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Net Radiation Climate of India

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ABSTRACT. A formula has been derived for computing net radiation using (1) radiation received outside the earth's atmosphere, (2) actual duration of bright sunshine and (3) maximum possible duration of bright sunshine. Computed values and actual recorded values are shown to be generally in good agreement for Poona and Calcutta, for which recorded values are available. Net radiation values are computed for 79 stations in India using the formula and maps are prepared showing the net radiation over India in each month. The main features of the monthly distribution of net radiation over the country are discussed.

1. Introduction

Net radiation is the most important parameter required for estimating evaporation or evapotranspiration by the energy balance method. In the absence of significant advective error, or in other words if the site of observation is representative of its surroundings, the net radiation represents the rate of available energy from which the energy for evaporation is drawn. A small fraction of this net radiation (R) goes as flux of heat (G) into the ground. The rest of it ($R-G$) is partitioned between H, the sensible heat flux into the air and LE the energy utilised for evaporation. This basic concept is represented by the equation —

$$R-G=H+LE$$

Thus, the measurement of R is the most important pre-requisite for the estimation of evaporation by the energy balance method.

R depends upon the type of the underlying surface, since albedo plays an important part in determining the value of R. This problem is common, whether R is actually measured with net radiometer or computed from meteorological parameters. The solution, however, lies in determining R for some appropriate underlying surface and finding out corrections applicable to other surfaces.

Recorded values of net radiation are meagre over most of the world and India is no exception. It will be several years before mean values of net radiation become available on the basis of actual recorded data over a network of stations. The need for getting a picture of this very important quantity for the country as a whole, at least on the basis of computed values, thus becomes evident.

2. Procedure

The radiation balance equation can be written as —

$$R=R_I\ (1-r)-R_B$$

where, R_I is the total incoming short wave radiation, r is the short wave reflection coefficient and R_B is the net long wave exchange between the surface and the atmosphere. R_I is measurable by means of commercially available solarimeters. However, since the network of radiation measuring stations is small, R_I can be computed using a formula of the type —

$$R_I=R_A\ [a+b\,(n/N)]$$

where, R_A is the radiation that would be received outside the earth's atmosphere, n/N the actual duration of bright sunshine expressed as a fraction of the maximum possible and a and b constants that can be worked out. The short wave reflection coefficient γ can be actually measured. Typical values for different surface covers are also given in published literature — Geiger (1957) and Brooks (1959). R_B is the net long wave radiation leaving the surface. Following Penman (1948) this can be expressed in the form —

$$R_B=\sigma\,T^4(0\cdot56-0\cdot09\,e^{\frac{1}{2}})\ [0\cdot1+0\cdot9\,(n/N)]$$

assuming that the earth radiates as a black body and that this radiation is reduced in proportion to the cloud cover and to a lesser extent by the water vapour (e) of the atmosphere.

In the above equations, if the effect of variation of e (the contribution of which, in any case, is much smaller than that of clouding) is neglected and the albedo taken as a constant, a simple formula can be written in the form —

$$R=(CR_A-k_1)\ [a+b\,(n/N)]+k_2$$

After taking into account the recorded values of net radiation at Poona and Calcutta for the short period for which they are available and after consideration of the computed values of net long wave radiation obtained with Penman's formula, the following approximate formula has been developed for the computation of net radiation for a bare soil surface.

TABLE 1

Net Radiation (cal/cm^2/day)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					POONA (1964 and 1965)							
A	125	194	200	254	289	228	169	211	212	215	160	111
C	138	197	231	265	283	226	177	186	199	198	155	127
D	10	1	15	4	2	1	5	12	6	8	3	14
					CALCUTTA (1965 and 1966—as far as available)							
A	115	158	209	273	290	193	—	182	165	163	134	123
C	104	160	192	256	262	181	194	173	169	160	120	96
D	8	1	8	6	10	6	—	5	2	1	10	22

A — Actual Average C — Computed Average D — Deviation (per cent) — Doubtful

$$R = (0{\cdot}2\ R_A - 0{\cdot}6)\,[1+2(n/N)] + 0{\cdot}15\ \text{cal/cm}^2\text{/min}$$

In order to verify the applicability of this equation for computing the net radiation, actual recorded data of net radiation for Poona (1964 and 1965) and Calcutta (1965 and 1966 as far as available) were compared with the net radiation computed for the two places using sunshine data for the same periods. The results are given in Table 1. It may be seen that the agreement is good (within 10 per cent) for most of the months except for March, August and December (deviation 12 to 15 per cent) for Poona and December (deviation 22 per cent) in Calcutta. It is found that the actual recorded values of net radiation themselves vary from year to year to this extent. It was, therefore, thought worthwhile to use the formula to compute the net radiation for as many stations in India as possible so that at least some approximate values of this important parameter may be available, pending the collection of actual data over a wide network of stations for a sufficiently long period.

