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ESTIMATION OF DAILY INCOMING SOLAR RADIATION AND ITS REFLECTION FROM SEA SURFACE OFF ALEXANDRIA COAST.

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ABSTRACT

The daily incoming solar radiation and the reflected radiation from sea surface off Alexandria coast are estimated using an empirical formulae. The total incoming radiation by clear sky varied between 296 gm cal cm^{-2} day^{-1} (during winter) and 892 gm cal cm^{-2} day^{-1} (during summer). The daily incoming solar and sky radiation slightly decreased from that radiation by clear sky due to the influence of clouds. The amounts of these radiations oscillate between 181 and 892 gm cal cm^{-2} day^{-1}.

The daily reflected radiation by clear sky changed from about 36 to 56 gm cal cm^{-2} day^{-1}. The presence of clouds reduces the amount of insolation and hence reduces the amount of reflected radiation from sea surface. The minimum reflected solar and sky radiation is 24 gm cal cm^{-2} day^{-1} while the maximum value is about 56 gm cal cm^{-2} day^{-1}.

INTRODUCTION

The only important heat source is solar radiation, which reaches the sea surface in the form of direct solar radiation and diffused sky radiation. Observations conducted over a period of years indicate that the solar radiation dose not change appreciably from year to year and varies only with latitude and season. In addition, the insolation differs locally, it depends on the altitude of the sun and on the length of the day from sunrise to sunset. The knowledge of the amount of incoming solar radiation and its reflection from sea surface is necessary and very important in calculation the heat balance terms for any region and also in some biological studies.

Laevastu (1960) derived an empirical formulae for the computation of insolation and its reflected amount from sea surface on a daily basis using the 102 full-day radiation measurements made on board USS "Rehobot" (U.S. Navy Hydrographic Office,1955) at different latitudes and during different seasons.

The reflection of the diffused sky radiation, having an average value of 6 % is taken for the whole day according to Ahmad (1982).

There are no any measurements of these incoming and reflected radiation from sea surface off Alexandria to make a comparison between these measurements and the calculated values and to derive their empirical formulae for the investigated area. Thus, in this study, I try to do a simple attempt to calculate the amount of incoming solar radiation and its reflected value from sea surface off Alexandria coast using the perfect known empirical formulae. This attempt is very effective and useful for computation of the heat budget for the coastal waters off Alexandria and may be used in biological and other studies later.

DATA AND METHODS

To calculate the daily incoming solar radiation off Alexandria coast, the amount of clouds is only needed. The cloud data were obtained from the meteorological station located at Kait Bey. Only one year cloud data (1977) were taken to compute the amount of insolation with varying cloudiness.

The astronomical parameters for Alexandria (Kait Bey) such as solar declination, astronomical daylength and solar altitude are calculated using Page (1986)'s equations. The total incoming radiation and the reflected radiation from sea surface are estimated using Laevastu (1960)'s formulae. These equations may be written as follows:

I) Basic equations needed to predict the solar declination, daylength and solar altitude:

$$J' = 360^{o}\ J/365.25$$

J is the number of the day in the year measured from noon on the 31 st December.
J' is the day angle (degrees).

$$= \sin^{-1}(0.3978\ \sin(J'-80.2^{o} + 1.92^{o}\ \sin(J'-2.80^{o})))$$

is the solar declination (degrees).

$$t_d = \cos^{-1}(-\tan\quad \tan\quad)/7.5$$

t_d is the astronomical daylength (hours).
is the latitude of the site. (=31.2^{o} for Alexandria)

$$w = 15(t-12)$$

w is the solar hour angle (degrees).
t is the local apparent (solar) time (hours).

$$A = \sin^{-1}(\sin\quad \sin\quad + \cos w \cos\quad \cos\quad)$$

A is the solar altitde (degrees).

II) Empirical formulae used for estimating the total incoming radiation and the reflected radiation from sea surface:

a- Total incoming radiation by clear sky (Q_{os}):

The formula used for determining incident radiation per 24 hours with a clear sky is written as:

$$Q_{os} = K\ A_n\ t_d \qquad (g\ cal\ cm^{-2}(24\ h)^{-1})$$

K is the proportionality factor = 0.014
A_n is the noon altitude of the sun (degrees).
t_d is the length of the day from sunrise to sunset (minutes).

