Calibration Report: Pyranometer CM22-040100

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Calibration date: 2022-04-22.
Next calibration: 2024-04-22.
Reference standard: AHF-31041, minimum irradiance 700W/m**2
The method here is described in "ISO 9846 Solar energy – Calibration of a pyranometer using a pyrheliometer, First edition 1993-12-01". The shade and unshade intervals have been extended to get several measurements on each cycle.

The calibration coefficients and their associated uncertainties (U95%) have been determined for one pyranometer. The unit of the calibration coefficient (S) is $\mu V/(W/m^2)$. Data were collected February through April 2022, see below. Only data between solar zenith angles of 40º and 50º were used.

NOTE: the desiccant plug was pointed to the northwest.

The sensitivity factors and their associated uncertainties (95%) are as follows:

Sensor	S ($\mu V/(W/m^2)$) ± U95%	Method
CM22-040100	9.189 ± 0.68%	relative to CM21-041282 & CM21-990005 & CM22-051417

Application

$$I = (\mu V \text{ output})/S \pm \text{sqrt}(2)*U95\%$$

Where: I = the irradiance measured by the pyranometer
(μV output) = microvolt output of the pyranometer
S = calibration coefficient of the pyranometer
U95% = the 95 % confidence level

Some supporting plots, a list of past calibration values, and a brief description of the calibration process is presented below.

CALIBRATION LOCATION

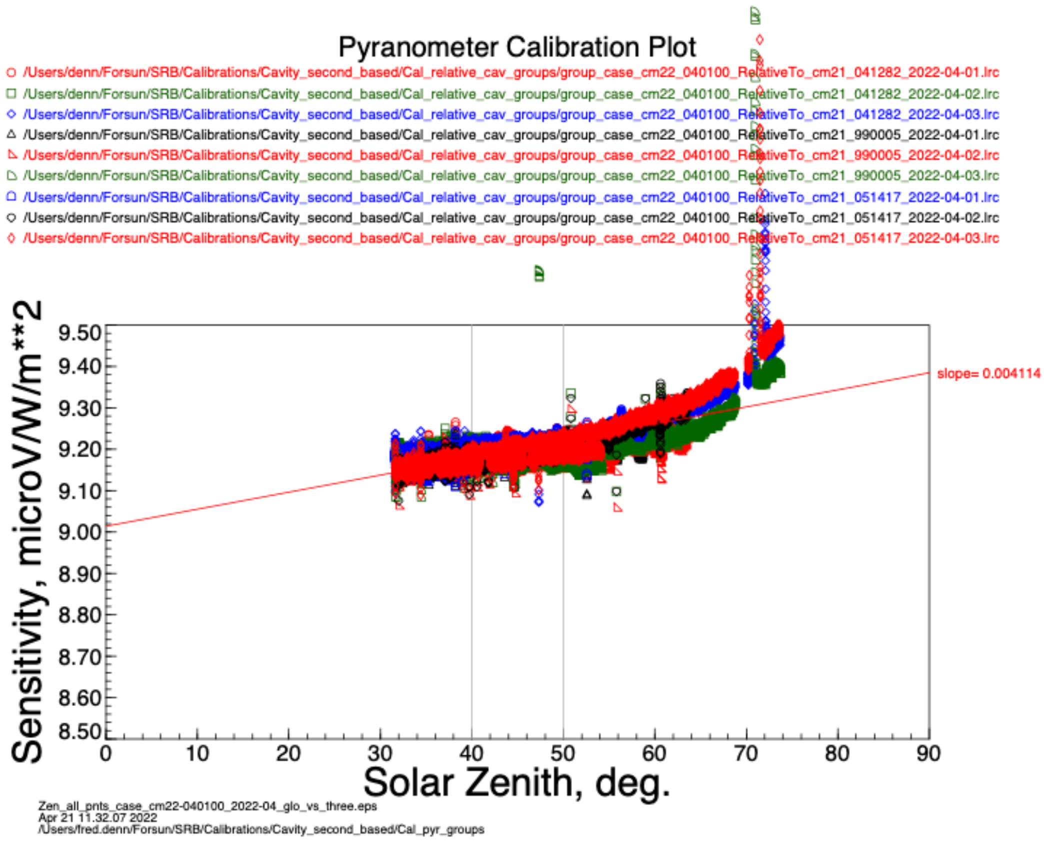
NASA Langley Hampton VA.
Latitude = 37.1038 deg., Longitude = -76.3872 deg., Elevation = 6 meters.

