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The dependence of Net-Radiation on Short-Wave Radiation at Waltair

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ABSTRACT. The constants of the general radiation balance equation suggested by Monteith and Szeicz (1961) are redetermined for the tropical latitude station, Waltair. The calculated radiation balance equation with new constants for the station is $R = 0 \cdot 86 \, (1-\alpha) \, S - 4 \cdot 2$. A high correlation coefficient $0 \cdot 99$ is obtained between net short-wave radiation $(1-\alpha) \, S$ and net radiation R.

1. Introduction

The total vertical flux of energy has been recognised as one of the most significant parameters of the meteorological elements which determine the climatological importance of net radiation at the surface of the earth from the sun and the sky. The amount of net radiation (incoming radiation of all wave-lengths *minus* outgoing radiation of all wave-lengths) is always lower than the direct solar radiation, integrated, over the month or year. In agricultural meteorology the importance of net radiation in determining crop evaporation was emphasized by Penman (1948) and Pasquill (1950). They suggested that in the climate of British Isles annual latent heat of evaporation from short grass is equal to the annual net radiation. The preliminary analysis of three years records at Rothamsted by House, Rider and Tugwell (1960), shows that there is close agreement between daily totals of latent heat and net radiation. The net radiation can be measured to a high degree of accuracy with the Gier and Dunkle (1951) net exchange radiometer, manufactured by Beckman and Whitley Co., California, which is of paramount importance in the studies of energy balance, evaporation and many other studies.

2. Analysis and Results

The purpose of this paper is to examine the general radiation balance equation suggested by Monteith and Szeicz (1961) for the tropical latitude, Waltair (17° 43′N, 83°17′E). The general empirical radiation balance equation, according to Monteith and Szeicz (1961), for the dependence of net radiation on short-wave radiation under clear skies is —

$$R = a \, (1-\alpha) \, S + b \qquad (1)$$

where R is the net radiation of all wave-lengths, S is the incoming short-wave radiation from sun and sky, a and b are the constants of the general radiation balance equation (1) and α is the reflection coefficient or the albedo of the ground surface.

Monteith and Szeicz (1961) also represented a general radiation balance equation under clear skies as —

$$R = (1-\alpha) \, S + L \qquad (2)$$

Eq. (1) can satisfy Eq. (2) only when L is a linear function of R having the form —

$$L = b/a - \beta \, R \qquad (3)$$

where $\beta = (1-a)/a$. The quantity β is called heating coefficient which is equal to the increase of net long-wave loss per unit increase of net incoming radiation. With the assumption that when $S=0$, L has the value L_0 $(=b)$ then Eq. (1) becomes

$$R = S \, (1-\alpha)/(1+\beta) + L_0 \qquad (4)$$

From the slope of Eq. (4), the heating coefficient β can be easily obtained after knowing the values of S, αS and R.

The net incoming long-wave radiation is expressed by the equation —

$$L = L_d - L_u = G - S - \sigma T^4 \qquad (5)$$

in which G is the incoming radiation of all wave-lengths, L_d is the downward long-wave radiation from the atmosphere, L_u is the long-wave radiation from the surface and T is the radiative temperature (°K) of the surface, σ being the Stefan–Boltzman constant $(=8 \cdot 13 \times 10^{-11}$ cal. cm.$^{-2}$ (°K)$^{-4}$ min.$^{-1})$.

From Eqs. (2) and (5) the total reflected short-wave radiation is given by—

$$\alpha S = G - R - \sigma T^4$$

The unit of radiation is gram cal cm^{-2} min^{-1} (or Langleys min^{-1}) or hr^{-1} or day^{-1}.

In the energy balance studies at Waltair the incoming short-wave radiation S is measured by an Eppley pyranometer. The total radiation G

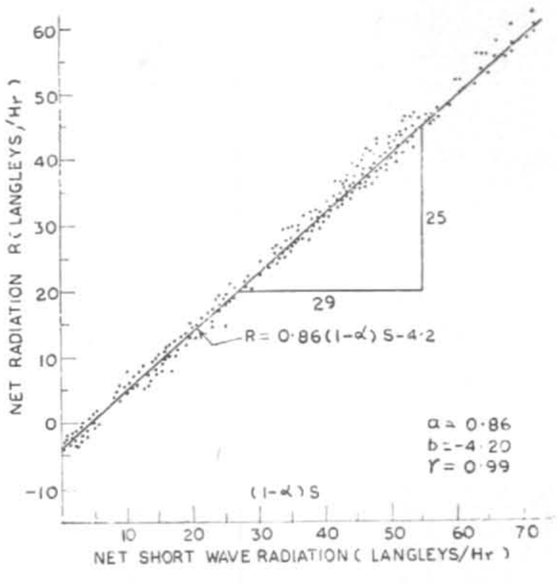

Fig. 1. Dependence of net-radiation on short-wave radiation

is measured with Beckman and Whitley total hemispherical radiometer, model H 188-1 (Gier and Dunkle total radiometer). For the measurement of net radiation R the Beckman and Whitley thermal radiometer, model N 188-1 (Gier and Dunkle) is used. The surface temperature T of the ground is obtained from an ordinary mercury-in-glass thermometer with due precautions regarding its calibration and exposure. For future exploitation, the dependence of net radiation on short-wave radiation under clear skies has been examined for a patchy level grass at Waltair.

