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ADANA İÇİN TOPRAK SICAKLIĞININ HESAPLANMASI*

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ÖZET: *Bu çalışmada, Adana'daki toprak yüzey sıcaklığı için bir analitik model sunulmuştur. Bu model, toprak yüzey sıcaklığı için enerji denge denklemine dayanmaktadır. Enerji denge denklemi, güneş ışınlarının periyodik değişiminin ve günlük sıcaklık değerlerinin yanında buharlaşmadan kaynaklanan gizli ısı akım şiddetini de içerir. Bütün hesaplamalar günlük değişimler için yapılmıştır. Sunulan modele göre çeşitli parametrelerin toprak sıcaklığı üzerine etkileri incelenmiştir.*

Anahtar Kelimeler: *Toprak sıcaklığı, Isı pompası, Isı akısı, Toprak absorpsiyonu, Toprakta buharlaşma oranı*

DETERMINATION OF GROUND TEMPERATURE IN ADANA*

ABSTRACT: *In this study, an analytical model was presented for the ground surface temperature in Adana. The model was based on the energy balance equation at the ground temperature. The energy balance equation includes the periodic variation of solar radiation and atmospheric temperature and also the latent heat flux due to evaporation. The calculations were performed for daily variations. Using the model presented, the effect of the various parameters was studied.*

Keywords : *Ground temperature, Heat pump, Heat flux, Ground absorptivity, Groundevaporation ratio*

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1. INTRODUCTION

The use of direct or indirect earth-coupling techniques for buildings requires knowledge of the ground temperature distribution. It is still commonly believed that ground temperature distribution at any depth below earth's surface remains unchanged throughout the year. (Penrod E. et al., 1960, Kusuda T., 1975) Ground temperature is also an important parameter for the passive heating and cooling of buildings. (Labs K.,1990)

Determination of ground temperature at different depths are very important for ground source heat pump applications. Therefore, many researches have been carried out studies for the determination of ground temperatures using analytical, numerical and experimental methods.

A simple analytical model was developed to predict annual variation of the ground temperature at the soil surface and at various depths by using long time measurements of the ground temperature values (Mihalakakou et al., 1992). A mathematical model based on heat conduction equations and the energy balance at the ground surface to predict the variation of the ground surface temperature for bare and short-grass covered soil was developed by Mihalakakou et al. (1997). Mathematical models based on the energy balance equation at the ground surface were developed by Salah El- Din (1999) to predict the hourly and daily variations of the ground temperature and heat flux into the ground with depth. Two estimation methods for modeling and estimating the daily and annual variation of soil surface temperature were presented by Mihalakakou (2002).

In this study we present analytically obtained results for the ground temperature in Adana. The energy balance equation includes the periodic variation of solar radiation and atmospheric temperature beside the latent heat flux due to evaporation. All the calculations are performed for daily variations.

2. MATERIAL AND METHOD

2.1.Modeling of ground temperature

The undisturbed ground temperature can be modeled accurately by the following one-dimensional, unsteady heat conduction equation:

$$\frac{\partial^2 T(x,t)}{\partial x^2} = \frac{1}{a}\frac{\partial T(x,t)}{\partial t} \qquad (1)$$

where *a* is the ground thermal diffusivity and *x* is the depth below ground surface. Figure 1 shows the such a model.

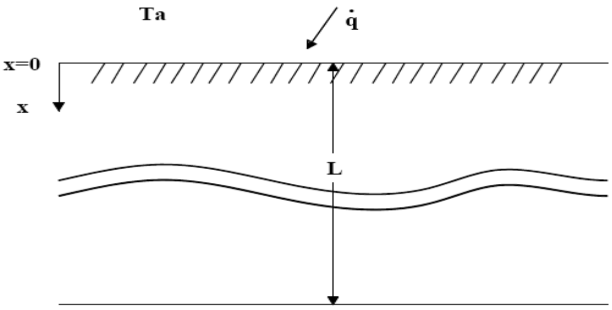

Figure 1. One layer soil

The following energy balance equation at the ground surface was used as a boundary condition equation at the ground surface: The energy balance at the ground surface can be expressed as follows:

$$x = 0 \quad ; \quad -k\left(\frac{\partial T}{\partial t}\right)_s = h(T_a - T_s) + \alpha_0 \dot{q} - \varepsilon_e \Delta R - \dot{q}_v \tag{2}$$

where k is the thermal conductivity of the soil.