The above formula is valid up to about 75^o of the noon altitude of the sun. Above this altitude, the formula becomes:

$$Q_{os} = 1.06\ t_d \qquad (g\ cal\ cm^{-2}(24\ h)^{-1})$$

b- Total incoming solar and sky radiation (Q_s):

The influence of cloudiness on insolation can be represented by the following formula:

$$Q_s = Q_{os}\ (1-0.0006\ C^3) \qquad (g\ cal\ cm^{-2}\ (24\ h)^{-1})$$

C is the cloudiness (in tenth of the sky).

The results of using the above formulae gives insolation values which may vary on an average ± 10 % from the measured values.

c- Reflection back from the sea surface (Q_r):

The amount of daily reflected radiation (Q_r) is computed from the daily insolation (Q_s) by the formula:

$$Q_r = 0.15\ Q_s - (0.01\ Q_s)^2 \qquad (g\ cal\ cm^{-2}\ (24\ h)^{-1})$$

RESULTS AND DISCUSSION

1) Astronomical parameters:
i- Solar declination:

Solar declination is a main astronomical parameter which used to determine the astronomical daylength and the altitude of the sun. From these determination the amount of insolation can be calculated.

Figure. 1 shows the daily solar declination for Alexandria (Kait Bey). At 1st of January the sun is located south of the equator (negative declination) and moves northward. At 21st of March it crosses the equator to the north and the declination becomes positive and increases to reach a maximum value during the periods of 20, 21 and 22 of June. Then the sun starts to move southward and crosses the equator again to the south at 23rd of September. The declination continues to decrease to reach a minimum value at times of 21, 22 and 23 of December.

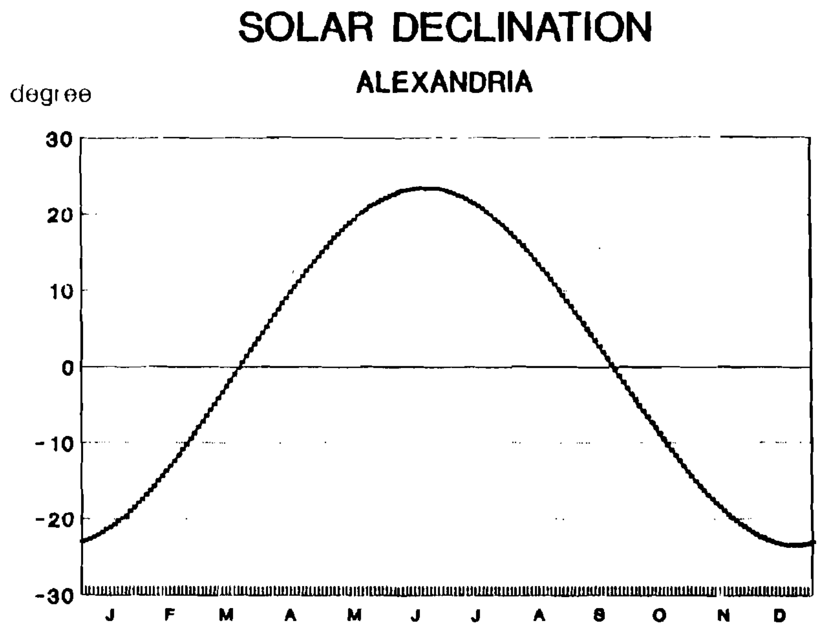

Fig. 1

The daily solar declination for Alexandria.

ii- Astronomical daylength:

Figure. 2 shows the astronomical daylength (hours) for Alexandria. The length of the daylight period increases from 10.01 hours at 1st of January to reach a maximum period of 14.03 hours during the period from 18 to 25 of June. Then the daylength begins to decrease gradually to reach a minimum time 9.97 hours through the period from 19 to 25 of December.

iii- Noon solar altitude:

The noon solar altitude for Alexandria is shown in Fig. 3. It increases from 35.79^{o} at 1st of January to reach a maximum altitude 82.24^{o} during the period of 19, 20 and 21 of June. After this time, it decreases to reach a minimum value of 35.36^{o} during the period of 21 and 22 of December.

