Journal of Agrometeorology 7 (1) : 14-20 (June 2005)

Estimating solar radiation from temperature

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ABSTRACT

Historical at weather datasets of some locations of India were compiled for radiation, maximum and minimum temperatures. Relationship of solar radiation with the square root of the difference in maximum and minimum temperatures was obtained. The northern region showed greater range of annual variation in solar radiation when compared with central and peninsular regions. The relationship of ratio of solar radiation to square root of temperature range with the julian day for various diverse locations could account for 30-64 per cent variability, which was statistically significant. The rate of change of solar radiation, which was found to vary spatially as well as temporally.

Key words: Solar radiation, maximum and minimum temperatures

Solar radiation is the dominant, direct energy input into the terrestrial ecosystem; and it affects all physical, chemical, and biological processes. In order to understand the solar radiation as related to climate change, there is a need to develop a simple method for the determination of this solar radiation from easily available datasets.

The intensity of solar radiation varies temporally and spatially over locations along with a diurnal course of variation. Extra terrestrial radiation, at the top of the atmosphere, is primarily a function of latitude and day of the year (McVeigh, 1977; Michels, 1979). The atmospheric composition, which happens to be highly dynamic diurnally as well as seasonally, influences the extent of absorption, reflection and transmission of the solar radiation. synthetically active radiation. Accordingly the temperature also rises from an early morning minimum to afternoon maximum.

Increased demand for radiation data has led to the development of numerous predictive methods ranging from simple

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empirical methods (Ganesan, 1970) to complex numerical models, depending on the available input data. Parameters used in such models include, air temperature, cloudiness, relative humidity, precipitation etc. (Huxley, 1973; Goldberg *et al.*, 1979). Interaction between solar irradiance and the highly variable atmospheric constituents is extremely complex and not well documented, particularly for cloudy sky (Rizzi *et al.*, 1980).

There is a need to evaluate radiation from the daytime temperature range as several locations in the country record temperatures and rainfall. Solar radiation, received during the daytime, is usually related to the diurnal variation in temperature and thus range of temperature can predict the solar radiation. A useful relationship exists between solar irradiance and the range in daily temperature extremes (Das and Pujari, 1993).

MATERIALS AND METHODS

The weather data ranging from 10-30 years of thirty locations (listed-Table 1), scattered over the country, was collected from agro-meteorological and IMD stations. The prime weather parameters included were measured solar radiation, maximum and minimum temperatures. This data was used to generate relationship of solar radiation with the temperature range.

Solar radiation was related with square root of difference in maximum and minimum temperatures for different seasons viz., summer (April to June), *kharif* (July to October) and rabi (November to March). The linear relationship of the type

$$SRAD = A * SQRT(Tmax - Tmin) + B \quad \text{..... (1)}$$

where, is SRAD solar radiation (MJ m^{-2} d^{-1}), Tmax & Tmin are in maximum and minimum temperatures, A and B are regression coefficients. This relationship was obtained for five diverse locations, three for northern region and two for southern region.

The second type of relationship developed was that of Das and Pujari, 1993.

$$\frac{SRAD}{SQRT} = A*X^2+B*X+C, \quad \text{..... (2)}$$

Where, X is Julian day and regression coefficients A, B and C are specific to a location depending upon latitude, longitude, altitude, distance from the sea etc. These constants were developed on the basis of annual datasets for various locations.

