A COMPUTER MODEL FOR CALCULATING THE DURATION OF SUNSHINE IN MOUNTAINOUS AREAS

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I. Development of the Model

Considering the fact that the sunrise (or sunset) at any point of the mountain is generally not earlier (or later) than that at the horizontal one, the Potential Duration of Sunshine (PDS) at horizontal spot T_0 could be divided into $n+1$ periods, the lengths of the former n periods are all equal to the time interval ΔT. So n is calculated by

$$n = \text{int}\left(\frac{T_0}{\Delta T}\right), \tag{1}$$

where int(x) is integer function. The PDS (in hour) on the horizon is expressed as

$$T_0 = 2\ \arccos\ (-\text{tg}\,\varphi \cdot \text{tg}\,\delta)/15, \tag{2}$$

where φ and δ are the latitude and solar declination at the given site and date respectively. For convenience, δ can be approximated in terms of its Fourier series representation

$$\delta = 0.006918 - 0.399912\cos\theta_0 + 0.70257\sin\theta_0 - 0.006758\cos 2\theta_0 + 0.000908\sin 2\theta_0, \tag{3}$$

where θ_0 is defined as

$$\theta_0 = \frac{2\pi d_n}{365}, \tag{4}$$

d_n is the ordinal number in the solar calendar, which is 0 on January 1 and 364 on the last day of a year but 365 if it is a leap year. The largest error of the representation (3) is 0.00254 radian.

Then the PDS at mountainous point can be given by

$$T'_{\alpha\beta} = \sum_{i=1}^{n} g_i \Delta T + g_{n-1}(T_0 - n \cdot \Delta T), \tag{5}$$

and we call g_i the shadow factor during the ith period. g_i is determined according to the solar elevations at a given period and the shadow angles which is equal to the arc tangent of the ratio of the altitude difference between the study point and the point on crest line to horizontal distance separating these two points at the same time.

Let h_{i-1} and h_i represent the solar elevations at the beginning and end of the ith period and Z'_{i-1} and Z'_i the shadow angles in the solar azimuths at the same moments, respectively. The determination for g_i can be separated into two situations according to their differences $D_{i-1}(=h_{i-1} - Z'_{i-1})$ and $D_i(=h_i - Z'_i)$.

(1) D_{i-1} and D_i are all not zero, then

$$g_i = \begin{cases} 1 & D_{i-1} \geqslant 0 \text{ and } D_i \geqslant 0, \\ 0 & D_{i-1} \leqslant 0 \text{ and } D_i \leqslant 0, \\ 0.5 & D_{i-1} D_i < 0. \end{cases} \tag{6}$$

(2) Otherwise, g_i depends on the difference at the middle juncture of the period (D):

$$g_i = \begin{cases} 1 & D > 0, \\ 0 & D < 0, \\ 0.5 & D = 0. \end{cases} \tag{7}$$

Expressions (6) and (7) have fairly physical meaning. When the solar elevations are not just equal to the shadow angles in the solar azimuths at corresponding moments, whether the study spot is exposed to the sun or not is entirely dependent on that at its beginning and end moments. Otherwise, it is only dependent on that at the middle juncture of the period.

The model for calculating the PDS in mountainous areas consists of formulae (1) to (7).

It is obvious that the shorter the time interval is used, the smaller the error will be. However, in fact, a short time interval is not necessary if the orographical environment of the point being studied is not too uneven, whereas using the shorter time interval will greatly increase the CPU time of computers. So a suitable time interval should at first be chosen in order to meet the needs of precision and to reduce the CPU time to the least as well.

For this reason, 40 min is used as the initial time interval to calculate PDS and the time interval is reduced by 2 min after each execution, then two kinds of relative error averages are determined, of the present result to one calcualted for the last time and to the other computed using a time interval of 1 min. The test results show that these two errors are whthin 5% when the time interval is reduced to 20 min. Furthermore, the time interval must vary slightly according to the roughness of the studied mountainous areas.

II. Computing Scheme and Discussion on Test Results

To calculate the PDS in mountainous areas, its contour map should be previously covered with networks and the altitude from the sea level data at every grid point, the main input parameter of the model, should be determined directly from the contour lines. The grid distance is chosen according to the topographical roughness and the scale of the map.

The test we have done using a time interval of 20 min, a grid distance of 100 m with the grid number of 31×36 in a $3 \times 3.5\,km^2$ rugged area in south Dabie Mountain (30°33′N, 116°28′E) gives out the PDS at every grid over this area in each month, from which the map of its distribution can be drawn.

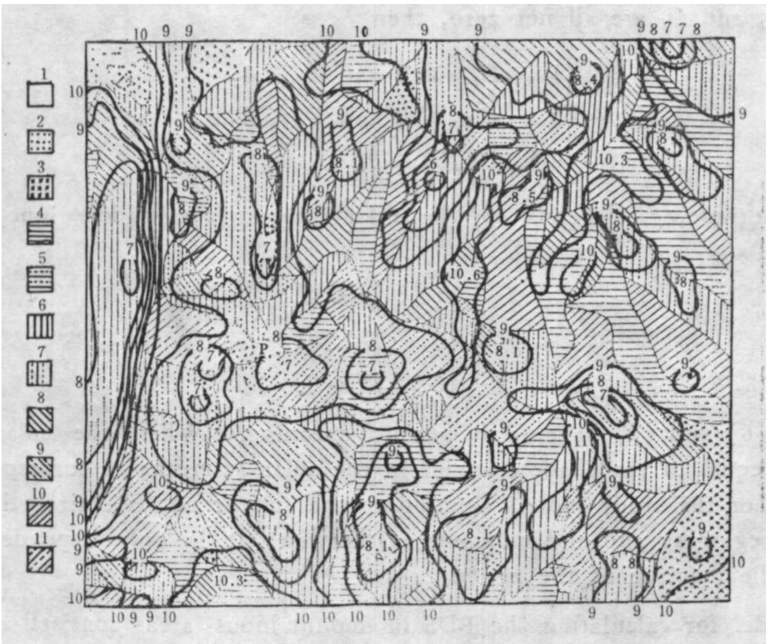

Fig. 1. Distribution of the computed duration of sunshine in the test area, south Dabie Mountain in January.

1, Summit; 2, watershed; 3, valley; 4, south slope; 5, north slope; 6, west slope; 7, east slope; 8, southwest slope; 9, northeast slope; 10, southeast slope; 11, northwest slope.

The distribution of the PDS in this area for January is given in Fig. 1, in which the base map shows the distribution of azimuth and kinds of special terrain over it simulated using the terrain parameter model. It manifests that the PDS varies considerably from place to place in January, the largest ratio of its maximum to minimum reaching up to 1.6 in such a small region. The variation of the PDS with the azimuth is quite noticeable, with the larger locating on the south-facing slopes, the lower on the north-facing ones and the medium on the east or west-facing ones. Moreover, the PDS is somewhat affected by the screening effect, for the largest of them is on the southern slope or summit exposed but the lowest on the northern one or in valley which are very much screened.

As compared with it in January, the variation of the PDS in the area in July according to sites is relatively slight and the influence of screening effect on it becomes more remarkable than that of azimuth.

In April and October, the influence of these two kinds of terrain parameters on the PDS is of the same importance (the figures are omitted).

To prove the validity of the model, comparison is made between the computed PDS using this model and that obained by means of diagram depending on the shadow chart measured at Jiangjiaban (spot P in the figure) during the exploration in 1985. The ratios between them are 1.05 and 0.98 in January and July, respectively.