Calibration Report: Pyrheliometers

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SUMMARY

Calibration date: 2004 July 03.
Next calibration due: 2004 July 03.

Calibration coefficients and their associated uncertainties (U95%) have been determined for pyrheliometers. The units of the calibration coefficients (S) are μV/ (W/m^2). These calibration coefficients can be traced to the World Radiation Reference determined by the World Standard Group kept at the Physikalisch-Meteorologisches Observatorium in Davos Switzerland. The sensitivity factors and their associated uncertainties (95%) are as follows:

Manufacturer	serial Number	S μV/(W/m^2)	U95
Kipp and Zonen	CH1-960133	10.70	+/- 0.88%
Kipp and Zonen	CH1-010254	10.65	+/- 0.76%

Application

$$I = (\text{mV output})/S \pm U95\%$$

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

The following sections contain figures and descriptions of the calibration process. Figure 1 shows cavity measured solar irradiance for the measurement period. Figures 2 and 3 show the calibration values in parts A, and the distribution of the calibration values about their means. Following the plots are the calibration histories descriptions of the measurement system and data analysis techniques.

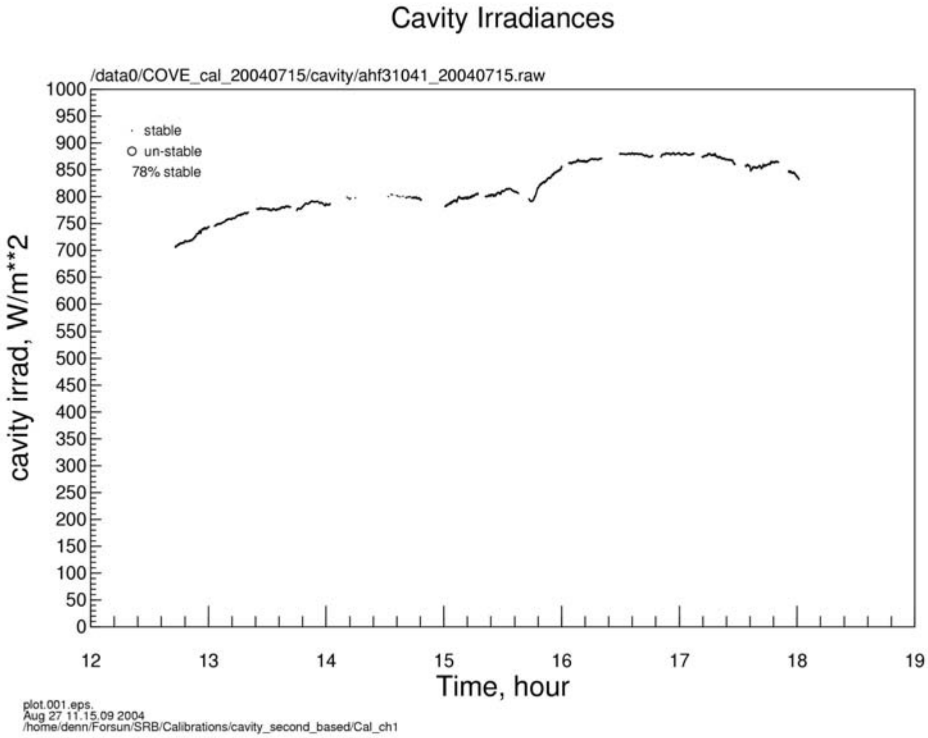

Figure 1. Irradiance measured by ACR AHF-31041 on the day of the calibrations.

