AUTOMATION OF SOLAR RADIATION STANDARD PARAMETERS MEASUREMENTS

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Received August 29, 1994

This paper presents a brief description of an automated facility for measuring such parameters of incoming solar radiation as the duration of sunshine as well as total and diffuse radiation. The results obtained with this facility are compared with the data of standard heliographic measurements.

Normally, quite simple and reliable measurement means like heliographs and pyranometers[1] are used in studies of the incoming solar radiation. The main drawback of these instruments is in the absence of measurement automation, for example, it is impossible to make measurements of total and diffuse radiation alternatively in an automated mode. Moreover, these devices, in their standard versions, are computer incompatible. This circumstance make their use for compiling arrays of measurement data on a long–term scale very inconvenient.

Besides, the heliographs are known to have very low accuracy, particularly under cloudy weather conditions, because of a very rough recording system used, which introduces certain personal factor into the determination of the lengths of lines burnt on the recording paper bands.

Our experience in radiation studies[2] in Tomsk since 1993 allowed us to develop an optimal approach to the automation of such observations that can be done using only one measurement device. According to this approach we use an M–80M pyranometer, a ten–bit ADC, and an IBM PC–AT/386 computer to automate the observations. In addition, we have designed a simple electromechanically driven screen to screen periodically the pyranometer from direct solar radiation in an automated mode also.

Block diagram of the whole facility is depicted in Fig. 1. Operation of the device is performed as follows.

The electromechanical drive *3* provides for a continuous return scanning with the solar sensor *2* in the plane of celestial equator between two (eastern and western) end switches *4*. The solar sensor *2* is mounted on the scanning platform taking into account the latitude of the observation site and the Sun declination. In the case when no clouds cover the sun disc a threshold device causes termination of the scanning process and the solar sensor is screened from direct solar radiation for about 100 s, or time necessary for the pyranometer to achieve stationary mode of operation. After such a time lag the control unit of the facility sends a triggering pulse to start measurements of diffuse solar radiation, *D*, and then the scanning process continues. Measurements of total solar radiation, *Q*, are performed in a 100 s time lag after the solar sensor reaches the eastern end of the scanning trajectory and stops.

Thus, the operation mode of the instrument provides for a periodic screening of the pyranometer from direct solar radiation as well as for alternatively measuring total, *Q*, and diffuse, *D*, solar radiation fluxes. In addition the command signals terminating the scanning process are also used for acquiring information about the sunshine duration, S_s.

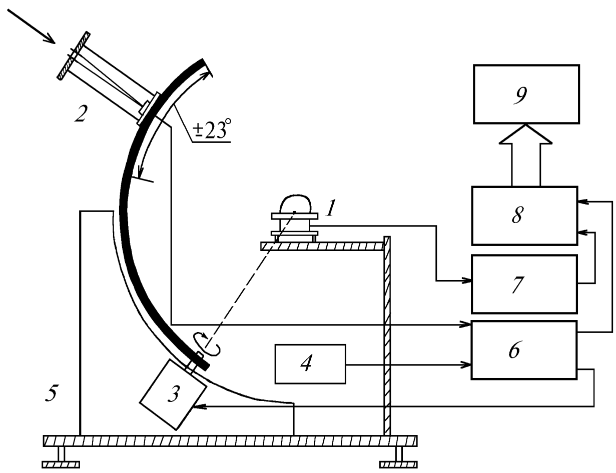

FIG 1. Block diagram of an automated facility for radiation measurement: a pyranometer M80–M (1), a solar sensor with a field stop and a shading screens (2), an electromechanical drive (3), an end switch (4), a platform (5), power supply and a control unit (6), an amplifier of the pyranometer signals (7), an ADC (8), and an IBM PC 386/387 (9).

The main specifications of the facility are as follows:

Field of view, deg	1×6
Plane angle of screening, deg	10
Mean time of a single measurement cycle, min	3.9
Level of the threshold signal from the solar sensor, cal/cm^2·min	0.2–0.3

The data on instantaneous values of diffuse and total radiation fluxes as well as on the duration of sunshine acquired with this instrument are stored in a PC memory in the form of three files. It is obvious that thus compiled measurement data can be easily processed in the computer to provide obtaining information about radiation fluxes summed for any desired time interval.

In order to test the functioning of the automated facility in field conditions we have arranged a ten–day measurement cycle on studying the variability of radiation characteristics at the measurement site of the Institute of Atmospheric Optics in Kireevsk village, Tomsk region.

0235-6880/95/05 358-03 $02.00

Figure 2 presents a computer plotted data on time behavior of Q and D quantities measured in the second half of July 27, 1994.

In order to estimate the quality of data on the duration of sunshine, S_s, acquired with this automated facility we have carried out, in parallel, similar measurements with a standard heliograph GU–1. Figure 3 and Table I present thus obtained data for making a comparison between the two techniques.

