Calibration Report: Eppley PIR Pyrgeometer

Summary

Calibration Date: March 23, 2007 Calibration Due Date: March 2009

Serial No.	C $\mu V/W/m^2$	k1	k2	k3	Cs $\mu V/W/m^2$	K'
26036F3	3.99	0.0100	1.0007	3.700	3.96	3.70
26169F3	4.06	-0.0200	0.9997	3.900	4.15	3.90

$$E = \frac{U_{emf}}{C}(1 + k_1\sigma T^3_B) + k_2\sigma T^4_B - k_3\sigma(T^4_D - T^4_B) - f\Delta T_{S\text{-}N} \qquad EQN\ 1$$

Where:

E = Irradiance, W/m^2

U_{emf} = Thermopile output voltage, μV

C = Sensitivity Coefficient, $\mu V/W/m^2$

$k1, k2, k3$ = Correction factors

σ = Stephan-Boltzmann Constant, 5.67 x 10^{-8} $W/m^2 K^4$

T_B = Output of body thermistor YSI 44031 , K

T_D = Output of dome thermistor YSI 44031, K

f = Correction factor for long wave component of direct sun if the instrument is used without a shading disk.

$\Delta T_{S\text{-}N} = (T_{SE} - T_N) + (T_{SW} - T_N)$

T_{SE}, T_N, T_{SW} = Output of dome thermistors, southeast, north and southwest respectively, K

$$E = \frac{U_{emf}}{Cs} + \sigma T^4_B - K'\sigma(T^4_D - T^4_B) \qquad EQN\ 2$$

Where:

E = Irradiance, W/m^2

Cs = Sensitivity Coefficient, $\mu V/W/m^2$

U_{emf} = Thermopile output voltage μV

σ = Stephan-Boltzmann Constant, 5.67 x 10^{-8} $W/m^2 K^4$

T_B = Output of body thermister YSI 44031, K

K' = Dome heating constant

T_D = Output of dome thermister YSI 44031, K

Calibration Report: Eppley PIR Pyrgeometer

Abstract

Two Eppley Laboratory, Inc. Precision Infrared Pyrgeometers (PIR) instruments were calibrated. This calibration was performed in order that the instruments comply with specifications set in the Baseline Surface Radiation Network (BSRN) Operator's Manual, V 2.1, 2005. Physikalisch-Meteorolisches Observatorium Davos (PMOD) in Davos-Dorf, Switzerland performed the calibration. The calibration date is 23 March 2007. The serial numbers of the units modified and calibrated were 26036F3 and 26169F3.

1. Introduction

Two Eppley Laboratory, Inc. PIR's were calibrated to meet the 2005 Baseline Surface Radiation Network (BSRN) specifications. PMOD in Davos-Dorf, Switzerland completed these calibration tasks.

2. Results

Calibration results for each instrument are shown in the above summary page along with the governing equations. The use of EQN. 1 with the above tabular values is described in each of the Calibration Certificates provided by PMOD. EQN. 2 and the associated tabular values are provided as a historical connection to the Albrecht et al. single sensitivity factor method.

3. Discussion

These sensors have been modified and calibrated to permit the measurement of diffuse radiation. Global measurements involve determination of the factor *f*. The manufacturer, Eppley Laboratories, Inc., defines an uncertainty of 5%. Field data need to be examined in order to assess the standard uncertainty made by the modified instruments.

The single sensitivity factor calibration histories of the two sensors calibrated at PMOD are as follows:

26036F3

Mar. 2007	PMOD	3.96 $\mu V/W/m^2$
Jan. 2002	PMOD	3.86 $\mu V/W/m^2$
Apr. 1998	PMOD	3.84 $\mu V/W/m^2$

26169F3

Mar. 2007	PMOD	4.15 $\mu V/W/m^2$
Dec. 1999	PMOD	4.07 $\mu V/W/m^2$

Each instruments single sensitivity factor, *Cs*, has remained within variability of 5% or less through each of the calibrations, which did not involve physical changes to the instrument. This variability is within manufacturer stated design specifications.

