Calibration Report: Pyranometer CM31-990005

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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 $\mu V/(W/m^2)$. The pyranometer was mounted on a sun tracker with the descant plug pointed in the sun direction. Data were collected February through March 2022, see below. Only data between solar zenith angles of 40º and 50º were used.

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

Sensor	S ($\mu V/(W/m^2)$) ± U95%	Method
CM31-990005	11.800 ± 0.68%	shade/unshade

Application

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

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 information, plots, a list of past calibration values, and a brief description of the calibration process are presented below.

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

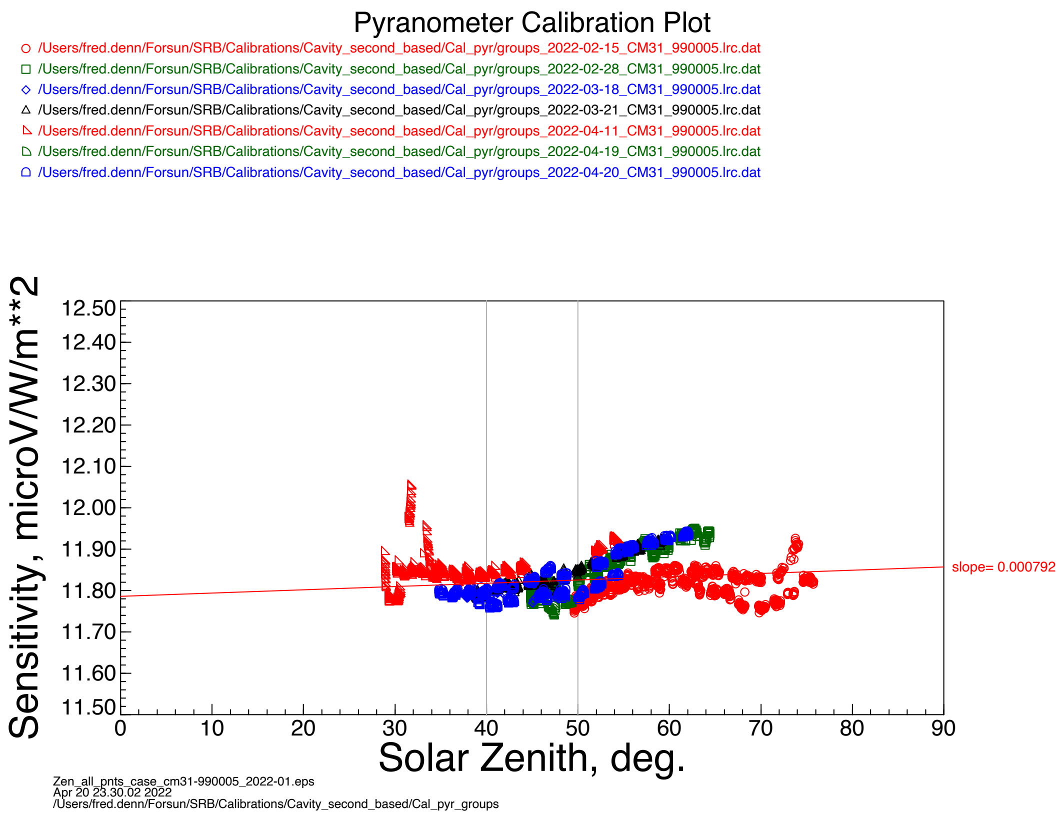
CALIBRATING PERSON(S)
Fred Denn, Bryan Fabbri

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.

