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Relation between global solar radiation and duration of sunshine in Tehran and Karadj

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ABSTRACT. Using mean monthly values of the relative global solar radiation, Q_m/Q_c, and the relative duration of sunshine, n/N, the least square regression constants a and b in equation $Q_m/Q_c = a + b \, (n/N)$ and the correlation coefficient, r have been calculated for Mehrabad, Tehran ($a=0.25$, $b=0.48$, $r=0.90$), Karadj ($a=0.38$, $b=0.35$, $r=0.79$), and also for Mehrabad (Tehran) and Karadj collectively ($a=0.30$, $b=0.43$, $r=0.84$), Q_m^* and Q_c being the daily global solar radiation received by one square centimetre of horizontal surface measured on the earth and calculated for the top of the atmosphere, respectively, and n and N the actual and the possible maximum duration of sunshine respectively. It is seen that the sum $a+b$ remains constant.

Furthermore, the ratio $(Q_m/Q_c)_M/(Q_m/Q_c)_K$ is considered for clear days, where M and K stand for Mehrabad and Karadj stations. The ratio is generally less than unity, indicating that less radiation is normally received in Mehrabad (Tehran) compared to Karadj in a clear day.

1. Introduction

In order to estimate the solar radiation received on the earth, Angstrom suggested an empirical linear relationship between the global solar radiation and the duration of sunshine in 1924. Since then, similar relations have been established by several investigators (Prescott 1940, Penman 1948, Black *et al.* 1954, Glover and McCulloch 1958a and 1958b, Exell 1976 etc) for a number of stations with various latitudes and altitudes.

It is now possible to compute the global solar radiation by making use of the information on the altitude of the sun, the atmospheric turbidity, the types, thickness, water droplet content and the amount of clouds. However, the lack of precise information particularly on the latter quantities and the complication of the computation makes this method not always desirable.

Since the duration of sunshine is available for various regions in Iran, and due to the simplicity of the relationships of the type suggested by Angstrom and the others, in order to investigate the relationship between the global solar radiation and the duration of sunshine the equation:

$$Q_m/Q_c = a + b \, (n/N) \qquad (1)$$

is used in this work, where Q_m and Q_c are the daily global solar radiation received by one square centimetre of horizontal surface measured

on the earth and calculated for the top of the atmosphere, respectively, and n and N are the actual and the possible maximum duration of sunshine, respectively. It is also to be mentioned that since the effects of the astronomical factors are cancelled in this equation, it becomes possible to compare the duration of sunshine and also radiation climate of different regions.

2. Records and Instruments

Daily values of Q_m and n were available from Mehrabad (Tehran) and Karadj Meteorological Observatories of Iranian Meteorological Organization (IMO) for the three years 1974 to 1976 inclusive, except for the Karadj station where the record of radiation was not completed for 1974. Mehrabad and Karadj stations are located, respectively, at Lat. 35°41′ N, Long. 50° 19′ E and 35°47′ N, 50°00′ E, and heights 1191 and 1313 m above mean sea level.

The Moll-Gorczynski pyranometer is used to measure the global solar radiation and the records of the duration of sunshine are obtained by the Campbell-Stokes recorder in both stations.

3. Analysis of records and the results

In addition to the daily values of the ratios Q_m/Q_c and n/N, the mean monthly values are also computed for each month of the period and plotted in Fig. 1.
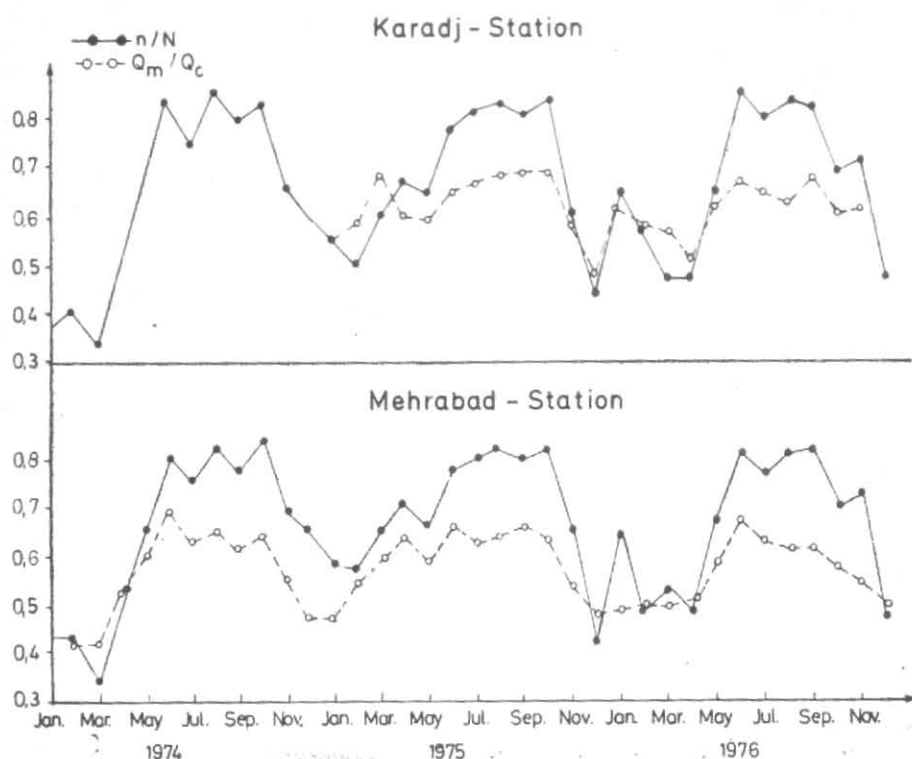
Fig. 1. Mean monthly, relative global solar radiation (Q_m/Q_c) and duration of sunshine (n/N) at Mehrabad (Tehran) and Kardaj stations

