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# Net radiation distribution in India

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सार -- सुगमतापूर्वक उपलब्ध मौसम विज्ञानी आंकड़ों से अनेक अन्योन्याश्रित सूत्रों का उपयोग करते हुए वाल्टेयर में कुल विकिरण बंटन का अनुमान लगाया गया है । संगणित मान मापे हुए मानों से भली-भांति मेंल खाते हैं । देश में विभिन्न भागों के हरे भरे क्षेत्र पर कुल विकिरण का अनुमान लगाने के लिये तब सर्वोत्तम समीकरण का उपयोग किया गया है । वर्ष के विभिन्न महीनों में देश के निवल विकिरण बंटन की चर्चा इस शोध पत्र में की गई है ।

ABSTRACT. Net radiation at Waltair is estimated from easily available meteorological data using several inter-dependent formulae. The computed values agreed well with the measured values. The best of the equations is then used to estimate the net radiation over vegetation in different parts of the country. Net radiation distribution over the country in different months of the year is discussed.

## 1. Introduction

For many climatological and agricultural problems concerned with the energy budget, knowledge of the net radiation at the earth's surface is required. From the records of net radiation alone evaporation can be estimated using the Bowen's ratio neglecting the heat flow into the soil on a long-term basis. Knowledge of the net radiation available at the earth's surface is essential for maximum and minimum temperature forecasting. Much of the available net radiation at the surface is disposed off in the form of latent and sensible heat fluxes. Air temperature is, therefore, strongly dependent on the net radiotion available at the surface.

In India net radiation values over vegetation are not readily available. Therefore, it would be desirable to estimate net radiation over vegetation from other easily available meteorological data.

Linacre (1968) has derived several inter-dependent formulae for the estimation of net radiation. In this note Linacre's method is used to estimate the net radiation at Waltair. The estimated values agreed well with the measured values. The best of the formulae is then used to estimate the net radiation over vegetation in different parts of the country.

## 2. Estimation of net radiation

The net radiation flux is given by :

$$Q_n = Q_s (1-\alpha) - Q_{nl}$$

where,

$Q_n$ = net radiation in cal/cm²/min

$Q_s$ = incoming global radiation in cal/cm²/min

$\alpha$ = albedo

$Q_{nl}$ = net terrestrial radiation in cal/cm²/min

Assuming that in the case of a well-watered crop the surface temperature $T_g$ is equal to the air temperature $T$ and that the surface emissivity is unity, Linacre (1968) has shown that

$$Q_{nl} = 32.10^{-5}(1+4n/N)(100-T) \text{ cal/cm}^2\text{/min} \quad (2)$$

where $n$ and $N$ are the actual and maximum possible numbers of hours of bright sunshine.

From Eqns. (1) and (2) weget

$$Q_n = Q_s (1-\alpha) - 16.10^{-4} f(100-T) \text{ cal/cm}^2\text{/min} \quad (3)$$

where, $f = 0.2+0.8n/N$.

This equation is used to estimate the net radiation at Waltair

Measured values of mean monthly net radiation over a bare soil surface at Waltair have been reported by Jaganmohan Rao (1961) and Viswanadham (1967). According to them the albedo at the experimental site was 0.20 and the constants of the Ångstrom's equation A and B were 0.24 and 0.55 respectively. At Waltair the mean daytime air temperature in degrees Celsius is about forty times the incoming global radiation, in cal/cm²/min.

Using these approximations and Eqn. (3) two more expressions for net radiation can be derived.

$$Q_n = Q_s (0.064f + 0.8) - 0.16f \text{ cal/cm}^2\text{/min} \quad (4)$$

$$Q_n = Q_A (0.24 + 0.55n/N)(0.0512n/N + 0.8128) - 0.128\, n/N - 0.032 \text{ cal/cm}^2\text{/min} \quad (5)$$

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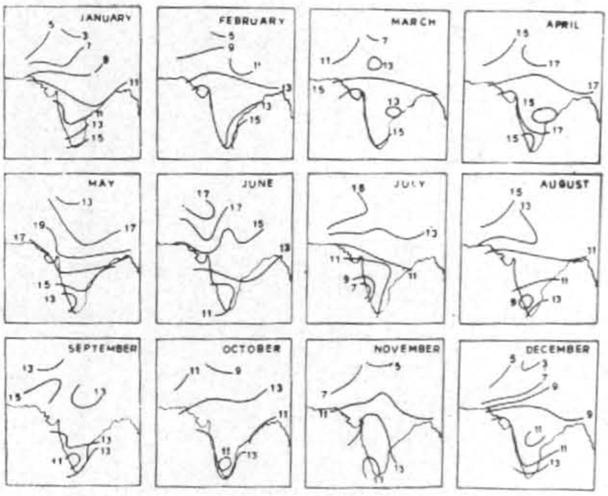


