DETERMINATION OF INFRARED HEATING RATE IN THE BOUNDARY LAYER

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ABSTRACT: The measurement of air temperature was carried out at one meter from the ground surface in a vegetated surface in Uyo, South-South, Nigeria, with a view to determining the infrared heating ratio. The boundary layer accumulated heat due to solar radiation by irradiative heating up to 3pm during the day time, and later begins to cool through the loss of energy by irradiative cooling. Infrared radiative rate varies from 7am to 3pm. The average obtained over the layer between the ground surface and temperature at one meter was used to determine the net flux which gives 0.9 kh^{-1}, 2.7 kh^{-1}, 4.0kh^{-1}, 2.1kh^{-1}, and 0.7kh^{-1} for 7am, 10am, 1pm, 4pm, and 7pm respectively. The mean downward flux from the atmosphere was calculated to be 3.85Wm^{-2}, and the emissivity also was found out to be 0.8. If the variation of this infrared heating rate with the earth surface is carefully taken care of, it can help in determining the energy balance between the earth and the atmosphere

INTRODUCTION

The amount of radiation absorbed by the atmosphere depends on the amount of absorbers in it and the principal absorbers in the atmosphere are water vapours, carbon dioxide and ozone, Abraham (1960). The actual process of long – wave radiative exchange in the atmosphere is very complex. The spectrum of solar light at the earth surface is mostly spread across the visible and near –infrared ranges with a small part in the ultraviolet Anderson and Palkovic, (1994). The radiation which is of utmost concern to man is that emitted from the sun ,the earth and the atmosphere lying within the ultraviolet ,visible and infrared spectral regions and the radiation of practical importance to solar energy consumers fall between 0.15μm and 3.0 μm Greg and Prakash (2002).

The atmosphere is comprised of a number of gases, some of which act as an insulation blanket over the earth's surface. The temperature absorbs long wave radiation at all level depending on the amount of absorbing constituent present, and re-emits long – wave constituents with its temperature and emissivity. The emission is directed both upwards and downwards, Parker (1971). Also, the reflectivity is the ratio of the radiation that a surface is able to reflect to incident radiation without change in wavelength, Akpabio, (1998).

The net irradiative heating or cooling rate through the upper and lower slab boundaries of a layer of air is defined in terms of the net flux entering and fluxes leaving the slab, Oke (1978). The net flux within a slab of air is the product of density, the specific heat capacity of the air and heating rate, Nwokoye (2009). Solar radiation is required in the estimation of solar heat gain in such areas as building, weather forecasting, agricultural potential studies and forecast of evaporation from lakes and reservoirs, Seller (1965).

Determination of the heating rate in the boundary layers is important because of these biological, economical and meteorological applications. This work was carried out in Uyo, South-South, Nigeria. The Swinbanks radiation formula has been employed to estimate the downward flux from the atmosphere. The emissivity and sky temperature were equally calculated which are essentially useful to micrometeorologist. The transmittance of direct solar radiation is known to be affected by the presence of pollutants in the atmosphere Karras, *et al* (1990).

MATERIALS AND METHOD

The materials used were mercury in glass thermometer with sensitivity ranging from 0, 5, 15, 20 etc and meter rule. All measurements were carried out in the boundary layer up to the height of 1m.

A site with vegetation was chosen since it was not possible to use irradiative instrument. The vegetation helps to reduce the short-wave coming from the atmosphere and also helps some to reflect back. It also helps to reduce the long-wave radiation sent by the ground to the atmosphere. In doing this work, two levels for the measurement were chosen; soil surface and a height of 1m measured from the soil surface. . The soil surface and height of 1m were marked and their temperatures were Ts and T respectively. The measurements were synoptically taken i.e. from, 7a.m, 10a.m, 1p.m, 4p.m and 7p.m each day for 62days. In taking measurements the thermometer was placed horizontally at each marked point on the plank and then results recorded. The measurements started from 1st July to 31st August 2009 in the day time and the mean temperature at the surface and at 1m height on each time were determined.

THEORY

The net flux of irradiative cooling or heating rate can be expressed only in two terms of temperature at the levels using the equation (1)

$$\Delta T/\Delta t = 0.32\sigma T^3(T_S-T)/\rho C_p\Delta Z \qquad 1$$

Where ΔT = Change in temperature

Δt = Change in time

σ = Stefan – Boltzman constant having the value 5.7×10^{-8} $WM^{-2}K^4$

T = Temperature at 1m height from the surface.