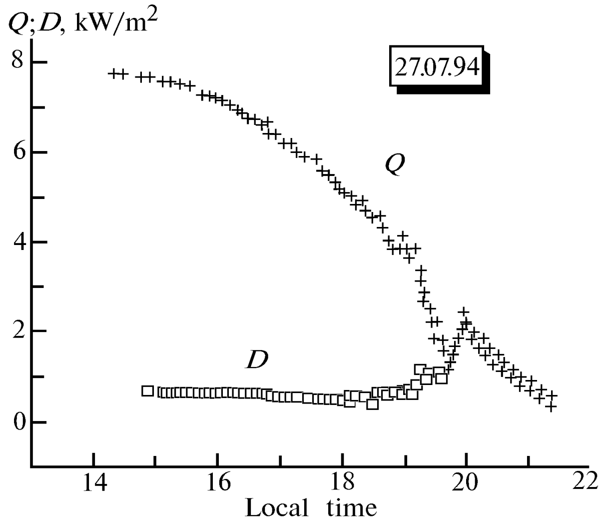

FIG. 2. Time behavior of the total, Q, and diffuse, D, radiation fluxes as recorded on July 27, 1994.

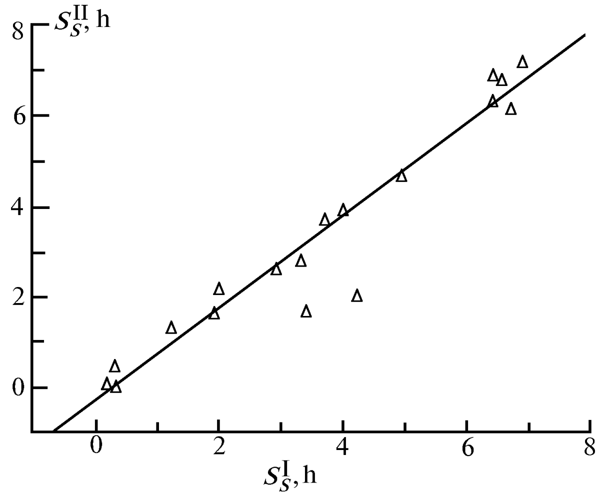

FIG. 3. Intercomparison of data on sunshine duration measured with a heliograph, S_s^{I}, and with the automated facility described, S_s^{II}.

TABLE I.

Date (1994)	Day–time duration, h	Sunshine duration, h						Cloud cover index during observations
		Heliograph S_s^{I}			Automated facility S_s^{II}			
		Whole day	1st half	2nd half	Whole day	1st half	2nd half	
19.07	16.70	6	4.0	2.0	6.054	3.908	2.146	8–9
20.07	16.62	7.5	4.2	3.3	4.827	2.014	2.813	Rainy 5–10
21.07	16.57	6.6	2.9	3.7	6.315	2.613	3.702	Rainy 6–8
22.07	16.52	3.1	1.9	1.2	2.265	1.654	1.311	8–10
23.07	16.47	0.5	0.2	0.3	0.525	0.075	0.45	Rainy 9–10
24.07	16.42	3.7	0.3	3.4	1.671	0	1.671	4–8
25.07	16.35	13.1	6.7	6.4	13.015	6.14	6.875	1–3
26.07	16.30	13.4	6.5	6.9	14.0	6.833	7.167	1–4
27.07	16.23	11.3	6.4	4.9	10.985	6.311	4.674	1–4

Prior to analyzing the differences in data presented let us consider two peculiar features in the heliograph measurements.

The matter is that determination of the sunshine duration from heliographic records is done by measuring the lengths of burnt strips on the recording paper band what does not exclude situations when the sun disc is screened with a translucent cloud and only means that thermal power flux of direct solar radiation focused on the paper exceeds the threshold value of 0.15 cal/cm^2 min (see Refs. 1 and 3). In fact some different energy criterion could be used when putting into operation the measurement facility discussed here, in order to exclude the cases of screening the sun disc by translucent clouds. However, in doing so we should violate a conventional approach to measurements of the sunshine duration, S_s. This, in turn, would not allow us to use formulas normally used for relating the sunshine duration S_s to the total fluxes of solar radiation.[3]

The second peculiarity in the operation mode of Campbell–Stokes heliographs is that they are insensitive to short–time (up to several minutes) screening of the sun disc with clouds. The burnt strips on the recording paper keep continuous thus causing overestimation of the sunshine duration. For instance, we have observed such situations on July 20 and 24, 1994. As a result, disagreement between the heliograph data on S_s and those obtained with our automated facility appeared to be maximum just on these days.

Regression equation, correlation coefficient, R, and the rms deviation, σ, for this data set are

$$S_s^{II} = (0.316 \pm 0.310) + (1.013 \pm 0.072)\, S_s^{I} ;$$

$$R = 0.961; \quad \sigma = 0.697; \quad N = 18 .$$

On the whole, the results of field test of the automated instrument described demonstrated it higher efficiency especially from the standpoint of better accuracy and higher speed of the measurement process.

Among the potential drawbacks of the instrument, the necessity of using continuously operating electromechanical drive and a little bit longer measurement cycle should be mentioned first of all. The latter circumstance can cause enhanced measurement errors under conditions of changeable cloudiness. However these drawbacks can be removed, since they are a result of combining the functions of two measurers in one device, one of which, pyranometer, is inherently inertial.

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