Monthly values of n/N are plotted against the corresponding values of Q_m/Q_c in Figs. 2, 3 and 4 respectively, for the Mehrabad, Karadj and Mehrabad and Karadj collectively. Then, the parameters a and b are reckoned by the least square method and the regression lines are drawn on the corresponding figures, where the dots represent the measured values.

The equations of the regression lines deduced so far are as follows.

For the Mehrabad station:

$$Q_m/Q_c = 0.25 + 0.48 \ n/N, \quad a+b=0.73,$$
$$r = 0.90 \tag{2}$$

For the Karadj station:

$$Q_m/Q_c = 0.38 + 0.35 \ n/N, \quad a+b=0.73,$$
$$r = 0.79 \tag{3}$$

For the two stations collectively:

$$Q_m/Q_c = 0.30 + 0.43 \ n/N, \quad a+b=0.73,$$
$$r = 0.84 \tag{4}$$

where r is the correlation coefficient between Q_m/Q_c and n/N.

As deduced from equations 2, 3 and 4 and given following each equation, the sum of a and b is actually constant with a value of 0.73. Also,

the following points may be seen in Fig. 1:

(1) A good correlation between Q_m/Q_c and n/N, particularly in the case of Mehrabad station which is also indicated by the correlation coefficient $r=0.90$, deduced from Fig. 2.

(2) Analogous of the corresponding curves for the two stations which is accounted for the small differences in latitude and altitude of the two stations.

(3) A very pronounced and consisting maximum from June to September which may occasionally be extended up to October.

(4) Minimum occurring sometime between December and the March of the following year.

In addition, the amount of daily relative global solar radiation received at two stations in clear days has been compared. The result of this comparison shows that in 95 per cent of the cases the ratio $(Q_m/Q_c)_M/(Q_m/Q_c)_K$ is less than unity, where M and K stand for Mehrabad and Karadj stations. This means that there is often less radiation received in Tehran (Mehrabad) than in the Karadj which may be accounted mainly for the relatively excessive air pollution in Tehran.
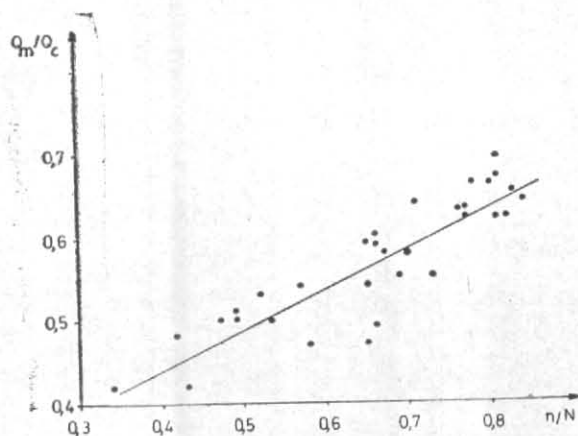
Fig. 2. Relation between Q_m/Q_c and n/N using mean-monthly values for Mehrabad (Tehran) station, 1974-1976
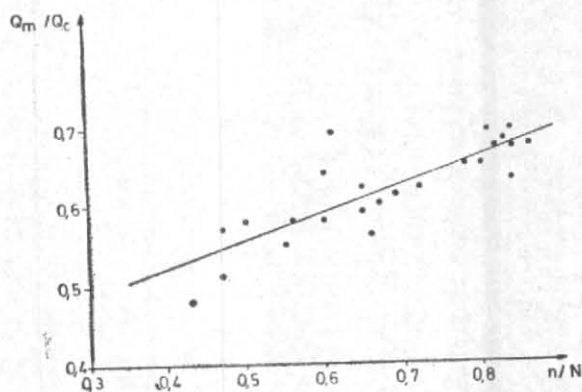

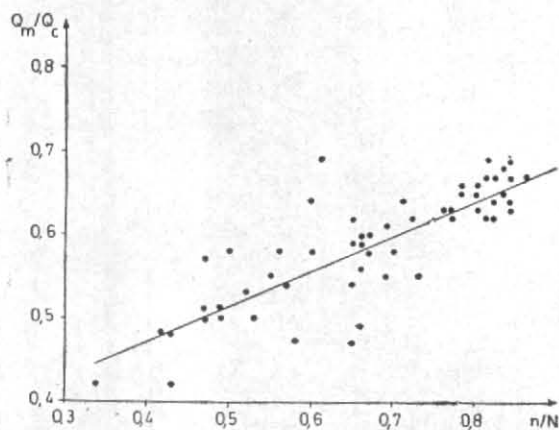Fig. 3. Same as Fig. 2, but Karadj station and except for 1974

Fig. 4. Same as Figs. 2 and 3, but Mehrabad (Tehran) and Karadj stations collectively

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