Ts = Temperature at the surface.

Cp = Specific heat capacity ($1.0\times10^{-3}Jkg^{-1}K^{-1}$)

ρ = density = P/RT

Δz = 1 m

Where P = Pressure = 1.013×10^5 pa

R = Universal gas constant, 2.87×10^2 Jkg^{-1} K^{-1}

T = Temperature at 1m height

Also in clear skies the downward flux L_d of atmospheric radiation is given as (Swinbank, 1963)

$$L_d = 1.20\sigma T^4 - 171 \qquad 2$$

and the emissivity ε is given as

$$\varepsilon = L_d/\sigma T^4 \qquad 3$$

RESULTS AND DISCUSSIONS

Table 1. Variation of mean temperature with time for the two levels (soil surface and height of 1m)

Time(hr)	Ts (^{o}C)	T(^{o}C)
7am	24.65	24.0
10am	29.8	28.0
1pm	33.1	30.55
4pm	30.9	29.55
7pm	26.2	25.7

Table 2: Variation of infrared heating rate in the boundary layer ($\Delta T/\nabla t$) with time

Time (hr)	$\Delta T/\Delta t$ (Kh^{-1})
7am	0.9
10am	2.7
1pm	4.0
4pm	2.1
7pm	0.7

The graph of $\Delta T/\Delta t$ against time in Fig. 1 shows that in the daytime infrared heating rate rises from (0.9 - 2.7) kh^{-1} during the time 7am(8.00hrs GMT)-10am(11.00hrs GMT) and also rises steeply to 4.0kh^{-1} at a time 1pm(14.00hrs GMT). This period shows an increased heating rate. It later falls from 4.0kh^{-1} to 0.7kh^{-1}. This shows the radiative cooling. In terms of energy, this means that the layer accumulates energy from 7am(8.00hrs GMT)- 3pm(16.00hrs GMT) after which it started expending energy from 3pm(16.00hrs GMT) -7pm(20.00hrs GMT).The flux convergence produces radiative heating while flux divergence produces radiative cooling.

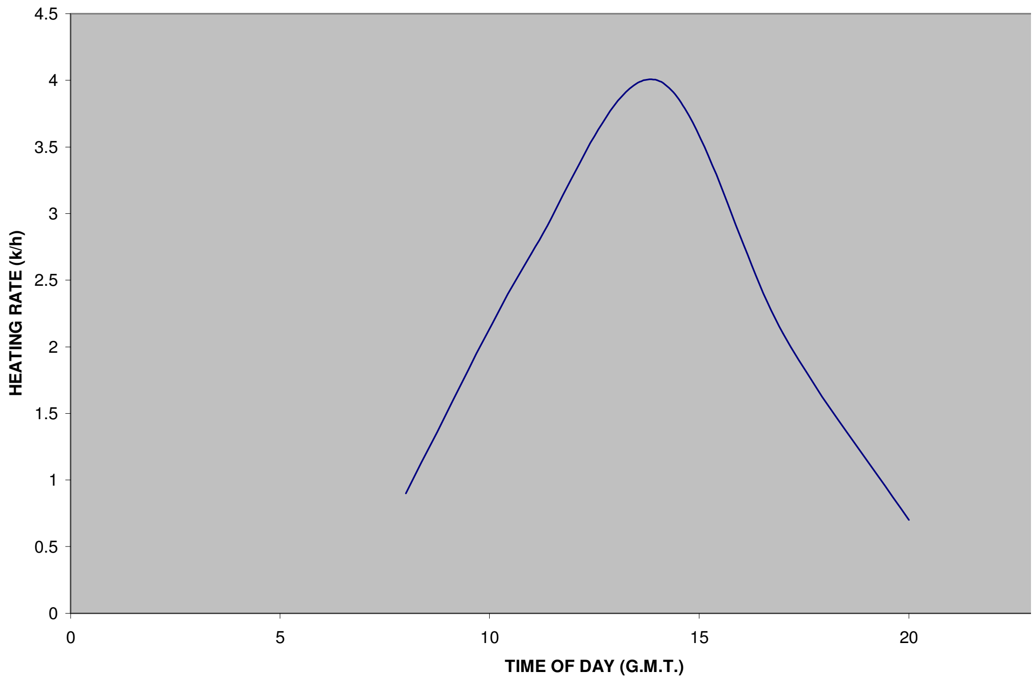

Fig.1 A graph of heating rate (k/h) against time in GMT

The form and site of climate modification varies in time and space as a result of meteorological and location characteristics. After the sunset the sky is cloudless with light winds. The graph shows the characteristics variation of air temperature with time. The infrared heating rate boundary exhibits a peak temperature gradient.