For from the ground surface there is no heat flux:

$$x = \infty \quad ; \quad \frac{\partial \mathrm{T}}{\partial \mathrm{x}} = 0 \tag{3}$$

The convective heat exchanged between the air and ground surface can be calculated from the following expression (Kreith and Bohn, 1993):

$$\dot{q} = h(T_a - T_s) \tag{4}$$

where T_s is the ground temperature, T_a the ambient temperature above the ground surface and h is the convective heat transfer coefficient at the soil surface and it can be calculated from the equation (Duffie and Beckman, 1991):

$$h = 2.8 + 3u \tag{5}$$

where u is the wind velocity above the ground surface.

The long-wave radiation for horizontal surfaces can be considered nearly constant. Its value can be estimated using the expression (Bliss, 1959):

$$LR = \varepsilon_e \Delta R \tag{6}$$

where ε_e is the emittance of the ground surface and ΔR is a term which depends on the relative humidity of the ground and the air above the ground surface, on the effective sky temperature and on the soil radiative properties. ΔR can be calculated from various empirical correlations (Clark and Allen, 1978; Geiger, 1961).

The latent heat flux from the ground surface due to evaporation can be calculated from the equation (Penman, 1963):

$$q_v=0.0168\, f\, h\, [(B_p\, T_s + B_p) - r_a\, (A_p\, T_a + B_p)] \tag{7}$$

where A_p =103 Pa K^{-1}, B_p = 609 Pa *and* r_a is the relative humidity of the air above the ground surface and f is a fraction which depends mainly on the ground cover and on the humidity level of the ground.

The fraction f can be estimated as follows (Penman, 1963):

- For bare soils the fraction f increases with the soil humidity

f = 1 for saturated soils,
f = 0.6-0.8 for moist soils,
f = 0.4-0.5 for dry soils and
f = 0.1-0.2 for arid soils.

- For grass covered soils the fraction f can be calculated by multiplying the previous values of the fraction f for bare soils with the coefficient 0.70.

Below values are given by ASHRAE (2003),

$\varepsilon_e = 1$, $\Delta R = 63$

From Eq. (2) and boundary condition follows:

$$-k\left(\frac{\partial T}{\partial x}\right) = h(T_a - T_s) + \alpha_0 \dot{q} - \varepsilon_e \Delta R - C_v A_p h T_s - C_v h B_p + C_v A_p h T_a + C_v B_p h \varphi \tag{8}$$

$$C_v = 0.0168.f \tag{9}$$

2.2.Analytical calculation method

Salah El-Din (1999) has solved the Eq. (1), with the boundary condition given in equations (2) and (3). Temperature is found dependent of time and x axis.

$$T = T_{sm} + \Delta T_s \exp(-x^*) \sin\left[2\pi\left(t^* - x^* + \varphi\right)\right] \tag{10}$$

Ground surface temperature is written as

$$T_s = T_{sm} + \Delta T_s \sin(2\pi t^* + \varphi_s) \tag{11}$$

Where

$$t^* = \frac{t}{t_0} \tag{12}$$

$t_o = 365$ *day*

$$x^* = \frac{x}{\left(\frac{at_o}{\pi}\right)^{1/2}} \tag{13}$$

The solar equivalent temperature can be expressed as a sine-wave, i.e.

$$T_{se} = T_{sem} + \Delta T_{se} \sin\left[2\pi(t^* + \varphi_{se})\right] \tag{14}$$

For annual calculation, T_{se} value is determined. From there T_{sem}, ΔT_{se}, and φ_{se} values are assigned to using different curve fitting methods. In this study Rosenbrock method is choosen . This method is the most suitable one among different applied methods such as Quasi-Newton, Simplex, Simplex and Quasi-Newton, Hooke-Jeeves pattern moves, Hooke-Jeeves and Quasi-Newton. (Hill and Lewicki, 2007)

