SUNLIGHT: A Computer Program for Calculation of Daily Solar Radiation

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Abstract

This paper presents an algorithm and software (available from ICLARM) for estimating the possible amount of sunlight that may fall on any location of the earth, any day of the year, as might be required for ecological modelling.

Introduction

Solar radiation is an important variable governing the productivity of aquatic and terrestrial ecosystems. Meteorological stations often measure it on a daily basis in form of energy reaching the surface of the earth, expressed in Watts/m^2, formerly in Joules/cm^2/day and Langleys/day. Bright sunshine on the surface of the earth is a value smaller than the theoretically possible amount of sunshine, due to cloud cover and other impurities in the atmosphere.

Often, measured values are compared with the theoretically available amount of solar radiation on top of the atmosphere. Roughly, the amount of solar radiation reaching the earth's surface is two-thirds of that reaching the top of the atmosphere. The latter can be calculated based on relationships known in astronomy, which are governed by day length, solar declination and the distance between the earth and the sun.

Possible Daily Sunshine

The theoretical daylength varies according to the time of the year and can be calculated with the common equation for solar elevation (Milankovitch 1930):

$$\cos Z = \sin LAT * \sin D + \cos LAT * \cos D * \cos h$$

where:

Z = solar zenith angle
LAT = latitude of the location in degrees
D = solar declination in radians
h = hour angle in degrees

At sunrise or sunset, cos Z = 0 and h = H, which is the half-day length in degrees. It follows (Sellers 1965):

$$\cos H = - \tan LAT * \tan D \quad ...(2)$$

and

$$H = \arccos(-\tan LAT * \tan D) \quad ...(3)$$

Since one hour equals 15 degrees, the astronomical half-day length for any given location on the globe can be calculated. Doubling the value produces the possible time of bright sunshine for any particular day of the year.

Table 1. Abbreviated sample table output of estimated solar radiation for latitude 10.5°

Latitude: 10.5°

Day	Hrs. light	Langleys per day	Joules per cm^2 per day	Watts per m^2
0	11.40	731.767	3,063.178	510,354.250
1	11.40	732.587	3,066.608	510,925.813
2	11.40	733.474	3,070.321	511,544 313
3	11.40	734.429	3,074.320	512,210.625
4	11.41	735.449	3,078,591	512,922.313
5	11.41	736.535	3,083.135	513,679.281
6	11.41	737.686	3,087.955	514,482.469
7	11.42	738.899	3,093.031	515,328.094
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
352	11.39	727.573	3,045.622	507,429.344
353	11.39	727.463	3,045.160	507,352.375
354	11.39	727.425	3,045.001	507,325.875
355	11.39	727.460	3,045.147	507,350.219
356	11.39	727.746	3,046.344	507,549.563
358	11.39	727.997	3,047.395	507,724.719
359	11.39	728.321	3,048.752	507,950.750
360	11.39	728.717	3,050.408	508,226.781
361	11.39	729.185	3,052.366	508,552.969
362	11.39	729.723	3,054.619	508,928.281
363	11.39	730.332	3,057.171	509,353,438
364	11.39	731.012	3,060.017	509,827.563

The solar declination depends only on the day of the year, for which an exact approximation is given by Spencer (1971):

$$D = -0.399912 * \cos A + 0.070257 * \sin A - 0.006758 * \cos 2A * 0.000907 * \cos 3A + 0.001480 * \sin 3A \quad ...(4)$$

The angle, A, is obtained by converting the day of the year J (Jan. 1 = 0, Dec. 31 = 364) to radians:

$$A = J\, 2 * \pi / 365 \quad ...(5)$$

Solar Radiation

Here, the time unit to which the incoming solar radiation is related refers to one day. The incident radiation on the ground is dependent upon the possible amount reaching the atmosphere from space (QT). This fluctuates over the year depending upon the distance to the sun and the earth's relative position. The amount of radiation available on top of the atmosphere can be calculated with some of the constants also used for sunshine prediction. The following equation integrates the amount over the whole day (List 1963; Sellers 1965):

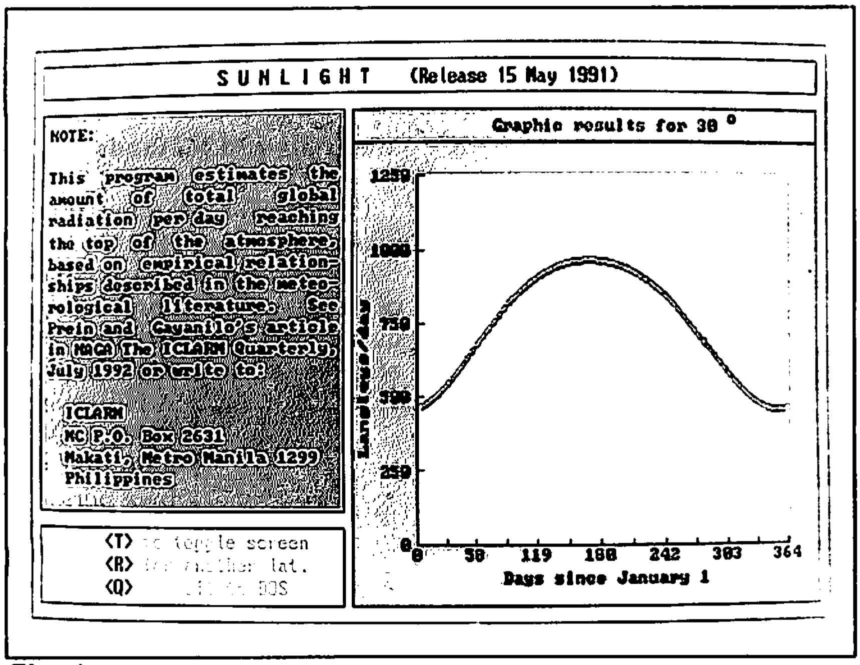

Fig. 1. *Sample output of SUNLIGHT for a site at 10°30'N (any longitude W or E). The latitude, given in degree (DEG) and minutes (MIN), ranges from -90°(S) to 90°(N). Options to print both graphics and numeric outputs (see Table 1) are possible.*

$$QT = \frac{1440}{\pi} * S * CD * (H - \tan H) * \sin LAT * \sin D \quad ...(6)$$

where:

- QT = daily total solar radiation incident on a horizontal surface on top of the atmosphere
- S = solar constant (=1.94 ly/min)
- CD = distance correction between the earth and the sun
- H = half-day length in degrees
- D = solar declination in radians

The factor for the distance correction between the earth and the sun lies between 0.97 and 1.03 depending upon the time of the year, and can be calculated with (Paltridge and Platt 1976):

$$CD = 1.00011 + 0.034221 * \cos A + 0.001280 * \sin a + 0.000719 * \cos 2A + 0.000077 * \sin 2A \quad ...(7)$$

The Software

The derivations and computations presented above are incorporated in a software for IBM PC (or compatible) microcomputers, SUNLIGHT. This software is distributed in one disk, 5¼" DD. No special installation routine is necessary and it requires only 512 Kbytes of memory. Since the output (by default) is presented in graphic form (see Fig. 1), SUNLIGHT requires that your system is equipped with a graphic card (HERCULES, CGA, EGA or VGA).

To request the software, write to:

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MC P.O. Box 2631
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