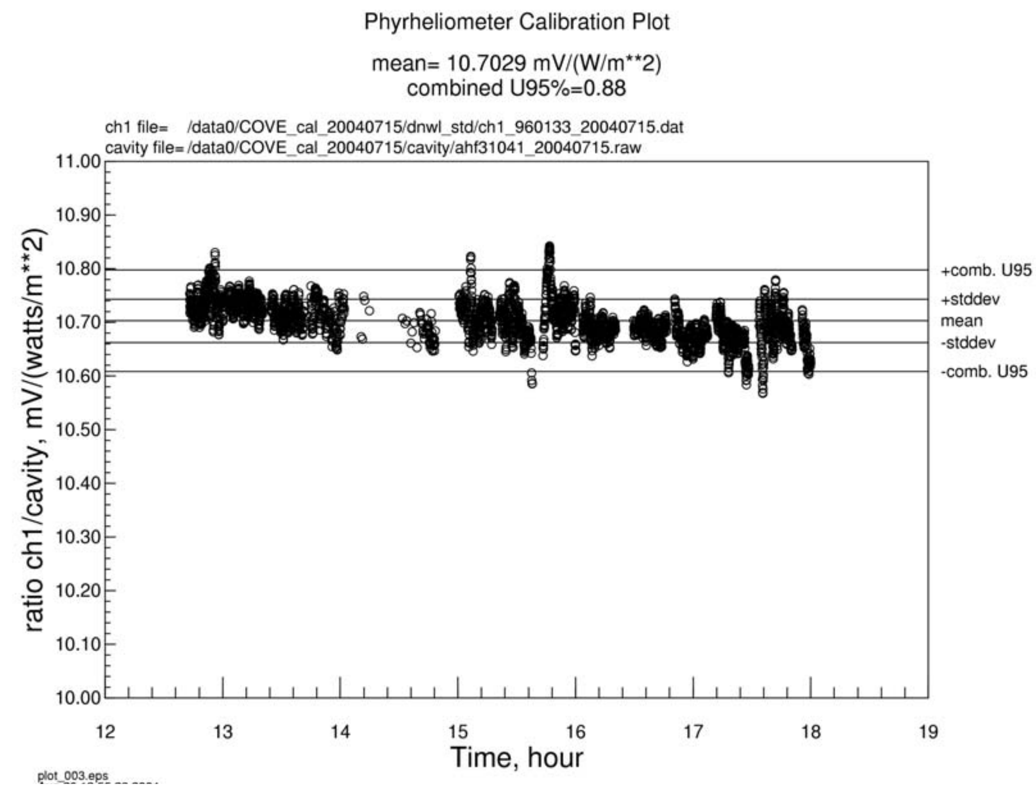

Figure 2A. The distribution of the 1Hz calibration measurements is shown for the pyrheliometer CH1-96033. The mean and limits of the standard deviation and U95 are shown.

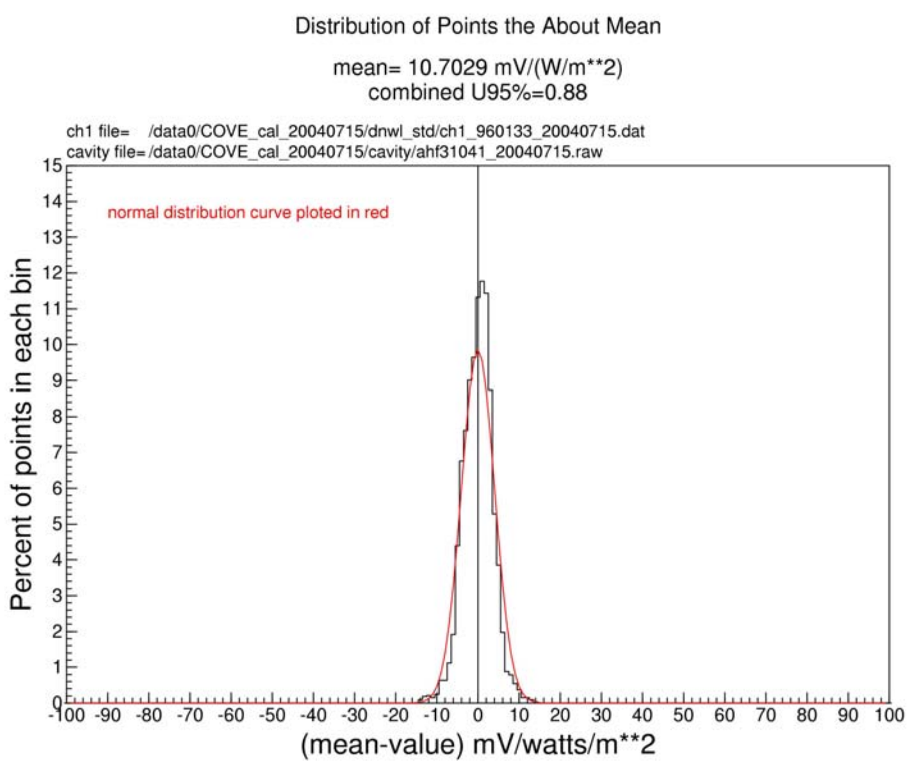

Figure 2B. A histogram of the distribution of the calibration points about the mean is shown for pyrheliometer CH1-960133.