3. Data

Data of mean actual number of hours of bright sunshine for 79 stations were used for the study. These consisted of observatory stations belonging to the India Meteorological Department as also agromet. observatories maintained by the Department of Agriculture of the various States or Soil Conservation Research Centres or similar bodies. For obtaining extra terrestrial radiation for each station, data from *Smithsonian Meteorological Tables* where the values are given for different latitudes and for different declinations of the sun per day were utilised. From these, the extra terrestrial radiation per minute was calculated for each station for each month. The possible hours of sunshine were worked out stationwise from data of the times of sunrise and sunset. Making use of these, the net radiation over bare soil for each station for each month was computed and plotted on charts. Isopleths of net radiation were then drawn.

4. Discussion

Figs. 1 to 12 give the monthly values of net radiation. These bring out the following features.

January — The net radiation steadily decreases, almost latitudinally, as one goes from south to north, from about 200 calories per day in the extreme south to less than 50 calories in the Kashmir area. North of latitude 25°N, the values are generally below 100 calories and south of 15°N, they are above 175 calories. The main exception to the latitudinal variation is Kerala where, due to some cloud cover, without too much of it, net radiation values are somewhat higher than places in the same latitude in the Madras State.

February — Net radiation shows an increase of about 50 calories per day from January, the values being about 225 calories in the south Peninsula decreasing to less than 100 calories in Kashmir. The increase from January is least marked in the Kerala area where the rise is only about 25-30 calories.

March — With the northward movement of the sun from the south of the equator, there is a further increase in the net radiation all over the country. The values are a little over 250 calories (an increase of 25 calories) in the south Peninsula but in the extreme north of the country, the increase is more marked, being about 50 calories.

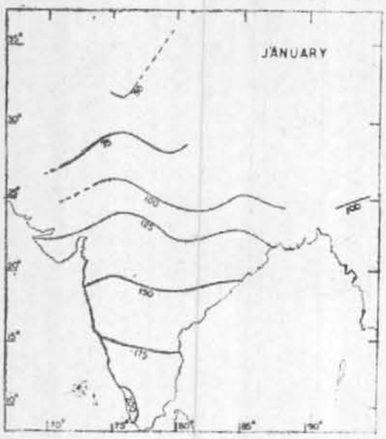


Fig. 1

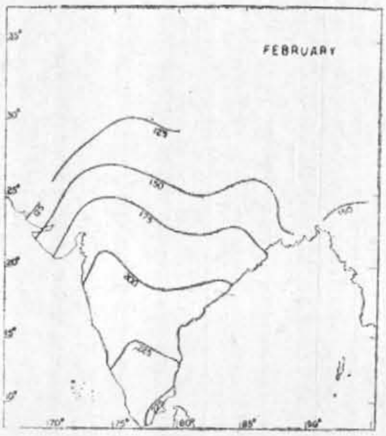


Fig. 2

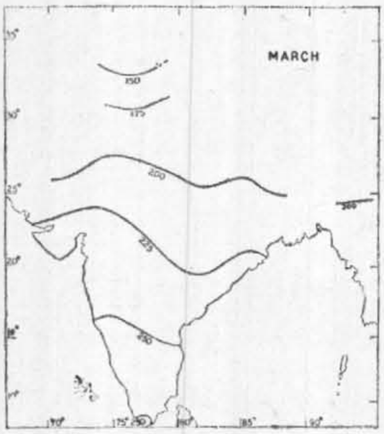
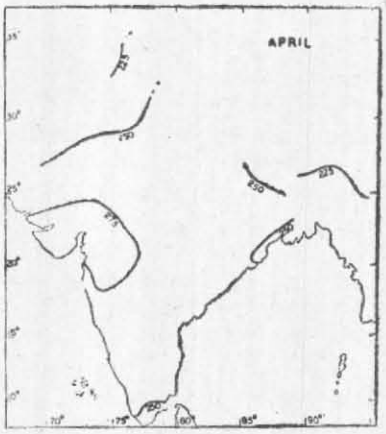


Fig. 3



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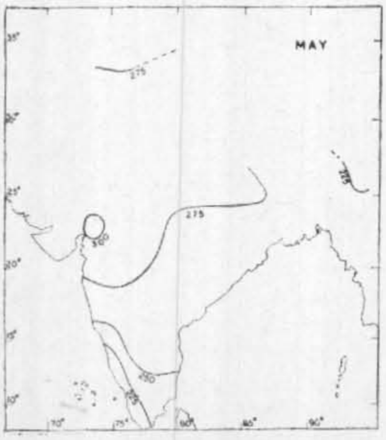

Fig. 5

Fig. 6

Figs. 1—6. Monthly values of net radiation (cal/cm^2/day)