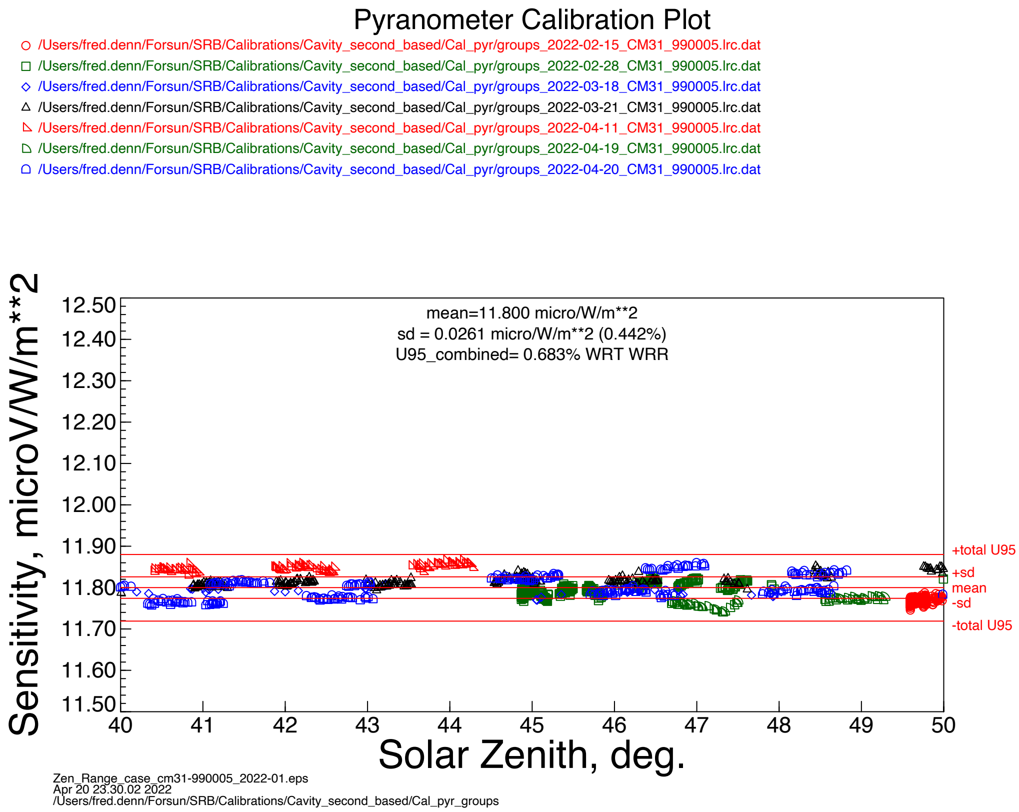
HARDWARE CONFIGURATION
The pyranometer was mounted on a Kipp Zonen 2AP tracker with the standard shading mechanism. The nut on the little bolt near the base of the tracker that holds the flat rod that that holds the shading mechanism is removed. The flat bar is removed from the bolt and the shading ball 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 during the date/times listed below. 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.