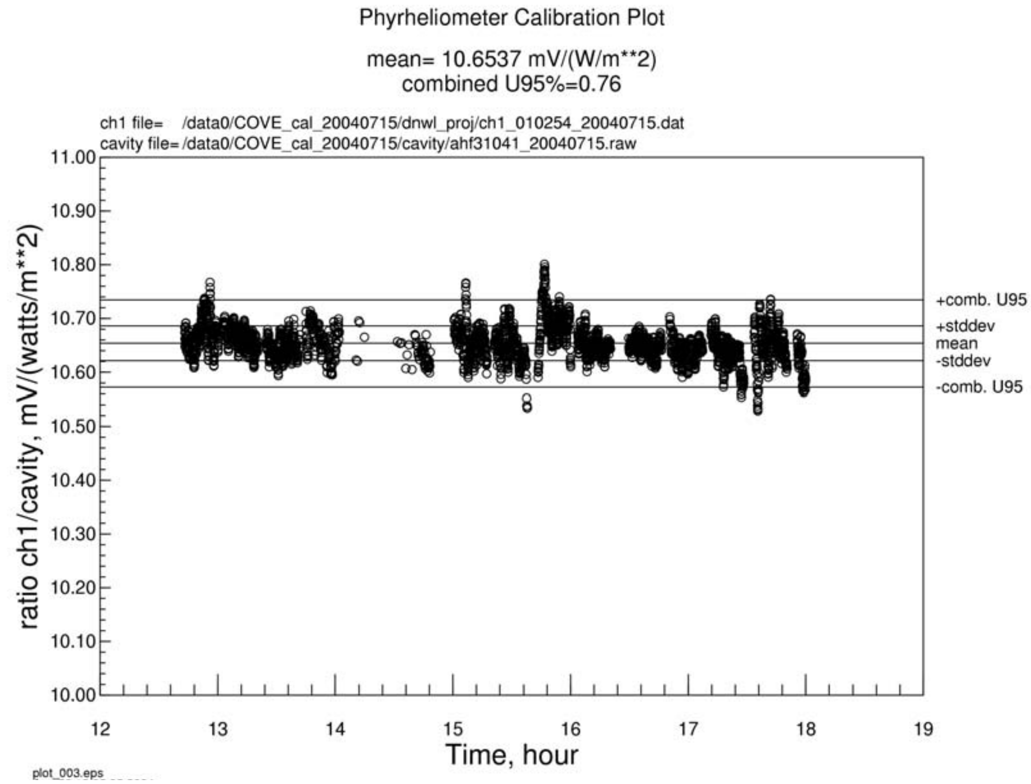

Figure 3A. The distribution of the 1Hz calibration measurements is shown for the pyrheliometer CH1-010254. The mean and limits of the standard deviation and U95 are shown.

