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On the climatological computation of net radiation components

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ABSTRACT. The suitability of a green vegetative cover as a standard surface for climatological computations of net radiation and the paucity of data on total daily long wave flux are discussed. The net radiation and associated data for bare soil at Poona are analysed and it is inferred that the night time pyrgeometric observations might be representative to obtain the long wave flux for the day as a whole.

1. Introduction

The definitive equation for net radiation of the earth's surface is

$$Q_n = Q_s(1-\gamma_s) + R_A(1-\gamma_l) - \epsilon\sigma T_s^4 \quad (1)$$

where,

Q_n = net radiation,

Q_s = global solar radiation,

R_A = thermal radiation from the atmosphere,

γ_s and γ_l = the albedos of the surface for short and long wave fluxes respectively,

ϵ = the emissivity of the surface,

T_s = the surface temperature (°K)

and σ = the Stefan-Boltzman constant.

Since the value of γ_l and ϵ for ground surfaces, independent of their nature, are of the order of 0·03 and 0·97 respectively, equation (1) could be simplified as

$$Q_n = Q_s(1-\gamma_s) + R_A - \sigma T_s^4 \quad (1a)$$

neglecting the insignificant terms.

Depending upon the values of γ_s and T_s the net radiation over various types of ground surfaces receiving the same shortwave and long wave influxes, will be quite different. It is, therefore, necessary in climatological studies of net radiation to consider a standard surface over which γ_s and T_s are specified.

Of the parameters in equation (1) Q_s and R_A are independent of the ground surface. Little data of daily total incoming long wave radiation is available. Since Q_n is a small fraction of R_A the need for a simple method for the accurate estimation of R_A is obvious.

2. Choice of the standard surface

Three natural ground surfaces can be considered for the purpose, *viz.*, bare soil, water and green vegetative cover. The daily mean albedo for clear water is 0·06. It varies widely from soil to soil, and ranges from 0·20 to 0·25 for green vegetation. Data on mean surface soil temperature are not commonly available. Since deep natural water bodies absorb radiation in summer and release the same in winter, only shallow natural water surfaces can be considered. In evaporation studies the Russian 20 m² tank, 5 metres in diameter and 2 metres deep, is taken to represent an extensive shallow water surface. The mean monthly water surface temperature recorded in this evaporimeter tank, in different climatic regimes (Table 1), show considerable deviations from the air temperature though for the Indian region, the deviation ranges from —1·0° to 3·0°C only. The mean radiative temperature of a freely transpiring vegetation will be more or less the same as the mean temperature of air, T_a (Monteith and Szeicz 1962; Linacre 1968).

In view of the above a short green crop fully covering the ground, freely transpiring and not subject to any large oasis effect, such as the one visualised by Thornthwaite (1954) for potential evapotranspiration computations may be taken as the standard surface for climatological computations of net radiation with $T_s = T_a$ and γ_s = 0·25 (Monteith 1959).

Such computations will give an idea of the relative water needs of crops growing at different places and seasons. They are also required for deriving the climatic parameter 'potential evapotranspiration' which can be put to diverse uses. Again they render easy the derivation of net radiation climate for any natural surface with known albedos and deviations from the mean air temperature, from considerations of solar radiation and air temperature climatology, through determination of the changes in short and long wave fluxes from the standard surface.

TABLE 1

Differences in 20 m² tank mean water surface temp. (T_s) and mean air temp. (T_a) in degrees Celsius

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						U.S.A.						
Sterling, Virgina	—	—	—	2·5	3·5	4·0	2·0	2·5	4·5	5·5	2·1	—
Lake Mead, Arizona	—1·0	—0·5	—1·5	—1·0	—4·0	—5·0	—7·0	—6·0	—5·0	—2·0	—0·5	—0·5
Davis, California	1·0	1·5	3·0	4·0	4·0	3·5	2·0	3·5	3·0	2·0	2·0	1·5
						U.S.S.R.						
Dubovka	—	—	—	—	2·0	2·5	0·5	0·0	1·5	1·5	0·0	—
Valadai	—	—	—	—	3·0	4·0	3·5	3·0	3·5	2·0	—	—
						INDIA						
Delhi	2·0	0·5	1·5	2·5	0·5	2·5	1·5	2·5	2·0	2·5	2·0	0·5
Poona	2·5	1·0	0·0	—1·0	—1·0	0·0	2·0	2·0	3·0	3·0	3·0	2·0

— No observations due to freezing weather

TABLE 2

Net radiation components (cal/cm² /day) over bare soil at Poona (1964-1968)

