Calculation of Sunshine Duration from Global Radiation Measurements in Denmark and in Greenland

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Abstract

The Danish network of about 30 sunshine duration measurements using Cambell-Stokes sunshine recorders operated since 1876 in Denmark was closed down gradually in the period from 2000 to 2005 when the last recorder were closed in April 2005. The direct measurements of sunshine duration using the Campbell-Stokes recorders were replaced by a method where measurements of global radiation and modelling of clear sky short wave radiation were combined to calculate hours of bright sunshine according to a method described by Oliviéri (1998) and fine results were achieved. Extending this method so that the much more northern located Greenlandic Campbell-Stokes sunshine recorders operated since 1955 also could be replaced by the more useful pyranometers where hours of bright sunshine could be determined as a by-product from the global radiation measurements proved unfortunately not so straight forward. Result from Denmark and Greenland are presented and ongoing work is discussed. Mostly due to the difference in time resolution there is a rather systematic deviation (from about 2 to 20%) between sunshine duration hours given by the two methods depending on the season. It has therefore been necessary to recalibrate the Danish meteorological 1961-90 normal period according to the found deviations.

1. Method

According to WMO Guide to Meteorological Instruments and Methods of Observation, no. 8 (WMO, 1996), the time of bright sunshine is defined as the period where the direct short wave radiation at normal incidence exceeds 120 Wm⁻².

Following the method described by Oliviéri (1998), the measured global radiation (incoming short wave radiation from the solid angle 2π incident on a plane surface), here after denoted \( E_M \), the direct short wave radiation at normal incidence exceeds 120 Wm⁻² if:

\[
E_M > F_C \cdot E_G
\]

(1)
where,
$E_M$ is the incoming short wave radiation from the solid angle $2\pi$ incident on a plane surface
$F_C$ represents an empirical factor which varies according to date and time with values about 0.7
$E_G$ is global radiation at the given time of the day under cloud less conditions modeled as:
\[ E_G = \frac{1080W}{m^2} (\sin(h + \alpha))^\beta \]  \hspace{1cm} (2)

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Where,
$h$ is the solar elevation
$\alpha$ is an empirical parameter between 0 and 0.15 (in the below = 0)
$\beta$ is an empirical exponent = 1.22

The empirical factor, $F_C$, was calculated according to Oliviéri (1998) taking into account both the
time of year (date) and the time of day:
\[ F_C = [A + B \cos(2\pi \frac{d}{365})] \cdot (a h + b) \]  \hspace{1cm} (3)

where,
$A = 0.74$
$B = 0.04$
$a = -0.0028$
$b = 1$
d denotes the day number

If the angle of the solar elevation is less than 3 degrees over the horizontal due to the problems of
the low solar elevations the values are forced to zero.

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2. RESULTS

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Figur 1 Example from 2 June 1997: Comparison between measured global radiation by the STAR pyranometer, the product $F_c \times E_g$ and measured sunshine duration by the HAENNI sunshine detector (the HAENNI is here set to indicate sunshine [$>120 \, \text{w/m}^2$] with the value “50” no sunshine with the value “0”).

Figur 2 Example from 2 June 1997: Comparison between measured time of bright sunshine (Casella solar authograph), measured time of bright sunshine by the STAR pyranometer and the product $F_c \times E_g$ and measured sunshine duration by the HAENNI sunshine detector.
Figur 3 Annual variation of the Campbell-Stokes (Casella) to pyranometer (STAR) method conversion factor for calculation of time of bright sunshine. The Danish meteorological 1961-90 normal period sunshine duration data has been recalculated/corrected according to the found deviations (the smoothed averages).

**Extending the method to Greenland**

In Greenland a network of 6 stations with sunshine duration measurements using Campbell-Stokes sunshine recorders (FUSS-type) has been operated for several years with the oldest since 1955 at Qaanaaq near Thule Air base.

Global radiation and direct short wave radiation at normal incidence has for some years been measured at the Danish Meteorological Institutes research station at Pituffik also near Thule Air base in North Western Greenland. For the Danish area the original empirical constants from Oliviéri’s Capentras site gave satisfactory results but the high northern Greenlandic site proved geographically, geometrically and climatologically too different so a new set of constants had to be found to fit the data (table 1).
<table>
<thead>
<tr>
<th>Constants used in Denmark</th>
<th>New constants used found for Pituffik (NW-Greenland)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>0,0000 1,1000</td>
</tr>
<tr>
<td>$\beta$</td>
<td>1,2200 1,7080</td>
</tr>
<tr>
<td>A</td>
<td>0,7400 1,0360</td>
</tr>
<tr>
<td>B</td>
<td>0,0400 0,0320</td>
</tr>
<tr>
<td>a</td>
<td>-0,0028 -0,0009</td>
</tr>
<tr>
<td>b</td>
<td>1,0000 0,9750</td>
</tr>
<tr>
<td>Integrated results</td>
<td>84,3% 94,2%</td>
</tr>
</tbody>
</table>

Table 1: Comparison of the two sets of empirical constants

**Figure 4** Example from 4 August 2004: Comparison between measured global radiation by a STAR pyranometer, the “old” and “new” product $F_c \times E_g$ and the measured direct short wave radiation at normal incidence.

The results from modeling sunshine duration at Pituffik indicate that presumably a set of site-specific empirical factors has to be found for each station in Greenland measuring global radiation. This also implies that correcting backwards the Campbell-Stokes recorded hours of sunshine duration at the Greenlandic sites as it was carried out for the Danish Campbell-Stokes data has to be based on a site-specific evaluation.
References


Nielsen, M. K.: Evaluering af soltimer. DMI Technical Report, No. 01-16

Nielsen, M. K.: Solskinstimer I Pituffik. DMI Technical Report, No. 05-18