Fig. 1. Distribution of net radiation in India ($MJ/m^2/day$)

Mean daytime net radiation was estimated for 14 months using Eqns. (3), (4) and (5) and the values obtained are given in Table 1 together with the measured values. Net radiation is a field of finger millet (*Eleusine coracane*) crop has been measured by the senior author (Karuna Kumar 1979) during the months June, July and August 1977. Net radiation values on corresponding days have been calculated according to Eqn. (3) making use of the corresponding global radiation, albedo, temperature and cloudiness values. Measures and estimated net radiation values are given in Table 2.

Since Eqn. (3) estimated net radiation with a high degree of confidence it is felt worthwhile to use this expression for estimating net radiation over irrigated vegetation in different parts of the country.

Following Linacre, we assumed that for vegetation well supplied with water the surface and air temperatures are equal and that the surface emissivity is unity. The albedo of vegetation is taken to be 0.25. At each station and for each month day time and night time net radiation values were calculated and daily net radation values were derived taking into account the duration of sunshine.

**3. Data used**

In this note net radiation over vegetation at 26 stations evenly distributed over the whole country was estimated. The global radiation values and the number of actual and possible hours of bright sunshine for a few stations were taken from Ramdas' paper (1956) while values for the remaining stations were obtained from the India Meteorological Department, Pune. The mean monthly air temperatures were taken from the *Climatological Tables of Observatories in India* published by the India Meteorological Department.

**4. Results and discussion**

The important feature of the net radiation distribution over vegetation in India in January is a steady increase from north to south. Lowest values of about 3 $MJ/m^2$ in a day are found over Kashmir while values of about 15 $MJ/m^2$ in a day are found over the southern tip of the Peninsula. The north-south increase in net radiation is steeper in south India than in north India. The net radiation distribution pattern in this month is exactly similar to the mean temperature distribution.

The distribution in February differs much from that in the previous month though there is still a north-to-south increase in net radiation. There is a large increase over the whole of north India. The highest values occuring over Tamilnadu, equal 15 $MJ/m^2$ in a day while the lowest values of about 5 $MJ/m^2$ in a day are found over Kashmir.

The increase in the values of net radiation continues in the month of March. The increase is more pronounced over the central and north-western parts of of the country than in the southern parts. The lowest values are found over Kashmir.

In April, net radiation over most parts of the country is about 17 $MJ/m^2$. During this month also the net radiation distribution is similar to the temperature distribution.

In May, the highest values are found over the central parts of the country. Net radiation is 13 $MJ/m^2$ in a day over Kerala and gradually increases northward attaining a value of about 19 $MJ/m^2$ in a day over West Bengal, Rajasthan and Madhya Pradesh. Further northward, it decreases to 17 $MJ/m^2$ in a day. Lowest values are again found over Kashmir.

In June, net radiation distribution is exactly opposite to that in January. Highest values are found over Kashmir and the northwestern parts of the country while the lowest values are found over Kerala,

**TABLE 1**

**Measured and estimated values of day time net radiation ($J/cm^2$) at Waltair**

| Month | Net radiation measured | Net radiation calculated | | |
|---|---|---|---|---|
| | | Eqn. (3) | Eqn. (4) | Eqn. (5) |
| Jul 1960 | 796 | 812 | 852 | 938 |
| Oct 1960 | 1484 | 1472 | 1504 | 1504 |
| Sep 1963 | 1131 | 1149 | 1165 | 1220 |
| Nov 1963 | 1145 | 1162 | 1187 | 1187 |
| Jan 1964 | 1225 | 1228 | 1300 | 1267 |
| Mar 1964 | 1507 | 1477 | 1546 | 1432 |
| May 1964 | 1868 | 1855 | 1868 | 1717 |
| Jul 1964 | 1167 | 1184 | 1190 | 1326 |
| Sep 1964 | 1026 | 1044 | 1050 | 1128 |
| Nov 1964 | 1134 | 1134 | 1193 | 1128 |
| Jan 1965 | 1175 | 1142 | 1231 | 1214 |
| Mar 1965 | 1534 | 1513 | 1537 | 1416 |
| May 1965 | 1861 | 1828 | 1851 | 1677 |
| Jul 1965 | 1134 | 1134 | 1207 | 1283 |