2) The insolation:

Figure. 4 shows the daily incoming radiation by clear sky (Q^{os}). The general pattern of this Fig. is similar to that of Fig. 2 and Fig. 3 because the incoming radiation, as mentioned before, is a function on both daylength and noon altitude of the sun. The total incident radiation increases from 301.08 g cal cm^{-2} day^{-1} at 1st, of January to reach a

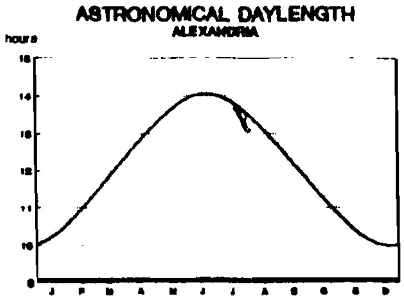

Fig. 2

Length of the day for Alexandria.

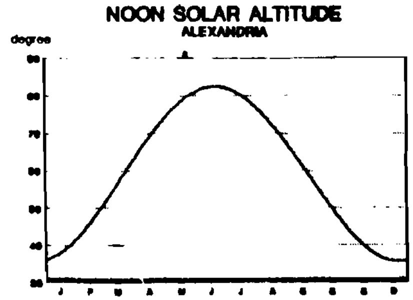

Fig. 3

Noon altitude of the sun for Alexandria.

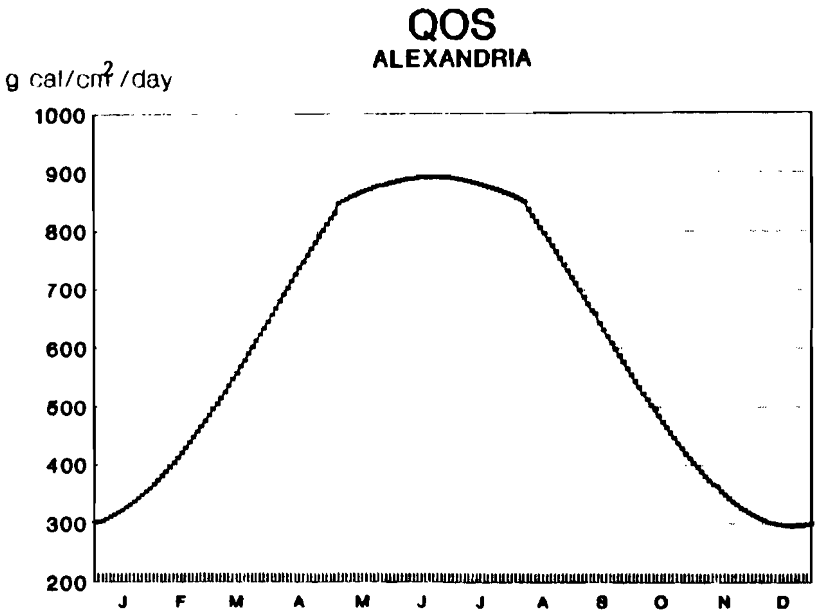

Fig. 4

The total incoming radiation by clear sky.

maximum amount of 892.32 g cal cm^{-2} day^{-1} at 21st of June. Then it decreases to reach a minimum one 296.16 g cal cm^{-2} day^{-1} at 22 of December.

Figure. 5 shows the curve of daily incoming solar and sky radiation (Q_s). The oscillatory feature of this curve is due to the variability in the amount of clouds. It is known that the clouds both absorb and reflect some of the incident solar radiation. Thus, presence of cloud leads to reduce the amount of radiation received from the sun. So, the general pattern of Fig. 5 is nearly the same as that of Fig. 4 but with slightly lower values. The following Table 1 shows, as an example, the amounts of incident radiation Q_{os} and Q_o at 1st and 15th days of each month with different amount of clouds.

Figure. 6 shows a daily amount of clouds off Alexandria coast for the year 1977.