	Observed Q_n	Observed Q_s	Observed T_s (°C)	Q_{s*} $\cdot87Q_s$ (Cal.)	$\cdot97\sigma T_s^4$	R_A (Cal.)	R_A from 2030 IST pyrgeo-metric values	Q_n using pyrgeo-metric estimates of R_A at 2030 IST
January	143	440	30·1	383	973	733	727	137
February	184	514	33·3	447	1015	752	736	168
March	220	570	38·3	496	1084	808	778	190
April	253	610	42·7	531	1147	869	827	211
May	284	636	42·1	553	1137	868	821	237
June	225	499	35·3	434	1043	834	848	239
July	166	380	29·0	331	960	795	854	225
August	205	403	29·9	351	971	825	832	212
September	214	460	33·2	400	1014	828	824	210
October	213	501	37·0	436	1066	843	796	166
November	166	435	32·2	378	1001	789	755	132
December	124	394	28·6	343	955	736	739	127

3. Availability of basic information for net radiation computation

Satisfactory climatological estimates of incoming short wave radiation (Q_s) are available (Venkataraman and Krishnamurthy 1967; Ganesan 1970). Hence over a standard green cover the net short wave flux which is only $0 \cdot 75\ Q_s$, by definition, is easy for computation.

For computing outgoing long wave radiation from the above surface, only data on mean air temperature is required, since, by definition $T_s = T_a$.

Regarding the long wave flux, systematic data recorded with Angström Pyrgeometer are available for selected night hours only for about 10 stations in India. On the assumption of back radiation of the sensor strips at air temperature (at the level of the instrument at the time of the observation), values of R_A for night hours are also available.

Thus, for net radiation computations the night time data of the net long wave flux or of R_A would be representative of the standard green cover but would require to be extrapolated for the day as a whole at individual stations. The daily estimates have then to be interpolated between the stations constituting the pyrgeometric network.

4. A pilot study for Poona

Cooley and Idso (1971) have shown that estimates of R_A obtained as a difference in the readings recorded by hemispherical all wave and short wave radiometers agree well with those estimated from global solar radiation, net radiation, albedo and surface temperature measured over a bare soil surface.

At the Central Agrimet. Observatory, Poona, besides global solar radiation, net radiation data over bare soil have been systematically recorded for the period 1964-1968. For this period ground surface temperature recorded at 07 hours and 14 hours LMT (the times of occurrence of minimum and maximum temperatures) by a thermometer placed on the ground with a thin layer of soil covering the bulb are also available.

The mean values of Q_n, Q_s and T_s for the period 1964 to 1968 are shown in Table 2. Using the albedo of $0 \cdot 13$ recorded for soil surface at the Central Agrimet. Observatory (Chacko *et al.* 1968), the value of net short wave flux have been worked out. The outgoing long wave flux taken as equal to $0 \cdot 97\ \sigma T_s^4$ is given in Table 2. The atmospheric radiation obtained from these readings by means of equation (1) is also shown.

The limited data on diurnal variation of R_A (Cooley and Idso 1971; Kondratyev 1969; Kalma and Stanhill 1969) appear to indicate increased atmospheric emission round about noon and early afternoon (the period of intense heating of the ground) and that the estimates of mean R_A for the day as a whole might be greater by about 5-10 per cent (depending on the state of the sky) than the average values for the night-time.

In a previous study (Gangopadhyaya and Venkataraman 1970) it was noticed that the night time variation of R_A was quite small. However, the value at 2030 IST was slightly higher (5 per cent) than the mean value. In the light of the above, it was decided to compare the computed value of total daily R_A with those obtained by assuming the pyrgeometric value of 2030 IST to be valid for the day as a whole. A comparison of these two estimates (in Table 2) brings out an interesting inference that the value of R_A' based on 2030 hours pyrgeometric reading agrees well with the derived value for the day as a whole, the deviations being not greater than $\pm$ 5 per cent.

Although estimates of the mean daily values of R_A can be had from the 2030 hours observation with an accuracy of $\pm$ 5 per cent, the percentage error in net radiation based on the 2030 IST estimates of R_A (*see* Table 2) becomes significant because of the small value of net radiation. Hence, it is necessary to devise a technique for deriving the day-time long wave flux value from the night-time data to achieve a higher accuracy.

5. Possible use of pyrgeometric data

Previous attempts in deriving long wave radiation have centred round the derivation of a function involving outgoing long wave flux, water vapour content and cloud cover. The pyrgeometric readings of net long wave flux integrate the effects of water vapour content and clouds. It would also be reasonable to assume that, on the mean, the values of water vapour content and the cloud during the night-time may not differ much from the mean daily value for the day as a whole. Thus at a station the pyrgeometric estimates of long wave flux offer possibilities of deriving the total daily long wave flux through a temperature function. Such estimations could then be related to other meteorological parameters.

6. Conclusions

(*i*) Adoption of an extensive, short, green vegetative cover as a standard natural surface appears warranted, from the point of view of data requirements, for reduction of net radiation to a standard datum.

(*ii*) A pilot study of the net radiation components over bare soil surface at the Central Agrimet. Observatory at Poona indicates that on an average, the 2030 IST pyrgeometric estimates of atmospheric radiation might be representative for the day as a whole.

(*iii*) For accurate estimates of net radiation, determination of atmospheric radiation even with 5 per cent accuracy may not be sufficient.

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