ANALYSIS OF HEAT FLUX AT EARTH SURFACE IN TURKEY

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ABSTRACT

Thermal structure of the lower atmosphere is connected with the heat flux near the earth's surface. It is known that the thermals play an important role in the gliding activities. In this study, the heat budget components were calculated for different geographical regions by using the climatological data so as to establish the thermal potential map of Turkey. Another aim of this study is to investigate the solar energy potential of Turkey. The variables used for this purpose are latitude, day of year, soil wetness, cloud cover, height of cloud base, daily average of air temperature, relative humidity, surface albedo, surface wind speed, roughness height, ground temperature, and cloud reflectivity. Daily total values of net radiation, storage of heat in the surface, latent and sensible cooling of the surface were obtained for sixteen cities in the different regions of Turkey.

1. INTRODUCTION

The surface energy balance equation includes incoming shortwave radiation, outgoing and incoming longwave radiation, energy fluxes associated with sensible and latent heat transfer and specified values for reflectivities. Description of the surface fluxes of heat and water vapour is useful for many purposes which are summarized below:

i) To describe the convective atmospheric boundary layer, especially for glider activities,

ii) To determine the evapo(transpi)ration from the surface, which is required by hydrology and agriculture,

iii) To estimate the stability of the air near the ground (air pollution problems, etc.).

iv) To determine the input of heat and moisture at the ground into the atmosphere for weather forecasting.

For some of these applications, the fluxes must be described in terms of variables which can be forecast, while for others a parameterization is needed in terms of routine weather data observed in the past. With the advent of satellites, a platform is now available outside the atmosphere from which meteorologically useful continuous measurements of the earth's radiation balance can be made. It, therefore, seems desirable to make a relatively detailed study on the seasonal variations of the radiation balance terms at Turkey. The main purpose of this paper is to analyze the thermal characteristics and to construct a thermal map of Anatolia. For this reason, some stations were chosen and gorund measurements for 1985 were considered.

Until recently, our knowledge of the radiative balance of the atmosphere was based on the important contributions of Houghton (1954), London (1957), Davis (1961) and Businger (1967) (1,2). The results of the heat budget at the surface of the Mediterranean Chart, and a brief discussion about the interpretation of these isolines is reported by M. Colacino (1975) (3). The detailed calculations of the heat balance of earth-atmosphere system were made by McCaughey (1975), K.B. Katsaros and R.J. Lind (1984) (4,5). In connection with the development of observations from meteorological satellites, there appeared the possibility of constructing maps of components of the radiational regime of the earth-atmosphere system directly from observational data. Averaged and instantaneous values of the earth's radiation balance were computed from the satellite measurements by R.W. Saunders (1983), H. Muller (1985) and B. Sequin (1988) (6,7,8). C. Lindemann (1988) compares different gliding fields in different countries under different climatological regimes in relation to their thermal convection (9). Thermal Convection Index was calculated and thermal qualities of Europe and also Anatolia were shown in Lindemann's study. The radiation balance of the atmosphere was investigated in the region of central Anatolia and its vicinity by M. Erkmen (1973)(1). In that paper, the heat budget components were calculated for different geographical regions of Turkey by using the climatological data.

2. MATERIAL AND METHODS

The energy balance equation of the earth's surface governs the fluxes of energy between the surface element and surrounding space. These fluxes include the radiative fluxes of heat, the sum of which is equal to the radiation balance. The energy balance equation for the earth's surface is given by:

$$G = R - LH - SH \qquad (2.1)$$

where G is storage of sensible heat, R net radiation, LH latent heat and SH sensible heat. In this study, ground storage of sensible heat was calculated as the functions of net radiation, latent heat and sensible heat. Net radiation is the primary energy input into the surface and it controls the other major exchanges of latent and sensible heat. The net radiation R, can be expressed as:

$$R = S(1-\alpha) + F_{down} + F_{up} \qquad (2.2)$$

where S is incoming shortwave radiation, α, surface albedo, F_{down} incoming longwave radiation and F_{up} outgoing longwave radiation. Hourly incoming shortwave radiation can be calculated with the following empirical equation with the consideration of relative humidity and cloud effect.

$$S = S_o \cos\theta (1-(0.09+0.13RH)).(1-\alpha_c C)(1-\alpha) \qquad (2.3)$$

where S_o is solar constant (S_o=1370 W/m²), θ, zenith angle, RH, relative humidity, α_C, cloud base albedo and C, cloud cover.