Now, the calculated daily incident radiation Q_s (g cal cm^{-2}) was divided by the length of the day t_d (in minutes) and plotted on the abscissa with the noon altitude of the sun A_n as ordinates with different cloudiness (0, 2.5, 5.0 & 7.5) as shown in Fig. 7. The average daily incident radiation increases with increasing the noon solar altitude until an altitude of about 75°. Above this altitude the average daily incident radiation is constant.

To study the role of cloudiness on insolation at the same conditions of daylength and noon solar altitude, the amount of clouds is considered a constant (from 0 to 10) overall the year. Fig. 8 shows the total incoming radiation with constant cloudiness (0, 2, 4, 6, 8 & 10) only for one month (January). The insolation decreases with increasing cloudiness. The difference between the insolation curves with cloudiness o & 2 is very small. This difference increases slightly with increasing cloudiness. The maximum difference occurred between insolation curves with cloudiness 8 and 10.

3) Reflected radiation from sea surface:

The daily reflected radiation from sea surface off Alexandria coast by clear sky is shown in Fig. 9. The reflected radiation (Q_{or}) increases from 36.10 g cal cm^{-2} day^{-1} at 1st of January to reach a maximum value 56.25 g cal cm^{-2} day^{-1} at 17 and 18 of April. Then it slightly decreases to about 54.22 g cal cm^{-2} day^{-1} at 21 and 22 of June. Follow that an increase of (Q_{or}) to a second maximum value 56.25 g cal cm^{-2} day^{-1} at 25 and 26 of August. From this situation the reflected radiation starts to decrease to reach a minimum value 35.65 g cal cm^{-2} day^{-1} at 22 of December.

Figure. 10 shows the daily reflected radiation from sea surface (Q_r) by considering the influence of cloudiness on insolation. The main feature of this Fig. is similar to that of Fig. 9. The oscillation pattern in Fig. 10 is due to the cloud variations. Table 1 shows some of reflected radiation (Q_r) with different amount of clouds.

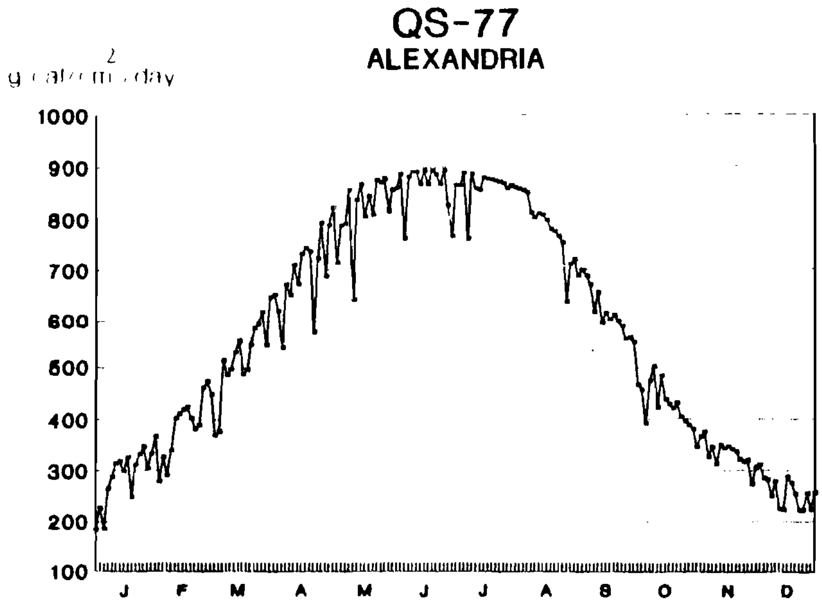

Fig. 5

The total incoming solar and sky radiation.

