Pyranometer Calibration Round Robin: Evaluation of Calibration Practices of Three Research Laboratories

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Abstract: The calibration methods of the three research labs are investigated through a calibration round robin where **the responsivity of three pyranometers was measured by each lab using the shade/unshade calibration method**. This study quantified the pyranometer calibration results from the three labs using their standard calibration method. The measurement techniques and data analysis methods are studied independently.

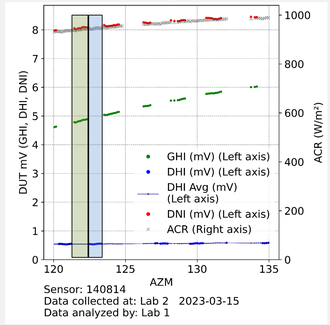
Key words: Pyrheliometer, pyranometer, round robin, shade/unshade calibration, absolute cavity radiometer (ACR)

Data analysis progression

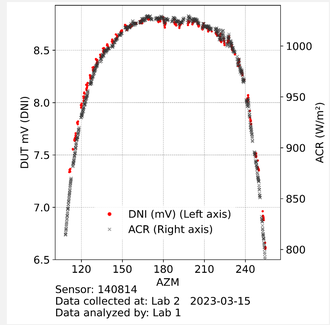
Shaded/Unshaded pyranometer measurements.

Result in alternating GHI and DHI data.

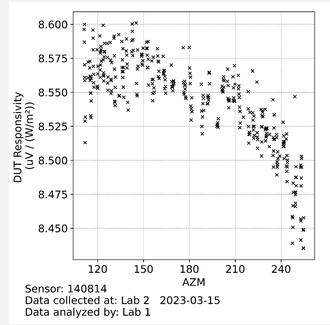
GHI, DHI, DNI vs AZM
(09:00 to 10:00)



DNI vs AZM
(All day)



Responsivity vs AZM
(All day)



Shade/Unshade calibration basics

1. Measure the DNI reference using a Pyrheliometer (ACR).
2. Sequentially measure Device Under Test (DUT) pyranometer voltage in full sun (Global) and shaded with a shadeball (Diffuse).
3. Remove data immediately after transition (not in thermal equilibrium)
4. Obtain interpolated diffuse during unshaded periods
5. Compute DUT DNI $$DNI = \frac{G - D_{Interpolated}}{Cos(AOI)}$$
6. Remove anomalous data points
7. Compute responsivity for every DNI(μV) value. $$R = \frac{DNI(\mu V)}{DNI_{Ref}}$$
8. Compute average responsivity in desired range.

Data collection specifics

Parameter	Lab 1	Lab 2	Lab 3
Number of ACR's	1	2	3
Shade/unshade interval	2 / 2 minutes	4 / 4 minutes	5 / 5 minutes
Data frequency	10 s	20 - 30 s	30 s
Sensor orientation	Horizontal	Horizontal	Normal
Shade mechanism	Manual	Automated	Automated
Number of data collection days	1-2	6	3
Dates	2023-07	2023-03	2023-06
Pyranometer ventilation	Not ventilated	Ventilated	Not ventilated

More conditions to be met:

- Sensors must be collocated
- Sensors clean, aligned properly
- Reference instrument traceable to the world standard
- Measurements taken over a range of zenith angles
- Clear sky conditions
- Data collection frequency of one minute or less
- Data acquisition clocks synchronized to 1 second accuracy
- A mechanism to filter out outlying data points must be incorporated.

