Evaluating the Sources of Uncertainties in the Measurements from Multiple Pyranometers and Pyrheliometers

I. Abstract

Traceable radiometric data sets are essential for validating climate models, validating satellite-based models for estimating solar resources, and validating solar radiation forecasts; however, the uncertainty of current radiometers is 2%–5% and sometimes more [1].

The National Renewable Energy Laboratory (NREL) and the Atmospheric Radiation Measurement (ARM) Program are identifying uncertainties, improving measurement performance, and developing a consensus standard methodology for radiometric measurements.

This study analyzes the impact of differing parameters—such as cosine response, thermal offset, spectral response, and others—on the accuracy of data from several radiometers. The study provides insight on how to reduce the impact of some of the sources of uncertainties.

II. Method

We estimated measurement uncertainty following the International Organization for Standardization procedure for evaluating uncertainty, the Guide to the Expression of Uncertainty in Measurement (GUM) [2], as shown in Figure 1.

III. Quantifying Sources of Uncertainties

A. Calibration, thermal offset, and cosine response errors

Figure 2 addresses the effect of different Broadband Outdoor Calibration methodologies and resulting differences [3]. These differences are attributed to the various sources of uncertainties, such as thermal offset and cosine response [4]. The result from the figure is used in the uncertainty estimation.

B. Radiometer spectral change coating

Radiometer response changes with time (Figure 3) because of changes in the optical transmittance of the glass dome and the reflectance of the black detector over time (Figure 4). Results from the figures are used in the uncertainty estimation.

IV. Result: Uncertainty Estimation

NREL in collaboration with industry developed a guide to an uncertainty estimation international consensus standard through the American Society for Testing Materials. NREL has a spreadsheet that implements the standard [6]. The output plots from the spreadsheet assist in illustrating the overall uncertainty versus irradiance (Figure 5) and the main contributions to uncertainty (Figure 6). Uncertainty estimates shown in Table 1 were obtained using the spreadsheet in which both ARM radiometers, PSP and NIP, have higher uncertainty from the global horizontal irradiance (GHI) and direct normal irradiance (DNI) groups, respectively.

Table 1. Uncertainty Estimated Using GUM

<table>
<thead>
<tr>
<th>Type</th>
<th>Model</th>
<th>Manufacturer</th>
<th>Measurement Uncertainty (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHI</td>
<td>CMP22</td>
<td>Kipp &amp; Zonen</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>SPP</td>
<td>Eppley Lab.</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>MS-802</td>
<td>EKO Ins.</td>
<td>3</td>
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<tr>
<td></td>
<td>PSP</td>
<td>Eppley Lab.</td>
<td>6.6</td>
</tr>
<tr>
<td>DNI</td>
<td>CHP-1</td>
<td>Kipp &amp; Zonen</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>NIP</td>
<td>Eppley Lab.</td>
<td>2.2</td>
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<td>1.7</td>
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<td></td>
<td>DR02</td>
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<tr>
<td></td>
<td>MS-56</td>
<td>EKO Ins.</td>
<td>1.8</td>
</tr>
</tbody>
</table>

V. Potential Benefit of Lower Uncertainty Radiometers for the ARM Program

Pros:
- Reduces uncertainty in predicting the solar resource, which in turn assists in accurately validating climate and radiative transfer models.
- Reduces time spent in quality analysis/quality check of measured radiometric data.
- Increases reliability of measurement, and provides more defensible solar resource data.

Cons:
- Expensive to replace existing radiometers with new ones.
- Causes a disruption in the historical consistency of the data due to the use of a different radiometer.

VI. Conclusions

• The radiometers presented in this poster are a cross section of the commercially available radiometers.
• Some sources of uncertainties that may affect radiometric measurements still need to be considered, such as soiling, effects of ventilation, extreme climates, and high-latitude locations.

References and More Information