CALIBRATING PERSON(S)
Fred Denn, Bryan Fabbri

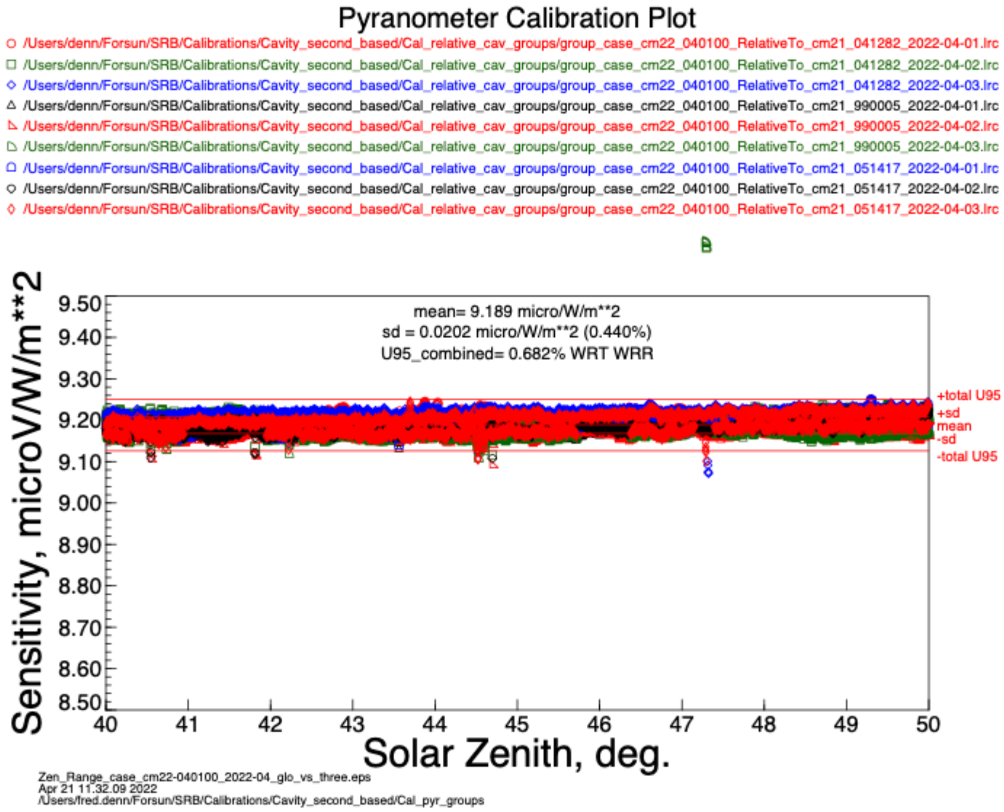
TRACEABILITY
The reference standard was Eppley Laboratories Inc., absolute cavity radiometer AHF31041, with its associated data acquisition system. Cavity AHF31041 participated in the 2015 International Pyrheliometer Comparison (IPC XII) at the Physikalisch-Meteorologisches Observatorium, in Davos Switzerland. It is therefore traceable to the World Radiation Reference. Cavity AHF31041's calibration is verified annually at the National Pyrheliometer Comparison held at the National Renewable Energy Laboratory in Golden Colorado, most recently in September of 2019.

HARDWARE CONFIGURATION
The pyranometer was mounted on a Kipp Zonen 2AP tracker with the standard shading mechanism. The nut on the little bolt near the base of the tracker that holds the flat rod that that holds the shading mechanism is removed. The flat bar is removed from the bolt and the shading ball mechanism is allowed to descend until it rests on the arm assemble to place the pyranometers in the unshaded position. The flat bar is placed on the bolt to place the pyranometers in the shaded configuration. Pyranometers are placed in the global position for approximately five minutes, and it the shaded position for about five minutes.