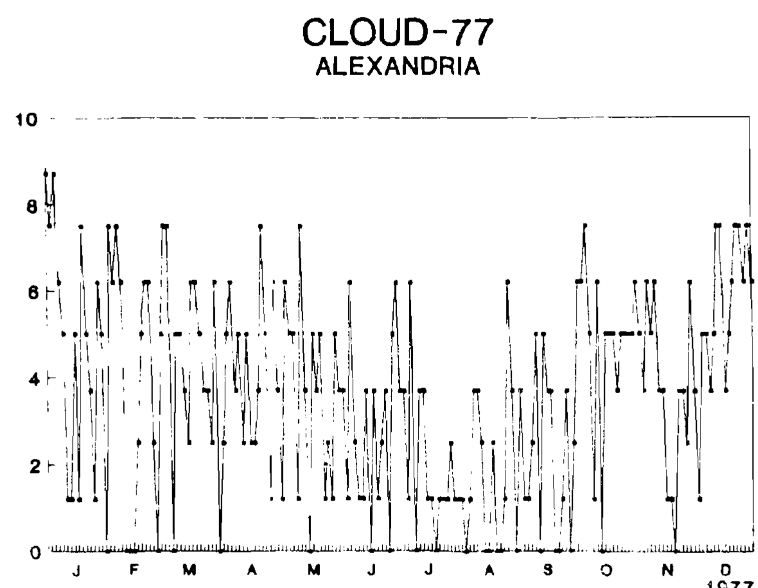

Fig. 6

The daily amount of clouds off Alexandria.

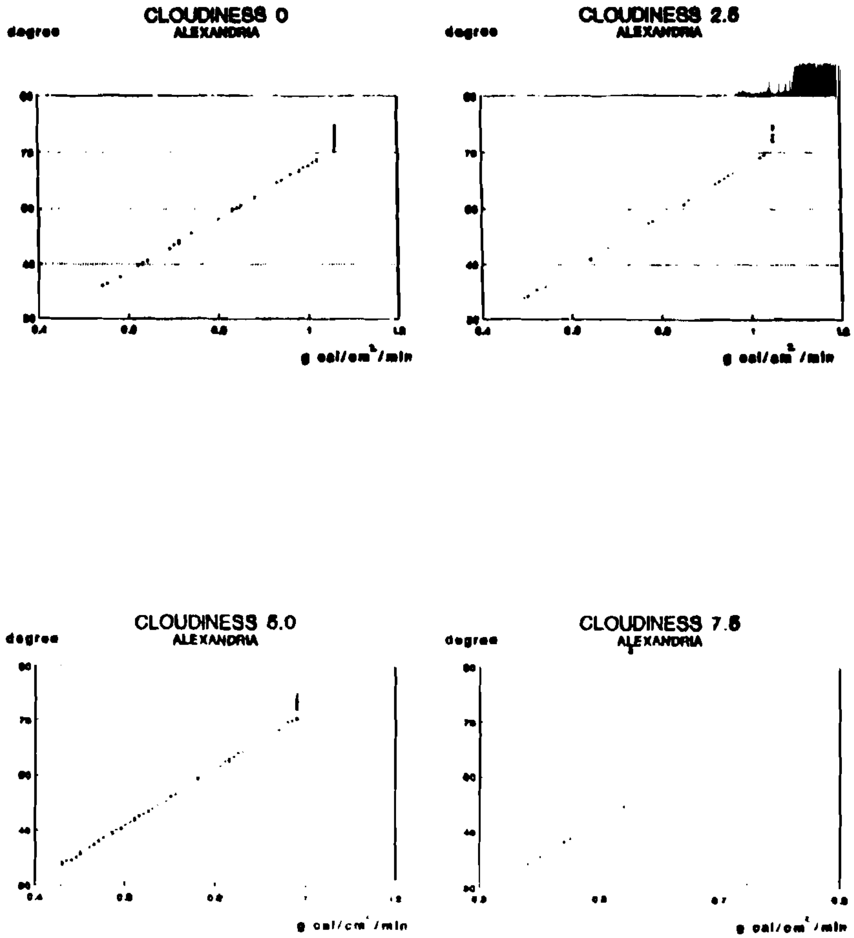

Fig. 7

Average daily incident radiation at different noon altitudes of the sun (cloudiness 0, 2.5, 5.0 & 7.5).