Fig. 7

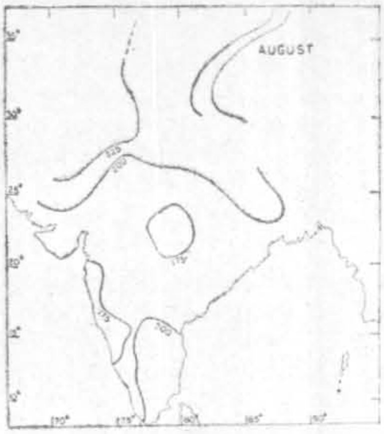

Fig. 8

Fig. 9

Fig. 10

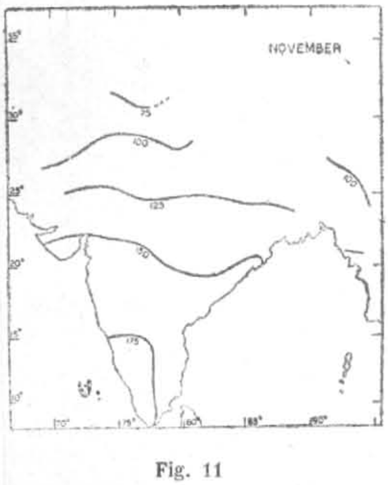

Fig. 11

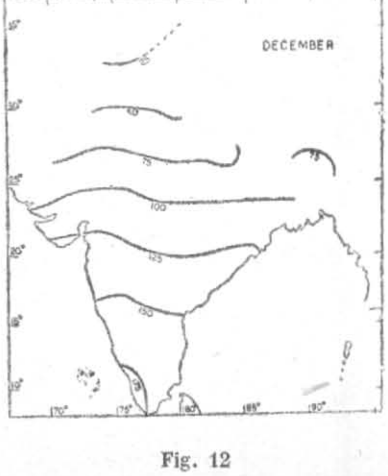

Fig. 12

Figs. 7—12. Monthly values of net radiation (cal/cm²/day)

April — There is a marked increase of net radiation in north India with very little increase in the south so that the latitudinal gradient noticed in the earlier months has disappeared. Over west Uttar Pradesh, Punjab and Jammu-Kashmir the increase is by about 75 calories and over the north Maharashtra and the Gujarat State, the increase is about 50 calories.

May — The picture in May is quite different from that in previous months. The net radiation is minimum over the southern half of the west coast with its heavy clouding and some rain which reduces direct solar radiation considerably. The values over this area are less by 40-50 calories from those in April. On the other hand, there is a general increase of net radiation over the rest of the country outside northeast India, where there is little variation. The maximum net radiation is obtained over northeast Gujarat and adjoining Rajasthan.

June — There is an almost complete reversal of the picture from January. The net radiation is a maximum in northwest India decreasing to the east and south, with the minimum along the Kerala-south Mysore coastal belt and a secondary minimum in Assam and neighbourhood. There is a general decrease of net radiation of about 50 claories per day almost throughout the country outside northwest India where there is little change and in the Madras State where the decrease is less. The monsoon sets in over Kerala by the beginning of June and advancing northwards spreads steadily over the country reaching NW India by the end of June or early July. The effect of this is seen in the net radiation pattern.

July — With the strengthening of the monsoon and cloudy or rainy conditions over most of the country, there is a further general decrease of net radiation. The area of lowest values, less than 175 calories, extends northwards along the west coast and into the interior of the Peninsula. There is a decrease of about 25 calories in northwest India which continues to have the maximum net radiation in the country. The decrease is, however, maximum over the Gujarat State, by as much as 50—70 calories per day.

August — The pattern is more or less similar to that in July with a further decrease of net radiation over northwest India over the southern portion of the west coast, there is some increase as a result of slight decrease in monsoon activity.

September — The broad pattern remains the same as in August, but with a further decrease of net radiation over north India and increase over the south Peninsula associated with the southward movement of the sun. Net radiation exceeds 200 calories in northwest India and the south Peninsula with the rest of the country having values generally below 175 and 200 calories.

October — The southwest monsoon withdraws from most of the country before the end of October except in the south Peninsula where it is replaced by northeast monsoon. Thus clouding decreases over most of the country with resultant increase in short wave radiation receipt. However, with the further southward movement of the sun, day length decreases which results in a decrease in radiation receipt. The net result of these opposing factors is that there is an appreciable fall in net radiation in north India and some rise in north Maharashtra and adjoining areas of Gujarat and Madhya Pradesh. There is a fall in south Peninsula with the heavy clouding and rain over a number of days associated with the northeast monsoon.

November — With the setting in of winter conditions and shorter days there is a further fall of net radiation over the whole country, except the south Peninsula. The values are less than 100 calories over west Uttar Pradesh, Punjab, Jammu and Kashmir and northeast Assam and below 150 calories over rest of the country outside Peninsula.

December — Taking the country as a whole this is the month with the lowest amount of net radiation. In the Jammu-Kashmir area, it is of the order of 25 calories per day. The highest values of about 175 calories occur over the Kerala area. As in January, the radiation shows a latitudinal decrease from south to north.

5. Conclusion

It should be emphasized that the picture of net radiation given in the paper, represents the broad pattern over the country over bare soil surfaces. For other surfaces with greatly different albedo, suitable corrections will have to be applied. The authors realise the limitations of computed values. However, considering the fact that net radiation values for any month vary somewhat appreciably even from year to year, the tolerance that can be allowed for computed values for climatological purposes should be liberal. In any case it will be quite a long time before recorded data of this important parameter become available on an extensive scale for India. In the meantime, the figures presented in this paper are expected to serve climatological and agricultural requirements to a reasonable extent.

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