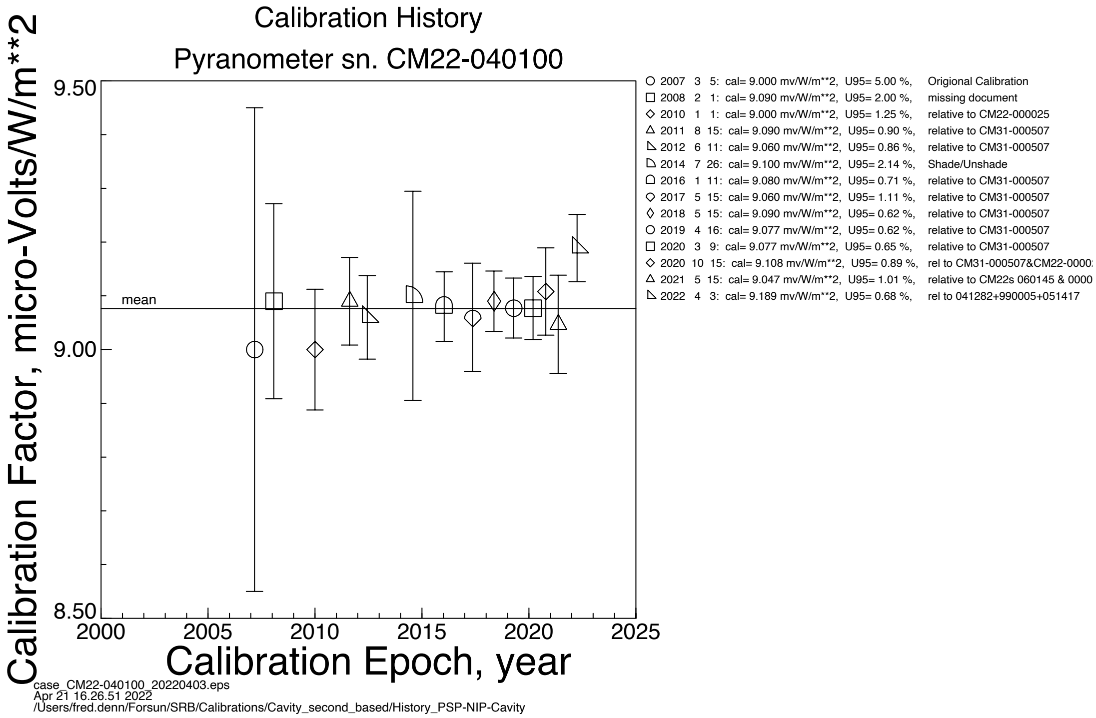
DATA DAYS
Data were collected on the dates indicated on the plots. Only the mean of measurements between solar zenith angles of 40º and 50º were used for the final value. Data outside that range illustrate the solar zenith angle response of the pyranometer. Da



Relative calibration coefficients for several days, for all zenith angles. These data are combined to get a final calibration coefficient for the entire, multi-day, calibration session. Data are for CM22-040100 relative to pyranometers CM21-841282, CM21-990005, and CM21-051417, which were calibrated with the shade/unshade method.



Calibration coefficients for several days. Each symbol represents an individual calibration value. The mean of these values will be taken to be the final calibration value. The overall U95 uncertainty is also displayed here.



Calibration history for pyranometer CM22-040100. The solid horizontal line represents the mean value. The symbols and their error bars represent the mean and U95 of each calibration event. The column on the right presents numerical values for each calibration event and a brief description of the calibration method used.

CALIBRATION HISTORIES

Pyranometer: Kipp and Zonen CM22-040100

Date	S (μV/W/m^2)	U95 (%)	calibration type
2022-04-22	9.189	0.68	rel. to cm21s 041282,990005,051417
2021-05-17	9.047	1.01	relative to CM22s 060145 & 000025
2020-10-15	9.108	0.89	relative to CM31-000507
2020-03-09	9.077	0.65	relative to CM31-000507
2019-04-16	9.077	0.62	relative to CM31-000507
2018-05-15	9.09	0.62	relative to CM31-000507
2017-05-02	9.06	1.11	relative to CM31-000507
2016-01-11	9.08	0.71	relative to CM31-000507
2014-07-02	9.10	2.14 (%)	shade/unshade
2012-06-01	9.06	0.86 (%)	relative to CM31-000507
2011-08-02	9.09	1.316	Forgan's alternate
2010-01-01	9.00	1.316	Forgan's alternate
2008-02-02	9.09	1.316	Forgan's alternate
2007-03-05	9.00	5.00	manufacturers original

A Very Brief Description of the Calibration Process.

1) Deploy the Cavity Radiometer, select the 4 second data collection parameter file. Start the cavity calibration process.
2) Modify the field radiometer program, set the parameter that causes one second data collection.
3) Prepare the tracker hardware to operate in manual shade/unshade mode. Either in manual mode or with the automatic pneumatic cylinder.
4) Start the cavity in sun-run mode, do this on a minute that is a multiple of 5 into the hour. Note a cavity calibration and sun-run takes almost 30 minutes.
5) Raise or lower the tracker shading balls every 5 minutes, on multiples of 5 minutes into the hour.
6) Continue this process as long as sky conditions permit while cavity irradiance is greater than 700 Watts/meter**2.
7) On both the cavity computer and the field radiometer computer, open a web browser and email the data files to the data processing computer, Files could also be copied to an external memory stick.
8) Remove data that is flagged as "unstable" in the cavity data file.
9) Run a splitter program on the field radiometer file to generate a separate file for the shaded and unshaded periods for each instrument.
10) Run a plotting program on each data file so the data can be reviewed for: cloud events; bad shading; errors in the splitting routine; etc. Remove bad data.
11) Run a calibration program to determine the calibration coefficient for each instrument.
12) Combine several days of calibration data to get a final calibration coefficient.
13) Produce a calibration document, such as this one, for each instrument. To be considered valid a calibration must be both traceable to recognized standards, in this case the World Radiation Reference (WRR) in Davos Switzerland, and documented.