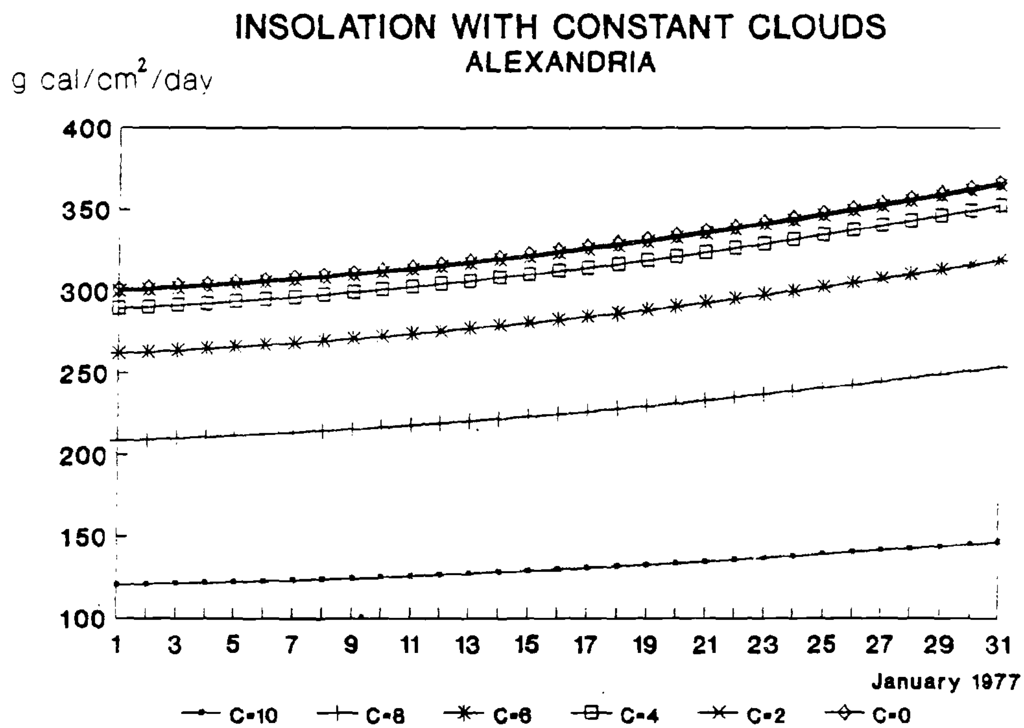

Fig. 8

The total incoming radiation with constnat clouds.

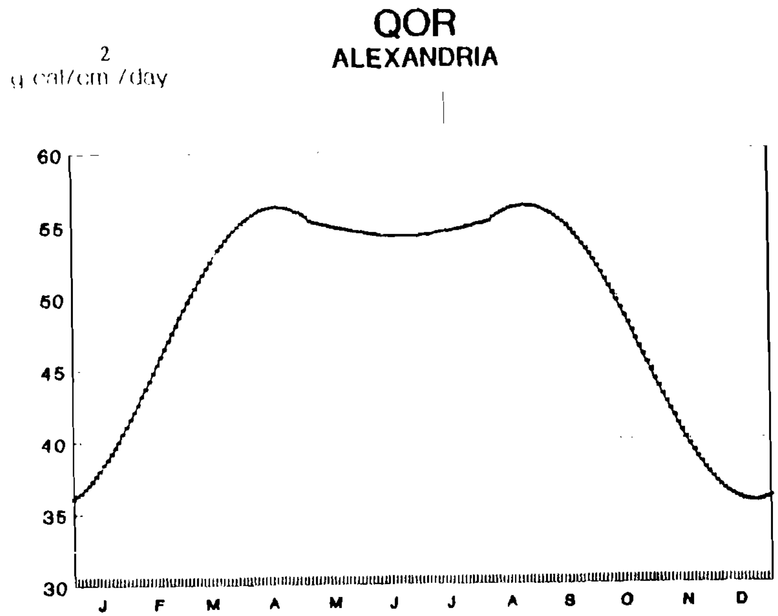

Fig. 9

The reflected radiation without cloudiness.