In the present model, daily averages of relative humidity, cloud cover and cloud type were considered by taking the surface properties and snow cover into account. The surface albedo is chosen between 0.17 and 0.30. The values of cloud base albedo was considered between 0.2 and 0.6 according to the various cloud types (10-12). Incoming long wave radiation is calculated from the following equation:

$$F_{down} = \varepsilon_a \sigma (T_a)^4 + (1-\varepsilon_a).C.\sigma(T_a - T_c)^4 \qquad (2.4)$$

Where ε_a is emissivity of atmosphere, σ, Stefan Boltzman constant (σ=5.67X10^{-8} W/m²), T_a, air temperature and T_c cloud base temperature (1,10).

Outgoing longwave radiation is calculated as:

$$F_{up} = \varepsilon_g \sigma T_g^4 \qquad (2.5)$$

where ε_g is surface emissivity ($\varepsilon_g \approx 1$), and T_g ground temperature. It is known that the value of the sensible heat flux depends on the intensity of turbulent exchange in the lower layer of the atmosphere. The vertical transfer of sensible heat is given by:

$$SH = \rho C_p.K^2 V(T_g - T_a)/(\ln(10/z_o))^2 \qquad (2.6)$$

where ρ is density of air ($\rho \approx 1$), C_p, specific heat of moist air (C_p=1004 J/kg.K), K, VonKarman constant (K=0.4), V the surface wind speed, (T_g-T_a), difference between ground and air temperature and Z_0 roughness height. Values of roughness height used in this study were calculated for the different seasons and different regions of Turkey by M. Erkmen (1,11).

The latent heat of evaporation under natural conditions varies slightly in accordance with the change in temperature of the evaporating surface. Latent heat flux is calculated with the following equation:

$$LH = L\rho \frac{K^2\, V\, W\, R_v\, 6,11}{(\ln(\frac{10}{z_0}))^2 . R_a . 1013} \left[\exp\left(\frac{L}{R_v}\left(\frac{1}{273} - \frac{1}{T_g}\right)\right) - \exp\left(\frac{L}{R_v}\left(\frac{1}{273} - \frac{1}{T_a}\right)RH\right)\right] \qquad (2.7)$$

where L is latent heat of evaporation, for positive temperatures L=25X10^{5}J/kg and for negative ones L=28.5X10^5 J/kg, R_v is gas constant of water vapour, (R_v=461 J/kg.K), R_d is gas constant of dry air (R_d=287 J/kg.K) and W, soil wetness. The values of soil wetness were estimated by considering air temperature, relative humidity, vegetation cover and precipitation regime in the present study.

3. ANALYSIS

By using the thermodynamic equations and considering the parameters defined above, the annual march of surface energy balance was analyzed. The isolines of storage energy and latent heat have been illustrated on the map of Turkey. Furthermore, comparisons of the annual march of these components were made between maritime regions and continental regions.

The annual march of the storage energy at surface for three selected stations are given (Fig. 3.1a). The storage energy shows an increase for the continental stations (Diyarbakir and Ankara) at the beginning of spring. The maximum value of it can be seen at the end of the summer period. One of the reasons for the occurence of a maximum value is the greater moisture deficit of a continental region in the warm season. The period of minimum values of storage energy corresponds more or less to the period of snow cover on the ground for continental regions. On the contrast, there is a minimum for the storage energy of maritime region (Antalya) for the summer period. Because, the important part of the storage energy has been converted for the evaporation process.

The latent heat variations are considered for Ankara, Antalya and Diyarbakir (Fig. 3.1b). It can be noticed that the maximum values accompany with the summer period. The maximum value of the heat for evaporation is earlier than the maximum in the storage energy of Ankara and Diyarbakir. The annual march of the latent heat for the three stations are very similar.

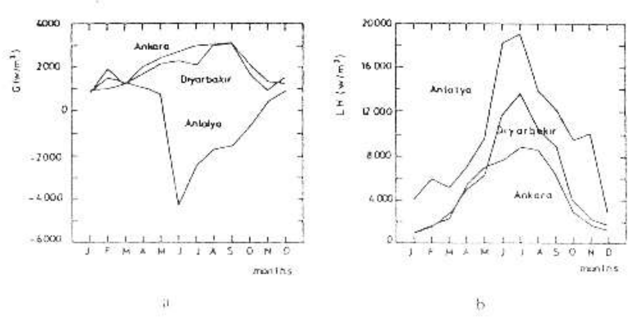

Fig. 3.1. Annual variations of the total daily storage energy (G) and the latent heat (LH).