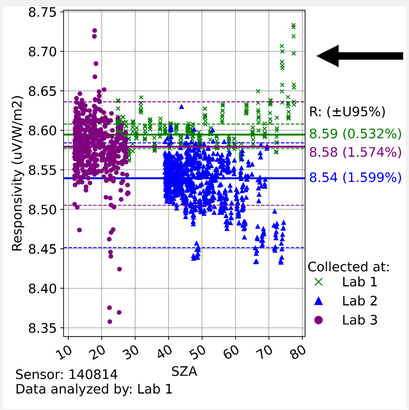
Data analysis specifics

Parameter	Lab 1	Lab 2	Lab 3
Outlier detection method	Manual	Manual	Manual/ Automatic
Seconds omitted after shade / unshade (*)	40	180	210
Seconds included in DHI running average (**)	120	240	90 (before point in question)
R computed at SZA/Solar Time	40 -50° (SZA)	40-50° (SZA)	10:00-14:00 (Solar time)

* Thermopile pyranometers take time to react to drastic changes in irradiance. Immediately after the sensor is shaded (or unshade), data is omitted while the sensor is coming to thermal equilibrium.

** Needed to generate diffuse values during the global measurements

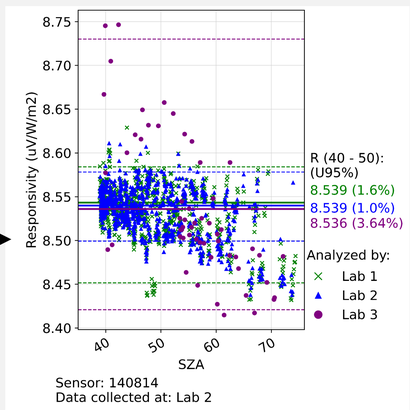
Three data collection methods
One data analysis method



Three data collection methods generate consistent results. Some differences are visible. Lab 1 has modified its protocol to collect more data in future campaigns.

Lab 1 and 2 generate consistent results.
Lab 3's results highlight the challenges of applying filtering methods optimized for normally oriented devices.

One data collection method
Three data analysis methods



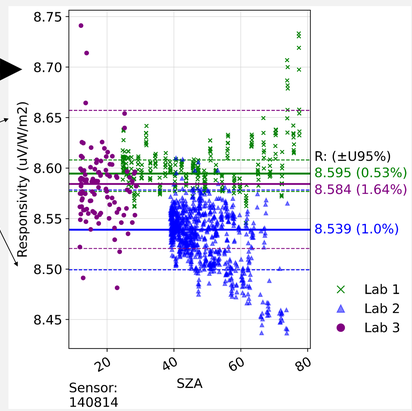
Three data collection methods
Three data analysis methods

Three data analysis techniques generate consistent results.

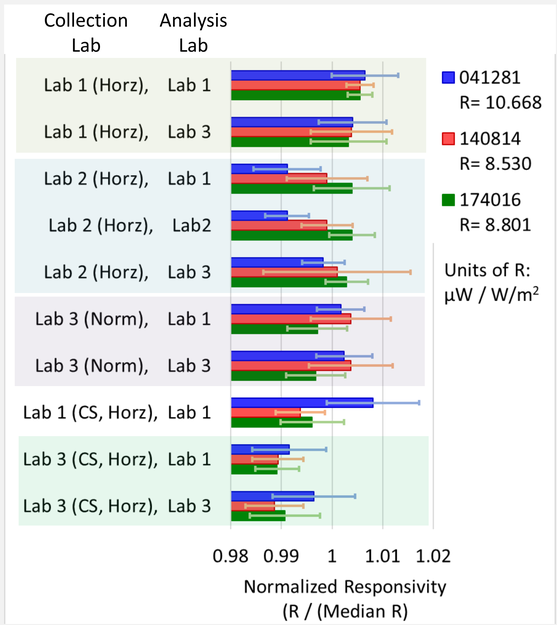
Spread in R: 1.9%

Lab 3 collects data solar noon ± 2 hours

Lab 1 had leveling issues at low sun angles



Results / Conclusions



- All lab's generate similar results
- All lab's have similar sized error bars
- All lab's data collection techniques consistent
- All lab's data analysis techniques consistent.
- Horizonal and normal calibrations are similar
- Responsivity of component sum calibrations slightly lower than shade / unshade

This exercise has been a very beneficial learning experience to all the participants. The participants encourage other groups to participate in a similar round robin process.

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