T_{sm}, ΔT_s and φ_s values are calculated fom below equations,

$$T_{sm}=T_{sem} \tag{15}$$

$$\Delta T_s = \Delta T_{se}\left[(1+\mu)^2 + \pi 2\right]^{-1/2} \tag{16}$$

$$\varphi_s = \tan^{-1}\left[\frac{(1+\mu)^2 \tan\varphi_{se} - \mu}{(1+\mu) + \mu \tan\varphi_{se}}\right] \tag{17}$$

μ and α values are found from below equations:

$$\mu = \frac{\alpha k}{h_c} \tag{18}$$

$$\alpha = \left(\frac{\pi}{a t_0} \right)^{1/2} \qquad (19)$$

For analytical method annual mean h_c values is required.

3. RESULT AND DISCUSSION

3.1.Effect of the evaporation fraction of ground *f*, on the solar equivalent temperature

Annually mean values of wind speed must be used for analytical calculation. Therefore, yearly variation of T_{se} values that calculated with mean annual wind speed, $\alpha_0 = 0.9$, $\varepsilon_e = 1$ and $\Delta R = 63$ values are given in figure 2.

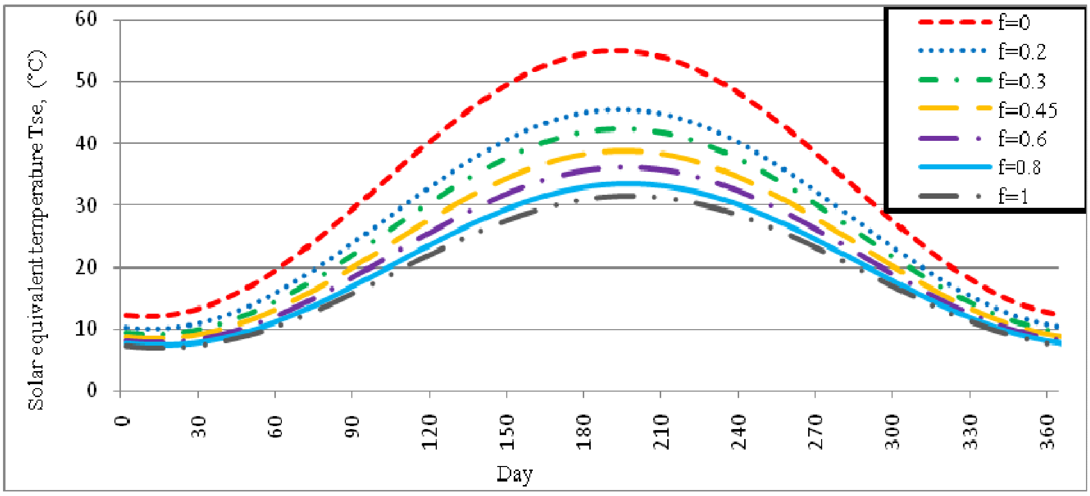

Figure 2. Effect of the evaporation fraction of soil on the solar equivalent temperature T_{se}, for the year 2000

This figure shows the daily variation of the solar equivalent temperature with different values of the evaporation fraction of soil. From this figure, it can be seen that the increase in evaporation fraction of soil decreases the solar equivalent temperature. This is due to the increase in the evaporation rate.

3.2.Effect of the ground types on the ground surface temperature

Figure 3 shows the daily variation of the ground surface temperature with different soil types (granite, moist ground, dry ground) and f=0.3. From this figure, it can be seen that an insignificant changing in the ground surface temperature occurs when the ground types change. From the comparison of figures 3 and 4, it can be seen that when evaporation fraction of the ground increases, ground surface temperature decreases.