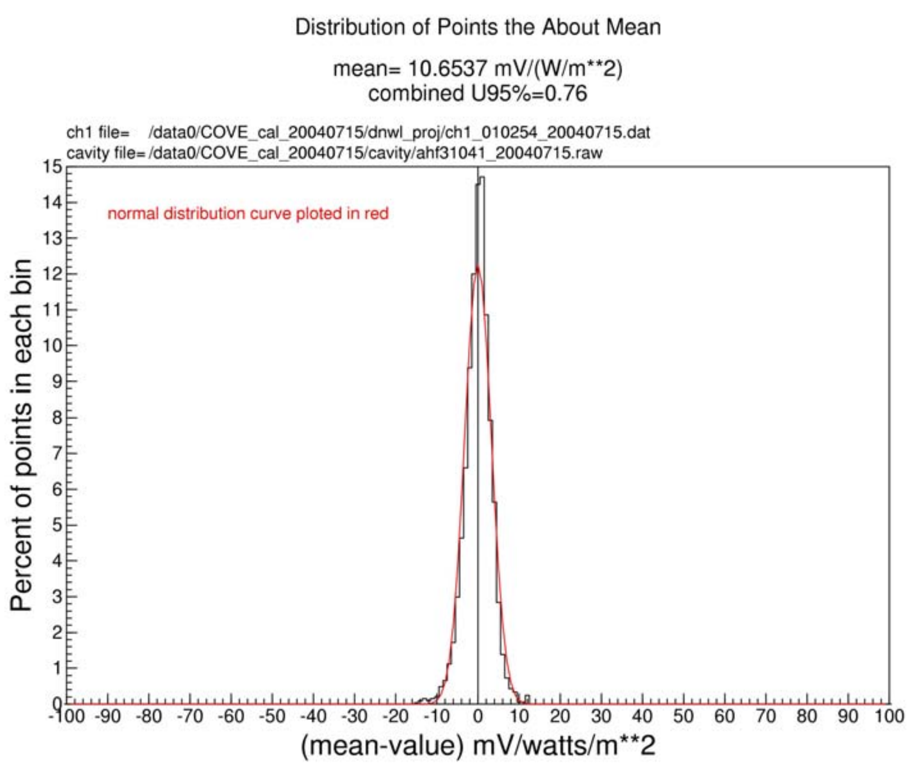

Figure 3B. A histogram of the distribution of the calibration points about the mean is shown for pyrheliometer CH1-010254.

CALIBRATION HISTORIES

Pyrheliometer: Kipp and Zonen CH1-010254.

date	day of year	S ($\mu V/(W/m^2)$)	U95 (%)	
2004 Jul 15	197	10.65	0.76	(1 HZ data)
2003 Apr 03	093	10.63	0.93	(minute data)
1002 Jun 01	182	10.63	5.00	(manufacturer calibration)

Pyrheliometer: Kipp and Zonen CH1-960132.

date	day of year	S ($\mu V/(W/m^2)$)	U95 (%)	
2001 Jun 01	152	damaged and removed from service		
2000 Nov 28	333	11.18	0.67	(minute data)
1999 Nov 19	323	11.19	0.71	(minute data)
1999 Feb 12	043	11.06	0.73	(minute data)
1996 Jun 30	182	11.06	5.00	(manufacturer calibration)

Pyrheliometer: Kipp and Zonen CH1-960133.

date	day of year	S ($\mu V/(W/m^2)$)	U95 (%)	
2004 Jul 15	197	10.70	0.88	(1 HZ data)
2003 Apr 02	093	10.70	0.87	(minute data)
2001 Aug 02	214	10.65	0.81	(minute data)
2000 Nov 28	333	10.71	0.66	(minute data)
1999 Oct 09	282	10.66	0.78	(minute data)
1999 Feb 12	043	10.53	0.73	(minute data)
1996 Jun 30	182	10.65	5.00	(manufacturer calibration)

Pyrheliometer: Eppley PSP-31375E6.

date	day of year	S ($\mu V/(W/m^2)$)	U95 (%)	
1999 Feb 12	043	8.14	1.06	(minute data)
1998 Feb 16	047	8.21	0.83	(minute data)
unknown		8.24	5.00	(manufacturer calibration)

Pyrheliometer: Eppley PSP-31376E6.

date	day of year	S ($\mu V/(W/m^2)$)	U95 (%)	
1999 Feb 12	043	7.88	1.00	(minute data)
1998 Feb 16	047	7.92	1.24	(minute data)
unknown		8.00	5.00	(manufacturer calibration)

ABSTRACT

Calibration data from pyrheliometer sensors have been collected during several time periods. The data is typically collected at the Clouds and the Earth's Radiant Energy System (CERES) Ocean Validation Experiment (COVE) site located at the Chesapeake light station, in the Atlantic Ocean approximately 25km east of Virginia Beach, Virginia. Data collection sites have also included NASA Langley Research Center (LaRC), Hampton Virginia, and the Mauna Loa Observatory (MLO) Hawaii. Calibrated devices have included Eppley Laboratory, Inc. Normal Incident Pyrheliometers (NIP) and Kipp & Zonen, Inc. CH1 sensors. These sensors were calibrated using an Eppley Laboratory, Inc. Absolute Cavity Radiometer as the reference. These calibration data are analyzed to produce calibration coefficients with 95% uncertainty bounds (u95). Current and historical calibration coefficients are presented here.