During a constant weather condition the heating rate diurnal variation is maximum a few hours after sunset and smallest in the middle of the day. The growth of the heating rate is rapid following sunset, because of the difference between the heating rate and cooling rate. During this period, the cooling areas rapidly expend its energy stored by long wave radiation, but cool at a slower rate.

From the T values of Table 1 and the calculated values of L_d in equation (2), its shows that the downward flux from the atmosphere increases with increase in the air temperature up to a maximum of 4.07Wm^{-2} at 1pm and temperature of 303.55k.

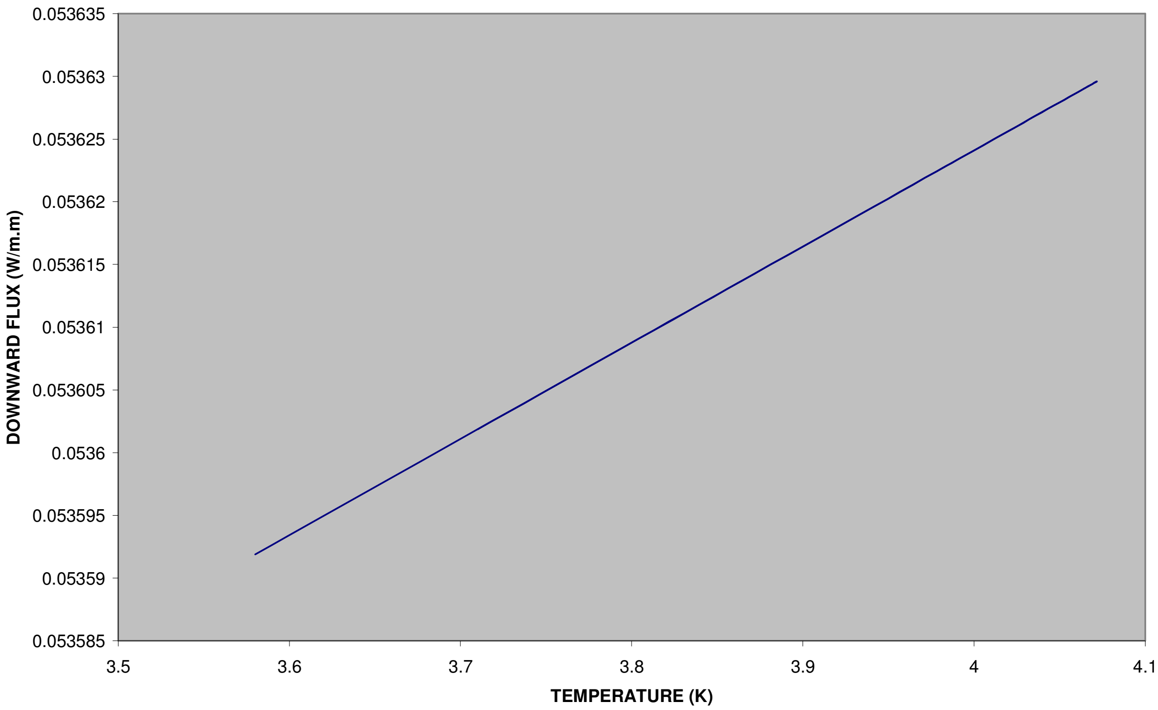

Fig 2: Plot of downward L_d flux against T^4

CONCLUSION

A plot of L_d against T^4 shown in Fig 2 shows that the downward flux from the atmosphere in Uyo can be estimated from the heating model such as

$$L_d = 0.068T^4 \ -1.756$$

If the variation of this infrared heating rate with the earth surface is carefully taken care of, it can help in determining the energy balance between the earth and the atmosphere.

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