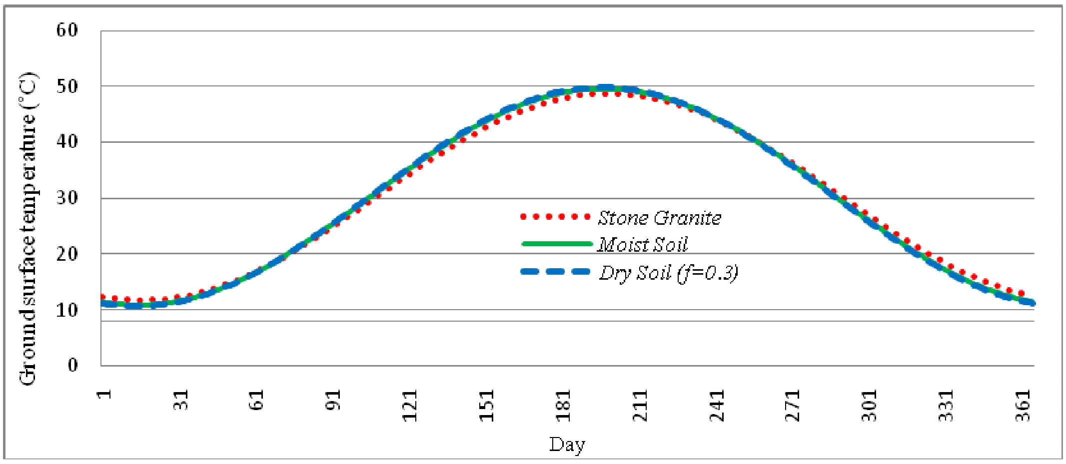

Figure 3. Effect of the soil types on the daily variation of the ground temperature T_s, f=0.3, for the year 2000

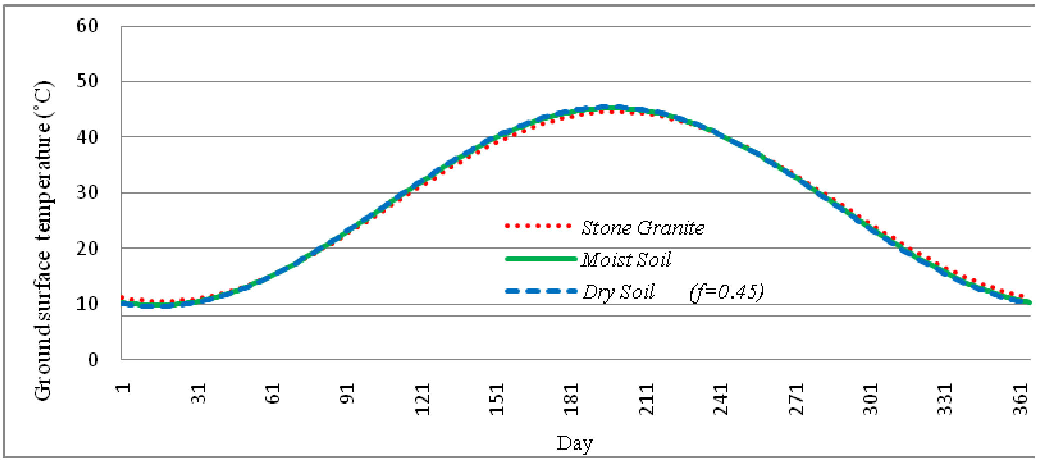

Figure 4. Effect of the soil types on the daily variation of the ground surface temperature T_s, f=0.45, for the year 2000

3.3.Effect of the ground absorptivity on the ground surface temperature

The daily variations of the ground surface temperatures are demonstrated in figures 5 and 6 with different values of ground absorptivity and evaporation fraction of the ground. From the figures it can be seen that the increase of the ground absorptivity increases the ground surface temperature. But comparison of figures 5 and 6 show that when evaporation fraction of the ground increases, ground surface temperature decreases. From the figures 5 and 6 it can be observed that an increase in the ground surface absorptivity leads to higher values of the ground surface temperature.