**TABLE 2**

**Comparison between measured and estimated net radiation in a crop field at Anakapalle**

| Date (1977) | Net radiation ($MJ/m^2/day$) | | Date (1977) | Net radiation ($MJ/m^2/day$) | |
|---|---|---|---|---|---|
| | Measured | Estimated | | Measured | Estimated |
| 3 Jun | 12.10 | 12.26 | 5 Jul | 9.63 | 9.75 |
| 8 Jun | 15.86 | 15.82 | 7 Jul | 13.02 | 13.02 |
| 10 Jun | 14.61 | 14.61 | 9 Jul | 4.56 | 4.56 |
| 12 Jun | 13.65 | 13.81 | 11 Jul | 13.56 | 13.60 |
| 14 Jun | 14.23 | 13.81 | 16 Jul | 8.66 | 8.83 |
| 16 Jun | 4.69 | 4.81 | 18 Jul | 13.56 | 13.85 |
| 19 Jun | 13.27 | 13.14 | 19 Jul | 16.12 | 16.12 |
| 22 Jun | 14.61 | 14.48 | 21 Jul | 10.17 | 10.13 |
| 24 Jun | 14.27 | 14.19 | 22 Jul | 10.05 | 9.67 |
| 27 Jun | 15.28 | 15.28 | 27 Jul | 13.52 | 13.10 |
| 29 Jun | 8.79 | 9.18 | 28 Jul | 9.04 | 9.29 |
| 1 Jul | 4.52 | 4.60 | 3 Aug | 4.35 | 4.52 |

Tamilnadu and Karnataka. Due to the southwest monsoon there is a steep decrease in net radiation over the central and southern parts of the country. The lowest values, found over Kerala, Tamilnadu and Karnataka are about 11 $MJ/m^2$ in a day.

In July, the distribution is similar to that in the previous month. But there is a general decrease in net radiation over the whole country. Because of the monsoon the temperatures are lower than in the previous months and the cloudiness associated with the monsoon reduces the incoming global radiation reaching the surface. Highest values of about 15 $MJ/m^2$ in a day are found over the northwestern parts. In south India it decreases from east to west the values ranging between 11 $MJ/m^2$ in a day and 7 $MJ/m^2$.

The distribution in August is different from that observed in the previous month. The highest values are still found over the northwestern parts of the country. Net radiation over south India slightly exceeds that over the central parts of the country.

In September, net radiation distribution is very irregular. Over most parts of the country, daily values of about 13 $MJ/m^2$ or more are found. Highest values are found over Rajasthan and Punjab whereas in the previous month highest values are found further north. This is the beginning of the southward shift of the region of maximum net radiation. There is a slight increase over the southern parts of the country.

In October, net radiation over northern and northwestern parts is less than the corresponding values in September. The southward increase in net radiation which starts in the previous month is easily discernable during this month.

The southward increase in net radiation continues in November. Net radiation values of 7 $MJ/m^2$ and 5 $MJ/m^2$ are found over northwestern India and Kashmir respectively. Maximum values of 13 $MJ/m^2$ are found over Maharashtra, Madhya Pradesh and parts of Andhra Pradesh. Further southward net radiation again decreases reaching a value of about 11 $MJ/m^2$ over Kerala.

The net radiation distribution in December is similar to that found in January. Highest values (13 $MJ/m^2$) are found over the southernmost part of the country while the lowest values (3 $MJ/m^2$) are found over Kashmir. There is a continuous increase in net radiation with decrease in latitude, the gradient being the steepest in south India.

In its main features the net radiation distribution (over vegetation) given in this paper is similar to the net radiation distribution (over bare soil) given by Harihara Ayyer and Krishnamurthi (1968). However, there is much difference in net radiation values which can be traced to the differences in temperatures and albedoes of bare soil surfaces and well watered crop-surfaces. The net radiation values reported here are fairly close to those given by Ganesan (1970). He used different values for albedoes of different surfaces and hence obtained net radiation values higher than those computed by Harihara Ayyer and Krishnamurthi (1968) and closer to the values given in this paper.

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