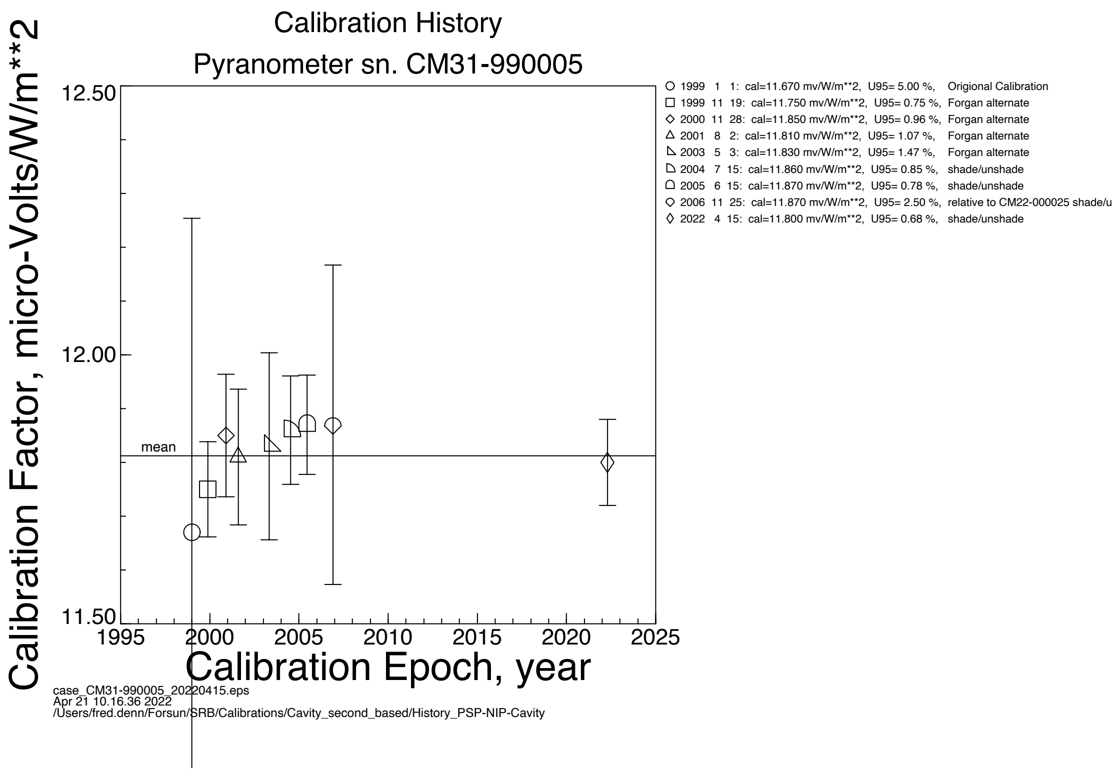
DATE	Hour, GMT	Zen range
2022-02-15	13:12 – 21:18	49º - 76º
2022-02-28	16:40 – 20:36	45º - 65º
2022-03-18	15:05 – 17:45	38º - 48º
2022-03-21	18:10 – 20:36	39º - 60º
2022-04-11	13:40 – 19:00	29º - 55º
2022-04-19	13:55 – 14:10	46º - 50º
2022-04-20	13:24 – 21:20	34º - 63º



Calibration coefficients for, all zenith angles, several days. This displays the solar zenith angle dependance of the calibration values.



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 CM22-060145. 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 HISTORY

Pyranometer: Kipp and Zonen CM31-990005

date	S ($\mu V/W/m^2$)	U95 (%)	calibration type
2022-04-20	11.800	0.68	shade/unshade"
2006-11-25	11.87	2.5	relative to CM22-000025
2005-06-15	11.87	0.78	shade/unshade"
2004-07-15	11.86	0.85	shade/unshade"
2003-05-03	11.83	1.47	Forgan alternate"
2001-08-02	11.81	1.070	Forgan alternate"
2000-11-28	11.85	0.96	Forgan alternate"
1999-11-19	11.75	0.753	Forgan alternate"
1999-01-01	11.67	5.00	Origional Calibration"

A Very Brief Description of the Calibration Process.

1) Pyranometers are to be mounted horizontally, while pyrheliometers are to be mounted on the tracker pointing at the sun.
2) Deploy the Cavity Radiometer, select the 4 second data collection parameter file. Start the cavity calibration process.
3) Modify the field radiometer program, so that a file of second data is produced in addition to the minute resolution data file.
4) Prepare the tracker hardware to operate in manual shade/unshade mode. Either in manual mode or with the automatic pneumatic cylinder.
5) Start the cavity system, first calibrating the cavity, then collecting data for about 20 minutes before doing a recalibration. Repeat the calibration/measure process for the entire calibration period.
6) Collect pyranometer data in the unshaded configuration for about 5 minutes, and in the shaded configuration for about 5.0 minutes.
7) Continue this process while sky conditions permit while cavity irradiance is greater than 700 Watts/meter**2.
8) Transfer the cavity and pyranometer data to the data processing computer.
9) Remove unstable (greater than 1 w/m**2 variation over 3 seconds) in the cavity data file. This depends on which cavity control system is used.
10) Run a splitter program on the field radiometer file to generate a separate file for the shaded and unshaded periods for each instrument.
11) 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 records.
12) Run calibration programs to determine the calibration coefficient for each instrument.
13) Combine several days of calibration data to get a final calibration coefficient.
14) Produce a calibration document, such as this one, for each instrument. To be considered valid, a calibration must be documented and traceable to recognized standards, in this case the World Radiation Reference (WRR) in Davos Switzerland.