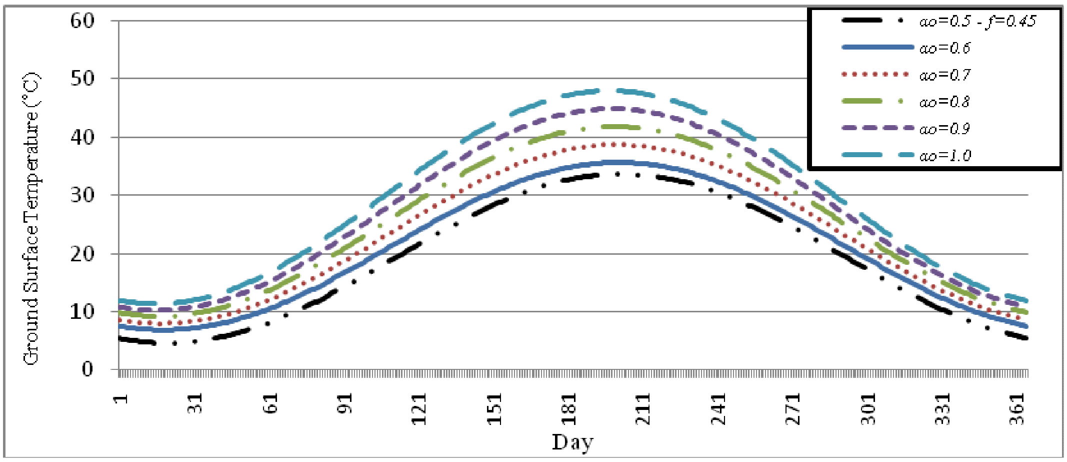

Figure 5. Effect of the ground absorptivity on the ground surface temperature T_s, f=0.45 for the year 2000

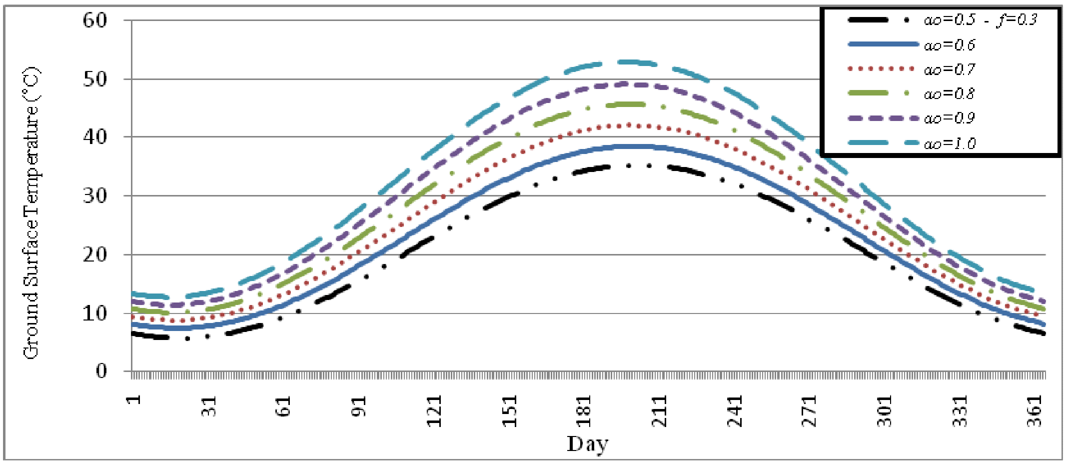

Figure 6. Effect of the ground absorptivity on the ground surface temperature T_s, f=0.3 for the year 2000

4. CONCLUSION

In this study, an analytical model based on the energy balance equation at the ground surface was used to predict the daily variations of the ground surface temperature for the city of Adana.

A parametric study was carried out to evaluate the influence of the various parameters on the ground surface temperature. It can be concluded that:

1. The ground surface temperatures decrease with increasing the evaporation fraction of the ground and the wind speed.
2. An insignificant changing in ground surface temperature occurs when the ground types change (Granite, moist soil, dry soil).

3. An insignificant changing in ground surface temperatures occur when the physical properties of the ground changes.

Nomenclature

a : Thermal diffusivity
A_p : Linearization parameter in Eq. (7)
B_p : Linearization parameter in Eq. (7)
C_v : A parameter defined in Eq. (9)
f : Evaporation fraction of soil
h : Heat transfer coefficient
k : Thermal conductivity
q : Heat flux
r_a : Relative humidity
t : Time
t_o : Day of year

T_m : Mean temperature
T_a : Ambient temperature
T_s : Ground temperature
T_{sm} : Mean ground temperature
T_{se} : Solar equivalent temperature
T_{sem}: Mean solar equivalent temperature
u : Wind speed
x : Depth of soil
ε_e : Long-wave emissivity of the surface
ΔR : Long-wave radiation,
α_0 : Surface absorptivity of solar radiaton
μ : A parameter defined in Eq. (18)

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