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Technical Note

Occurrence of standard skies during typical daytime half-days

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Abstract

The current trials to introduce new daylight assessment criteria for future building designs as well as for renewable energy simulations with the trend to implement annual daylight profiles for a specific locale or region need more detail information on the exterior daylight conditions. Bratislava is the only locality in Central Europe where a CIE-IDMP general station is recording 1-min regular daylight measurements since 1994 and 10-year data gathered can be used now to derive models valid for wider regions. In this paper, the analysis of measurements and sky-type occurrence is representing daylight conditions only for this single site. As the meteorological net of observatories register sunshine duration for longer periods worldwide, also this information may serve as the basis for modelling exterior daylight illuminance courses as well as typical sky conditions when no other measurements are available. Furthermore, the new General Sky Standard adopted by CIE in 2003 and by ISO in 2004 gives the possibility to study actual skies occurring under four characteristic daylight situations associated with sunshine duration during typical half-days.

Keywords: Daylight climate; Standard skies; Sunshine duration; Skylight; Illuminance daytime courses

1. Introduction

For a quite long time, regular sunshine duration measurements using the Campbell–Stokes glass sphere heliograph were registered in many locations and reported in several publications or yearly reports of meteorological stations worldwide. Therefore, these were utilized as the only trustworthy information of the availability of solar energy, sunlight or daylight changing in time and location. For instance, Soler [1] used sunshine duration data of 77 European stations to compare models for the monthly average daily global radiation and later Soler and Gopinathan [2] studied the possibility to derive hourly global radiation courses based on data from 26 locations with the latitude range from 1° to 81°. Similarly sunshine duration data were used in daylighting either to find the occurrence probability of typical skies [3] or to predict annual daylight profiles [4].

Since 1992, when the International Commission on Illumination (CIE) initiated the International Daylight Measuring Programme (IDMP), several IDMP stations started regular measurements of the local daylight climate taking instantaneous data every 1 min. The Bratislava IDMP general station was established in 1994 and nowadays 10 fluent years of data gathered during 1994–2003 can be used to specify daylight climate in Slovakia or even in Central Europe. Long-term sunshine duration can be applied to characterise specific conditions or differences in several locations in comparison with data available for Bratislava. The 1-min irradiance data simultaneously registered with the illuminance records at the Bratislava IDMP Station can be used to calculate measured relative sunshine duration representing the 10-year period of measurements, which will be analysed in this study. The basic assumption to calculate sunshine is the threshold intensity 120 W/m^2 produced on a plane perpendicular to sunbeams. Thus half-day or daily sunshine duration in hours or relative sunshine duration normalised to astronomically possible daytime can be calculated as well as monthly or yearly averages or even a long term, e.g. 10-year mean value. In Fig. 1 is shown the relative sunshine duration in every month within the 10-year measurement period and their mean course

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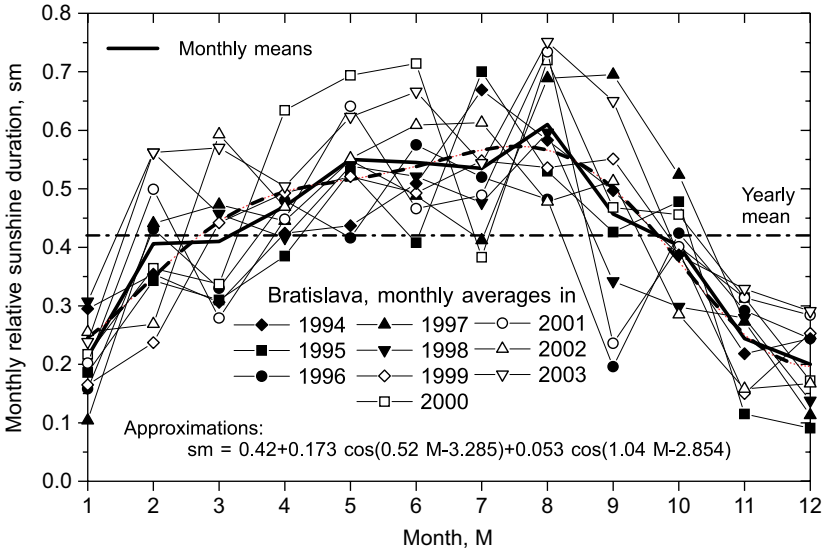

Fig. 1. Relative sunshine duration monthly changes, Bratislava 1994–2003.

(solid line) with the long-term yearly mean (dot-dashed horizontal line).

It is evident that monthly sunshine in any particular year is representing specific weather conditions with seasonal characteristic increases and decreases but in a certain month the differences in some years are quite noticeable. For instance, the minimum 9% sunshine duration in December 1995 has risen to 23.7% in the next year 1996 or even to 30% in 2003, while the 10-year average is just under 20%. In contrary, in July 1995 occurred the maximal 72.2% sunshine duration and the minimal 41.5% in 2000, while in June and August 2000 duration over 73% of possible sunshine were present.

The 10-year mean monthly variations with relations to the long-term average sy = 0.42 valid for Bratislava IDMP Station can be fitted by a cosine function of arc angles after the approximation:

$$\mathrm{sm} = 0.42 + 0.173\cos(0.52\,M - 3.285) + 0.053\cos(1.04\,M - 2.854), \quad (1)$$

which is shown in Fig. 1 by a dashed curve quite close to the full lines of 10-year means in any month M. This approximation is useful when absolutely no data are available. This situation applies to the vast territory of Central Europe from the German and Polish Baltic shores roughly from the 54° geographical latitude to the Southern borders of Switzerland, Austria and Hungary, i.e. to 46°. However, according to map 2 in Kittler, 1995, [5] in these latitudes the distribution of the long-term average yearly relative sunshine duration approximates from 0.35 for $\varphi = 54°$ to 0.45 for $\varphi = 46°$.

As monthly average sunshine duration is closely linked with the probability of half-day situations which characterise daily illuminance profiles there is a possibility to specify also sky types causing diffuse illuminance levels, methods and procedures were published in [4]. The estimation of the occurrence probability and number of half-day situations within any month was derived up to now. However, relevant standard sky types have to be applied in accordance with long-term occurrence to simulate daylighting during the whole year.

If in a specific location no sunshine duration data are available, then Eq. (1) can by used to approximate monthly averages with expected differences in the range of ±20%.

2. Typical half-day illuminance courses and their corresponding sunshine duration

The graphical images of actually measured illuminance courses and levels during any half-day has identified their possible sorting into four categories which were already described in [6]. These were already applied in the comparison study of the Daylight Reference Year for Bratislava and Athens [7]. The illuminance courses can be characterised in half-day situations with different sunshine durations as well as instability.

Thus two selection criteria for each half-day category were applied:

- the relative half-day sunshine duration s derived from 5-min instantaneous measurement data,
- the additional parameter of instability U defining the changeability of global illuminance levels Gv in consecutive time sequences as

$$U = \ln[(1/(n-1))\sum|\mathrm{Gv}_i - \mathrm{Gv}_{i+1}|], \quad (2)$$

where global illuminance Gv differences in time intervals i and the next $i+1$ are summarised and divided by their total number n within the half-day.