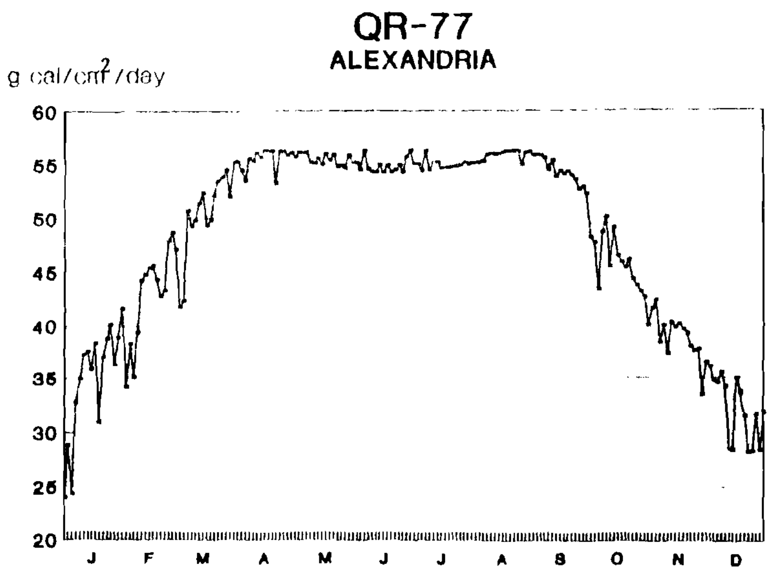

Fig. 10

The reflected radiation with cloudiness.

Table 1.

The amount of insolation and reflected radiation at 1st, 15th days of each month with different cloudiness off Alexandria coast.

Day	C	Q_{os}	Q_s	Q_r
1	8.7	301.08	182.12	24.00
15	5.0	322.57	298.38	35.85
32	6.2	369.97	317.06	37.51
46	2.5	424.17	420.19	45.37
60	3.7	489.33	474.46	48.66
74	3.7	562.56	545.46	52.07
91	2.5	657.67	651.51	55.28
105	2.5	736.79	729.88	26.21
121	1.2	822.13	821.28	55.74
135	0.0	864.43	864.43	54.94
152	3.7	883.61	856.75	55.11
166	1.2	891.47	890.55	54.27
182	3.7	890.26	863.21	54.97
196	1.2	880.51	879.60	54.57
213	1.2	859.72	858.83	55.07
227	0.0	806.12	806.12	55.94
244	5.0	714.84	661.22	55.46
258	6.2	636.58	545.55	52.07
274	5.0	549.10	507.92	50.39
288	5.0	478.01	442.16	46.77
305	6.2	403.03	345.40	39.88
319	3.7	353.89	343.13	39.70
335	3.7	314.99	305.42	36.48
349	7.5	298.17	222.69	28.44

CONCLUSION

Laevastu (1960) equations are used to calculate the amounts of daily incoming solar radiation and its reflected value from sea surface off Alexandria coast. These calculations give a good idea about the daily variations of these two parameters due to the lag in their measurements. The result of this estimation showed that:

The total incoming radiation by clear sky increases from winter to summer. The maximum amount 892.32 g cal cm^{-2} day^{-1} is calculated at 21^{st} of June. The minimum value 296.16 g cal cm^{-2} day^{-1} is occurred at 22 of December.

The total incoming solar and sky radiation oscillate with slightly lower values from that by clear sky due to the effective influence of clouds. The maximum value 892.01 g cal cm^{-2} day^{-1} is estimated at 25 of June 1977. The minimum one 180.75 g cal cm^{-2} day^{-1} is calculated at 14 of December 1977.

The daily reflected radiation by clear sky has a maximum value 56.25 g cal cm^{-2} day^{-1} calculated at two different times 17 & 18 of April and 25 & 26 of August. The minimum value 35.65 g cal cm^{-2} day^{-1} is occurred at 22 of December.

The presence of clouds reduces the amount of insolation and hence reduces the amount of reflected radiation from sea surface. The maximum reflected radiation 56.25 g cal cm^{-2} day^{-1} occurred at 18 of May and at 25 of August 1977. The minimum value 24.00 g cal cm^{-2} day^{-1} is calculated at 1^{st} of January 1977.

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