INSTRUMENT TEST REPORT 700

Investigation of the accuracy of the Delta-T Devices
BF3 Sunshine Sensor

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Authorisation

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6 Pages
1. PURPOSE
The WMO requires that the uncertainty of measurements of sunshine duration be ± 0.1 hours [1]. This investigation examines whether the Delta-T Devices BF3 Sunshine Sensor (“BF3”) fulfils this requirement by comparing BF3 data with measurements from two pyrheliometers.

2. METHOD
The WMO states that the “sunshine duration during a given period is defined as the sum of that subperiod for which the direct solar irradiance exceeds 120 W m$^{-2}$. The WMO also states that the uncertainty of the sunshine duration should be ± 0.1 hours [1]. We will refer to this condition as the uncertainty requirement. In two of the four recommended calibration methods the WMO indicates that the sunshine sensor should be adjusted if calibration reveals it to be more than 20% from 120 W m$^{-2}$.

A BF3 was co-located with a pyrheliometer (the roof pyrheliometer) on the solar annex at the BoM’s training centre in Broadmeadows, Victoria. A second pyrheliometer (the ground pyrheliometer) was located approximately 140 m away in the meteorological enclosure.

The pyrheliometers measure the direct solar irradiance every second. For the sixty solar irradiance values determined each minute, the number of seconds above the three thresholds of 120 Wm$^{-2}$, 96 Wm$^{-2}$ (=120 - 20%) and 144 Wm$^{-2}$ (=120 + 20%) are recorded. The uncertainty of the direct solar irradiance measurement is estimated as 3 Wm$^{-2}$ when referenced to the Australian representation of the WRR.

The BF3 reports every second whether the sunshine exceeds the threshold (120 W m$^{-2}$).

3. RESULTS
This analysis used data for the dates shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>BF3</th>
<th>ground pyrheliometer</th>
<th>roof pyrheliometer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>9/10/2004-13/10/2004</td>
</tr>
</tbody>
</table>
In order to compare the BF3 data with a pyrheliometer there must be valid data for both instruments on the same day. Days for which an instrument was off line for part of the day were removed from the data, leaving the number of days shown in table 2.

### Table 2. Number of complete days of data for the BF3 and pyrheliometer.

<table>
<thead>
<tr>
<th></th>
<th>BF3, ground pyrheliometer</th>
<th>BF3, roof pyrheliometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>number of complete days of data</td>
<td>175</td>
<td>142</td>
</tr>
</tbody>
</table>

3.1 **UNCERTAINTY REQUIREMENT**

The BF3 sunshine duration for each day was compared with six pyrheliometer sunshine durations: the ground pyrheliometer with thresholds of 120 Wm\(^{-2}\), 96 Wm\(^{-2}\) and 144 Wm\(^{-2}\), and the roof pyrheliometer with the same thresholds.

### Table 3. Number and percentage of days that meet the uncertainty requirement (±0.1 h) when the BF3 is compared with the ground (G) and roof (R) pyrheliometers at thresholds of 120 Wm\(^{-2}\), 96 Wm\(^{-2}\) and 144 Wm\(^{-2}\).

<table>
<thead>
<tr>
<th></th>
<th>days</th>
<th>percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF3; G(120 Wm(^{-2}))</td>
<td>34</td>
<td>19.4%</td>
</tr>
<tr>
<td>BF3; G(96 Wm(^{-2}))</td>
<td>59</td>
<td>33.7%</td>
</tr>
<tr>
<td>BF3; G(144 Wm(^{-2}))</td>
<td>25</td>
<td>14.3%</td>
</tr>
<tr>
<td>BF3; R(120 Wm(^{-2}))</td>
<td>47</td>
<td>33.1%</td>
</tr>
<tr>
<td>BF3; R(96 Wm(^{-2}))</td>
<td>58</td>
<td>40.8%</td>
</tr>
<tr>
<td>BF3; R(144 Wm(^{-2}))</td>
<td>37</td>
<td>26.1%</td>
</tr>
</tbody>
</table>

Table 3 shows that the uncertainty requirement is satisfied most often for the lowest pyrheliometer threshold of 96 Wm\(^{-2}\), suggesting that the sensitivity of the BF3 may be too high. However, none of these comparisons meet the uncertainty requirement for even 50% of the days.

The comparison with the co-located roof pyrheliometer is better than the ground pyrheliometer suggesting a difference in sunshine duration over the 140 m between the pyrheliometers. So, for the rest of the analysis the ground pyrheliometer data will not be used.
Figure 1 shows the difference between the number of sunshine seconds recorded by the BF3 and the roof pyrheliometer (with a threshold of 120 Wm$^{-2}$) for each day with valid data. It can be seen that there is generally an over-reporting of sunshine by the BF3, with more points lying above the 0 s line than below it. Analyzing these data reveals a mean difference between the BF3 and the roof pyrheliometer of 427.4 s, and a standard deviation of 949.9 s. The 95% confidence interval is (-1504 s, 1998 s).

The size of this confidence interval (3502 s) is over 4 times the size of the required uncertainty range of 720 s (from -6 min to +6 min). This rules out the possibility of using a constant offset as a correction.
3.3 PROPORTION OF SUNSHINE IN A DAY

![Graph showing the difference between the BF3 and roof pyrheliometer plotted against the proportion of sunshine in a day.](image)

*Figure 2. The difference between the BF3 and the roof pyrheliometer plotted against by the proportion of sunshine in the day (the sunshine measured by the pyrheliometer divided by the time the sun is more than 1 degree above the horizon).*

From Figure 2 it can be seen that the BF3 over reports sunshine when there is sunshine for less than 70% of the day and under reports sunshine when there is sunshine for more than 90% of the day. Apart from days with very little sunshine, the spread of data is independent of the proportion of sunshine in the day. Hence the uncertainty criterion is not met regardless of the amount of sunshine.

4. CONCLUSION

The BF3 does not measure the daily sunshine duration within the uncertainty requirements of the WMO. On average, the sunshine in our data set was too great by 427.4 s when compared with a co-located pyrheliometer. The variability of the measurements was also a problem with 95% of the values falling within a 3502 s band, much larger than the allowed uncertainty range of 720 s. The variability was largely independent of the proportion of sunshine in the day.

5. RECOMMENDATION

The BF3 should not be used to record sunshine duration, if the uncertainty requirements of the WMO are required.
REFERENCES