57	0.53	0.70
b	5.24	4.78	4.52	12.09	12.74	5.40	8.22	7.81	4.86
r	0.76	0.84	0.72	0.75	0.66	0.79	0.82	0.82	0.83
20 cm									
a	0.53	0.58	0.69	0.40	0.26	0.64	0.70	0.66	0.79
b	6.77	6.97	5.74	12.76	17.49	6.70	5.96	6.10	3.07
r	0.64	0.82	0.72	0.67	0.41	0.76	0.77	0.82	0.82
40 cm									
a	1.34	0.70	1.12	0.34	0.19	0.47	0.76	0.59	0.85
b	4.61	4.05	2.16	15.67	19.75	12.61	4.47	8.25	2.00
r	0.59	0.34	0.54	0.45	0.24	0.52	0.64	0.54	0.56

Table 3. The value of the conductivity coefficient (*K*)

Tablica 3. Vrijednosti koeficijenta provodljivosti *K*.

Stations	Soil	Period 5 to 20 cm.	ln a/a_h 5 to 80 cm	ln a/a_h 5 to 20 cm	*K* 5 to 80 cm	*K*
Vlora	PA	1953-1982	0.13554	0.55727	3.84	5.69
Shkodra	PA	1961-1982	0.13783	0.43375	3.72	9.38
Kuçova	PA	1958-1982	0.12638	0.40545	4.42	10.74
Gjirokastra	GBP	1960-1982	0.09937	0.40546	7.15	10.74
Peshkopi	PB	1961-1982	0.07663	0.41576	12.03	10.21
Sheqeras	BP	1960-1982	0.13547	0.53835	3.85	6.09
Xarra	MGB	1963-1982	0.06544		16.50	
Kamza	GBP	1959-1982	0.12107	0.44573	4.82	8.88
Kukës	BP	1962-1982	0.12543	0.43642	4.49	9.27

where: PA - pasture alluvial; GBP - grey brown pasture; PB - pasture brown; BP - brown pasture; MGB - mountainous grey brown

a, a_h = the temperature amplitudes in two different layers

t = time lag
K = coefficient of conductivity ($=\lambda/\sigma$ c)
λ = heat conductivity
σ = soil density
c = specific capacity

(The K value expresses the heat quantity passing through a surface of 1 m^2 during a year)

Using the Equation 2 the coefficients of heat conductivity through soil are computed for depth intervals of 5 to 20 cm and 5 to 80 cm. The results are represented in Table 3. From this table we can see that the K values belonging to 5-20 cm depths are smaller than those of 5 -80 cm.

This fact can be explained by the higher porosity and air content of the surface layer and those layers next to the surface and may be by the presence of a low humidity content in the surface layers, due to evaporation and the penetration of water toward the deep layers (with the exception of Peshkopia station). The smaller coefficients of conductivity belong to Sheqeras and Vlora, 6.09 and 5.69 respectively and the greater ones to Gjirokastra and Kuçova, 10.74.

These different values correspond to the different kinds of soil and their physical quality. Sheqeras has trophic soils, while Vlora has subclayer soils with smaller thermal conductivity (Veshi and Spaho, 1974). The soil in Gjirokastra and Kuçova is composed of grey brown pasture (GBP) and pasture alluvial (PA) respectively, with great thermal conductivity.

4. CONCLUSIONS

1-The time when minimum temperature is observed moving from January to February and that of the maximum temperature from July to August.

2-The coefficient of correlation between the air and soil temperature decreases during the summer and increases during September and April. At the same time, this coefficient decreases with depth.

3-Lower values of conductivity coefficients have been observed in the layers between 5 and 20 cm than in those between 5 and 80 cm.

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