1. Introduction

Calibrations of pyrheliometers are made periodically to maintain data quality and traceability to the World Radiometric Reference (WRR). The sensors are calibrated using an Eppley Laboratory, Inc. Absolute Cavity Radiometer (ACR) as the reference. The ACR is traceable to the WRR cavity pyrheliometers at the Physikalisch-Meteorologisches Observatorium Davos (PMOD) in Davos, Switzerland.

2. Methodology

Verify that the pyrheliometer desiccant was within the proper tolerance. Attach the ACR and pyrheliometers to the solar tracker. Verify instrument alignment with respect to the sun. Connect the ACR to the ACR controller and the controller to the PC. Attach the pyrheliometers to the Campbell Scientific Inc. data logger system. Clean the pyrheliometer windows. Verify that the ACR window and the ACR cover are off. Use a computer program, supplied by NREL, to operate the ACR system. Use the Campbell data logger system to record voltages produced by the pyrheliometers.

3. Data Analysis

ACR data is collected every 3 to 4 seconds and multiplied by the WRR factor. The ACR data is tested for stability during a 3 second measurement interval, if the datum is not sufficiently stable it is flagged as unstable and not used in the data analysis. Voltages are collected from test pyrheliometers every second. For each second during which both an ACR irradiance and voltage for each pyrheliometer are obtained, pyrheliometer calibration factors are determined. A mean calibration factor and its standard deviation are determined for each pyrheliometer for the entire measurement period. A percent U95 for the measurements is then calculated by multiplying the standard deviation by two and converting to percent of measurement.

4. Calibration Uncertainty

The reference unit used in these pyrheliometer calibrations is an Eppley Laboratory Inc. ACR. The ACR is linked through national reference group at the National Renewable Energy Laboratory (NREL) in Golden Colorado which in turn is linked to the WRR determined by World Standard Group (WSG) at the Physikalisch-Meteorologisches Observatorium Davos. The LaRC ACR AHF-31041 was linked to WSG through the NREL ACR standard group in 1997, 1998, 1999, 2001, 2002, and 2003 and directly to the WSG in 2000. The NREL ACR standard group was linked to the WSG at the Eighth and Ninth International Pyrheliometer Comparisons (IPC-VIII and IPC-IX). The defined magnitude of the WRR uncertainty is 0.3, (U95% wrt SI units) reported at IPC-VIII.

The U95% for any specific pyrheliometer conveys the expected statistical relationship between an individual measurement made by that pyrheliometer and a hypothetical collocated individual measurement made by the WSG. This relationship is conveyed by the U95% metric which allows investigators to determine the 95% confidence intervals of measurements made by their radiometers. The measurement and its associated U95 would span the WSG measurement 95% of the time.

The final uncertainty of the test pyrheliometer calibration factor is the root sum square of the U95s of the WRR, the cavity with respect to the WRR and the test pyrheliometers with respect to the cavity.

$$U95_{total} = \mathrm{sqrt}((U95_{wrr})^2 + (U95_{cavity})^2 + (U95_{measured})^2)$$

Where:

$U95_{total}$ is the total U95 for the test pyrheliometers

$U95_{wrr}$ is the U95 of the WRR (0.3%)

$U95_{cavity}$ is the U95 of the cavity with respect to the WRR

$U95_{measured}$ is the U95 of the test pyrheliometers with respect to the cavity.

USEFUL REFERENCES

American National Standard for Expressing Uncertainty-U.S. Guide to the Expression of Uncertainty in Measurement, ANSI/NCSL Z540-2-1997. Reprinted 16 February 1998.

Swiss Meteorological Institute, (May 1996). “International Pyrheliometer Comparison IPC-VIII.” Working Report No. 188, Davos and Zurich.

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