If we consider the seasonal distributions of storage energy which are not given in the paper, the most favorable regions for thermal organizations are central and Southeast Anatolia in the spring and summer. During autumn, the central part of Turkey can be considered as a favorable region. During winter, this region shifts towards the Eastern part of Turkey. The annual distribution of storage energy is shown in Fig. 3.2. As shown in this figure, central Anatolia (Ankara, Sivas, Konya and Sskisehir), Southeast and East Anatolia (Gaziantep, Diyarbakir, Van and Erzurum) have the storage energies higher than average.

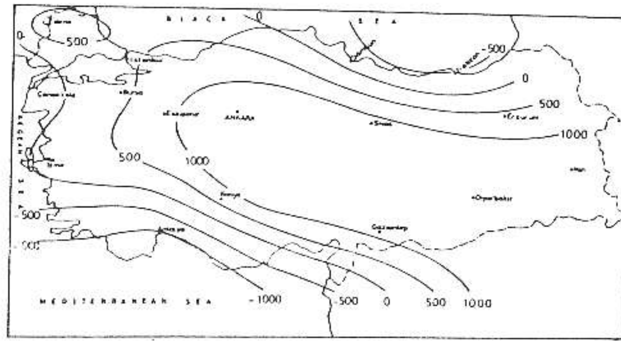

Fig. 3.2. Annual distribution of storage energy, G (W/m²).

From the point of view of latent heat the convenient regions for thermal soaring are central and East Anatolia in spring (the figures of seasonal distributions are not presented in the paper). the most convenient conditions for soaring occur in the East and Central Anatolia, but not in Southeast Anatolia.

In the autumn, central part, particularly Eskisehir is the most favorable area for thermal soaring. In winter Central and Eastern parts of Turkey can be considered as potential thermal areas.

Figure 3.3 shows the annual distribution of latent heat. We can list the most favorable regions as Eastern Anatolia (Erzurum, Sivas, Van) and Central Anatolia (Eskisehir (Inonu), Konya, Ankara) in decreasing order of potential.

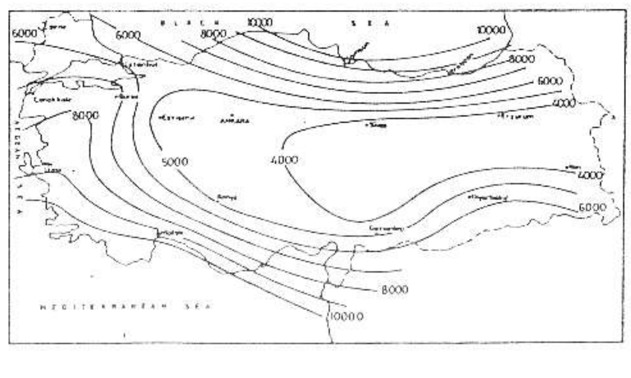

Fig. 3.3. Annual distribution of latent heat, (W/m²).

It is clear that according to the analysis of the both annual distributions (G and LH) except the coastal parts, most continental parts of Turkey have very favorable conditions for thermal soaring.

4. RESULTS AND CONCLUSIONS

We can summerize the results as follows:

1) The storage energy shows an increase for the continental stations at the beginning of spring. The maximum value of it can be seen at the end of summer period (Fig. 3.1a).

2) The annual march of latent heat variations for continental and coastal stations are very similar (Fig. 3.1b).

3) If we only consider the annual storage energy distribution of Turkey, it can be concluded that the central and southeastern parts are more convenient for the thermal soaring.

4) If we only consider the annual latent heat distribution, it can be concluded that the central and east Anatolia are more convenient than the other regions.

5) If we consider Fig. 3.2 and Fig. 3.3 together, which shows the annual distributions of storage energy and latent heat of Turkey, we can list the favorable regions for the thermal soaring as central Anatolia (Sivas, Ankara, Eskisehir (Inonu) and Konya) and Eastern Anatolia (Van, Erzurum and Gaziantep). The analysis shows that the thermal qualities of Turkey are better in the central and Eastern part than in the other regions.

6) The seasonal isolines of the storage energy and latent heat of Turkey which are presented in this paper coincide with the isolines of maximum Thermal Climatology Index (TCI) given by C. Lindemann (9).

As a result, we constructed a thermal map of Turkey by analyzing the storage energy and latent heat. It would be useful to support it by a vegetation index map which will be prepared by "remote sensing system."

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