Eq. (1) or (4) is evaluated from the above measured radiation components. The correlation coefficient r between the net short-wave radiation $(1-\alpha)\ S$ and the net radiation R for 265 cloudless hours in different months during two years period (August 1963 to July 1965) are obtained by the method of least squares. The calculated values are: $a = 0 \cdot 86$, $L_0 = b = -4 \cdot 20$ and $r = 0 \cdot 99$. For these values a straight line is fitted in Fig. 1 showing the dependence of net radiation on short-wave radiation.

The heating coefficient β is obtained from the slope of the regression line (Fig. 1) and it is equal to $0 \cdot 163$ for a patchy level grass surface of the experimental site at Waltair. The smaller value of β implies a smaller diurnal variation of patchy level grass surface temperature for given radiation income. The heating coefficient for patchy level grass is slightly lower than the heating coefficient of grass surface calculated by Monteith and Szeicz (1961) for British Isles. The slight variation of the heating coefficient may be due to the type of soil and also the density of grass cover over the ground at the two places. But the statistical value of L_0 (*i.e.*, $b = -4 \cdot 20$ Langleys hr^{-1}) for patchy level grass at Waltair is very well compared with that of the mean net long-wave flux $-4 \cdot 00$ Langleys hr^{-1} obtained by Monteith and Szeicz on a typical clear night for a short grass surface. The values of a, b and β obtained by the authors at Waltair are approxi-

TABLE 1

Mean monthly values of net radiation and net short-wave radiation at Waltair

Year	Months	R	$(1-\alpha)S$
1963	Aug	11·83	16·58
	Sep	22·03	27·39
	Oct	22·52	29·18
	Nov	23·46	31·57
	Dec	21·23	27·53
1964	Jan	26·63	32·65
	Feb	26·41	33·52
	Mar	29·96	37·20
	Apr	33·66	41·52
	May	34·14	42·88
	Jun	27·09	34·50
	Jul	19·52	27·22
	Aug	19·65	25·72
	Sep	17·90	25·06
	Oct	22·97	30·05
	Nov	24·16	29·50
	Dec	20·78	27·23
1965	Jan	25·39	32·54
	Feb	25·12	32·24
	Mar	30·54	37·56
	Apr	32·32	40·15
	May	31·53	38·97
	Jun	27·52	34·25
	Jul	20·50	26·31

Note — All radiation values in langleys/hour

mately of the same magnitude as reported by Monteith and Szeicz (1961) for cloudless days.

The measured diurnal cycles of radiation components show that for an approximate equal short-wave radiations of S and $(1-\alpha)\,S$, the net radiation is always smaller in the afternoon than in the morning because of higher afternoon surface temperatures. Table 1 shows a mean monthly net radiation and net short-wave radiation obtained from daily values of radiation components on clear days at Waltair. The seasonal variation of these components is similar to that of solar radiation. The values of these components are higher in summer months and lower in monsoon months.

The only data purposely omitted from Fig. 1 are for net short-wave intensities above 70 Langleys hr^{-1} in summer, when the radiometer was not raised during very rapid growth. In summer anomalously high net radiation is recorded during the middle of the day, probably because reflected radiation is not properly received by the under side of the plate. Such hourly values of net radiation are also not considered in the evaluation of regression equation of Fig. 1.

Radiation measurements of Pasquill (1949), Robinson (1951), Lettau and Davidson (1957) and Monteith and Szeicz (1961) for different heights of grass are in good agreement with the straight line correlating net and short-wave radiation under clear skies. The results of the above workers suggested that the radiation balance of grass is virtually independent of height of the grass. The radiation observations (Table 1, Fig. 1) obtained by the authors for Waltair also provide further support for the validity of Eq. (4).

The development of the climatological formula for calculating net radiation absorbed by surface other than short grass awaits analysis of the dependence of β and L_0 on wind speed, on surface properties and on season. Such studies at tropical latitudes are very important in agriculture and energy balance of air-earth interface and they are being carried out by the authors.

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