Thirty locations (Table 2) were chosen to estimate the rate of change of

Table 1: Locations selected for solar radiation estimation

Location	Year	Latitude (°N)	Longitude (°E)
Annigeri	1973-97	15.13	75.05
Aurangabad	1969-96	19.97	75.30
Bellary	1969-96	15.15	76.85
Bheemara	1980-97	16.60	76.83
Bijapur	1983-97	16.80	75.72
Coimbatore	1961-94	11.00	77.00
Cuttack	1968-95	20.50	85.90
Delhi	1968-94	28.60	77.20
Dharwad	1974-95	15.43	75.12
Gulbarga	1969-93	17.35	76.85
Gwalior	1960-88	26.20	78.20
Hagari	1974-97	15.17	77.07
Hisar	1969-95	29.20	75.70
Hyderabad	1975-98	17.40	78.50
Indore	1960-97	22.70	75.90
Jabalpur	1970-96	23.20	79.90
Jammu	1970-00	32.70	74.90
Jeur	1970-96	18.20	75.20
Jodhpur	1963-99	26.30	73.00
Ludhiana	1975-96	30.90	75.80
Nandyal	1989-96	18.47	76.48
Parbhani	1969-96	19.30	76.80
Patanch	1974-96	17.50	78.27
Patna	1967-80	26.50	85.20
Pune	1990-96	18.32	73.51
Rahuri	1976-96	19.40	74.65
Raichur	1986-96	16.20	77.35
Saharanpur	1960-91	29.90	77.35
Solapur	1969-92	17.67	75.90
Varanasi	1990-97	25.30	79.50

Table 2: Linear relationship of solar radiation with square root of temperatures range in different seasons [SRAD=A*SQRT(Tmax-Tmin)+B]

Location	A	B	R^2	A	B	R^2
		Summer			Kharif	
Coimbatore	0.130	0.060	0.40	0.147	0.024	0.32
Hyderabad	0.150	0.015	0.50	0.168	-0.005	0.45
Ludhiana	0.110	0.126	0.30	0.140	0.081	0.41
Karnal	0.107	0.197	0.40	0.135	0.150	0.44
Delhi	0.090	0.250	0.20	0.120	0.200	0.40
		Rabi			Annual	
Coimbatore	0.119	0.143	0.40	0.129	0.087	0.40
Hyderabad	0.140	0.066	0.54	0.143	0.073	0.53
Ludhiana	0.190	-0.140	0.41	0.140	0.060	0.40
Karnal	0.140	0.085	0.45	0.110	0.190	0.44
New Delhi	0.110	0.189	0.20	0.093	0.026	0.30

solar radiation in various seasons. The locations were well spread over the country to get an overall estimate of climate change (in terms of radiation). The latitude, longitude and duration of the historic weather datasets used have been reported. IDRISI package was used to delineate the regions within the country on the basis of the extent of radiation change over time and season.

RESULTS AND DISCUSSION

(a) Linear relationship

The linear relationship developed between solar radiation and temperature range for different seasons as well as for annual are reported in Table 2 for selected stations.

In summer season, the value of A was relatively higher in southern locations when compared with the locations falling in the north, whereas as the reverse in trend was noticed for B. The degree of prediction was relatively better for locations in the south.

In *kharif* (monsoon) season, the degree of prediction of solar radiation was relatively poor in the southern location, whereas the predictability in northern locations got improved. For Hyderabad, the value of A was highest compared with other locations and thereby resulting in relatively smaller but negative value of B. The result was quite contrasting due to relatively higher

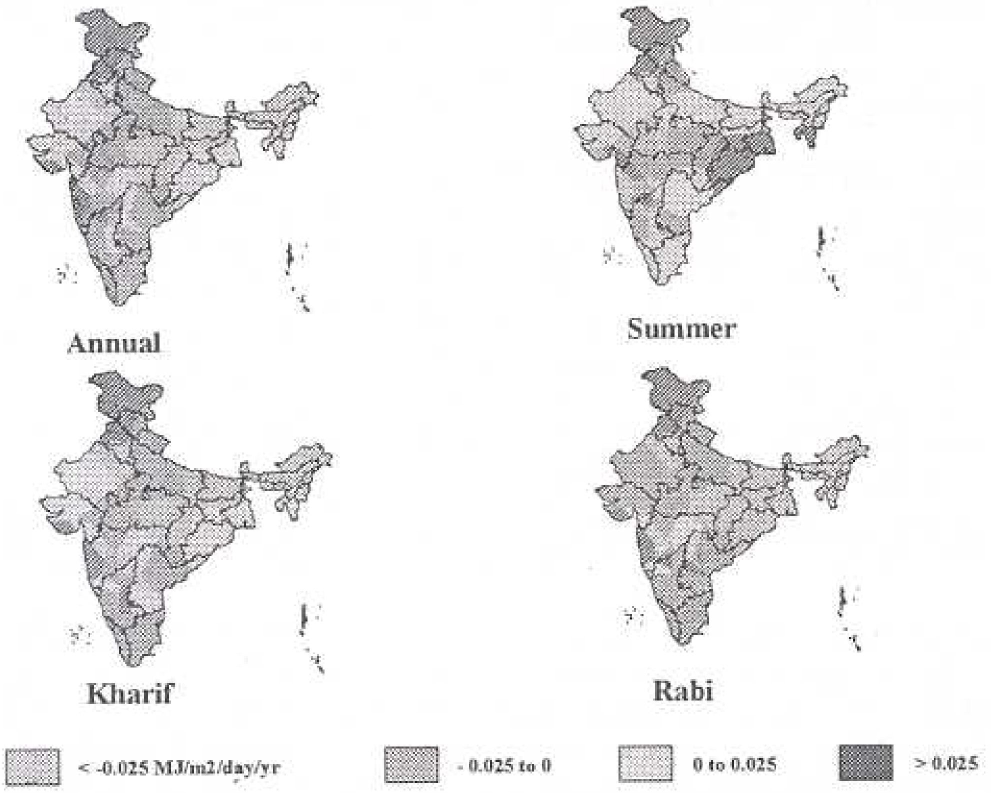

Fig. 1 : Spatial and temporal course of solar radiation change in different seasons

but positive values of B for the other locations. In the rabi season; similar trend was noticed for Ludhiana, where B was large but negative along with higher slope for A.

The degree of prediction for solar radiation in the *rabi* (winter) season was statistically significant at all locations, excepting for New Delhi environment. On annual basis, the degree of prediction ranged from 0.30 (New Delhi environment) to 0.53 (Hyderabad environment), along with intermediate average value of 0.41 for other locations.

(b) Relationship as quadratic function of Julian day

The relationship developed as per equation two for selected stations of India are presented in Table 3. It may be sean that the value of the regression coefficients are different for locations and R^2 ranged from 0.30 to 0.64 which

Table 3: Regression coefficients and predictability for estimating solar radiation at a given time of the year for various locations.

Location	A	B	C	R^2
New Delhi	-0.00010	0.052	2.24	0.60
Hissar	-0.00010	0.041	2.23	0.51
Jodhpur	-0.00010	0.037	3.38	0.58
Karnal	-0.00010	0.050	2.32	0.64
Ludhiana	-0.00010	0.040	2.26	0.50
Saharanpur	-0.00010	0.048	2.31	0.60
Cuttack	-0.00008	0.030	4.10	0.30
Indore	-0.00008	0.030	3.43	0.30
Jabalpur	-0.00010	0.040	3.40	0.34
Patna	-0.00010	0.040	3.29	0.41
Varanasi	-0.00010	0.040	3.14	0.50
Coimbatore	-0.00005	0.020	4.20	0.30
Hyderabad	-0.00006	0.022	4.32	0.41

were statistically significant. The degree of prediction was higher for locations in the Northern and Western regions, whereas it was poor for locations in southern and eastern regions.

This method of radiation determination can be employed successfully for simulation exercises. The chances of error propagation with this simple approach are also reduced when the radiation estimates are integrated over a period of time, viz. for *kharif, rabi* or summer seasons.

(c) Trend analysis

Trend of solar radiation variation in different seasons over locations indicated mixed trend of increase/ decrease in the rate variation. Regions in western Himalayas showed an increase in all the seasons (Fig. 1). On annual basis, the decrease in the rate of variation of radiation per year was noticed in most locations excepting parts of Rajasthan, Gujarat, Maharashtra and Andhra Pradesh, where increased values were noticed. Similar trend was noticed for *kharif* season. During the winter (*rabi*) season, decrease in radiation was noticed in almost all parts of the country (excepting parts of western Himalayas, Gujarat and Maharashtra). During the summer season, increased variation in radiation was noticed in almost all parts of the country, excepting in Maharashtra, Karnataka, Madhya Pradesh, Gujarat and Uttaranchal. Since these trends have been worked out from the historic datasets collected over years (10-30 years) for locations, these results should be used with caution. There is a need to in-depth work out the extent of the radiation change for various locations of the country. But the reported results clearly indicate the differential course of spatial and temporal changes in the country.

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