4. Summary

A calibration of two Eppley Laboratory Inc. PIR instruments has been completed. Data analyses have been performed. The calibration factors are presented in the summary table above and in the Calibration Certificates.

No apparent performance anomalies are indicated from the single sensitivity factor calibration history of the sensors.

These calibration factors can be used with these two instruments from 23 March 2007.

REFERENCES

Albrecht, B., and S.K. Cox, Procedures for Improving Pyrgeometer Performance, Journal of Applied Meteorology, 16, 179-188, 1977.

Frohlich, C., and R. Philipona, Characterization of pyrgeometers and the accuracy of atmospheric longwave measurements, Ch., Betz, Applied Optics, 34(9), 1598-1605, 1995.

McArthur, J.B., World Climate Research Program, Baseline Surface Radiation Network Operations Manual, Version 2.1., 2005.

Calibration procedure:

This instrument was calibrated by an outdoor comparison to the pyrgeometer reference group (PIR 31463F3, PIR 31464F3, CG4 FT004, and CG4 030669) of the IR-Centre at PMOD/WRC. The comparison is made during nighttime with cloudy and cloud-free situations. The pyrgeometer was installed in a PMOD-VHS ventilation unit with a heated air flow around the dome.

From the measurements the sensitivity factor **C** is determined by using the standard relation (shown below), which involves the pyrgeometer signal U_{emf}, the dome temperature T_D and body temperature T_B of the pyrgeometer. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors. The dome temperature T_D is calculated from the average of the three dome temperature measurements (N, SE, and SW). The longwave downward irradiance *E* is calculated using the following equation:

$$E = \frac{U_{emf}}{C}(1 + k_1 \sigma T_B^3) + k_2 \sigma T_B^4 - k_3 \sigma (T_D^4 - T_B^4)$$

Sensitivity: $C = 3.99\ \mu V/Wm^{-2}$

$u = 0.08\ \mu V/Wm^{-2}$

coefficients in use: $k_1 = 0.01$

$k_2 = 1.0007$

$k_3 = 3.7$

The coefficients k_1, k_2 and k_3 were determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 and +10 °C and Pyrgeometer body temperatures between -10 and +25°C.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR):	210 to 325 Wm^{-2}
Net radiation:	-120 to -9 Wm^{-2}
Pyrgeometer body temperature:	-2.5 to 13.9 °C
Standard deviation of the residuals	0.31 Wm^{-2}
Measurement period:	March 23, 2007 to April 18, 2007
Measurement days used for the calibration:	21

Remarks:

It is recommended to use this pyrgeometer with a shading disc. If the pyrgeometer is used without a shading disk the longwave part of the solar radiation has to be subtracted during daytime measurements.

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$$E = \frac{U_{emf}}{C} + \sigma T_B^4 - \mathrm{K}\sigma(T_D^4 - T_B^4)$$

Sensitivity: **C = 3.96 μV/Wm^{-2}**

u = 0.09 μV/Wm^{-2}

coefficient in use: **K = 3.7**

The coefficient **K** was determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 and +10 °C and Pyrgeometer body temperatures between -10 and +25°C.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR):	210 to 325 Wm^{-2}
Net radiation:	-121 to -9 Wm^{-2}
Pyrgeometer body temperature:	-2.5 to 13.9 °C
Standard deviation of the residuals	0.37 Wm^{-2}
Measurement period:	March 23, 2007 to April 18, 2007
Measurement days used for the calibration:	21

Remarks:

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Physikalisch-Meteorologisches Observatorium Davos
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Certificate No. 2007/16/2

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$$E = \frac{U_{emf}}{C}(1 + k_1 \sigma T_B^3) + k_2 \sigma T_B^4 - k_3 \sigma (T_D^4 - T_B^4)$$

Sensitivity: $C = 4.06\ \mu V/Wm^{-2}$

$u = 0.08\ \mu V/Wm^{-2}$

coefficients in use: $k_1 = -0.02$

$k_2 = 0.9997$

$k_3 = 3.9$

The coefficients k_1, k_2 and k_3 were determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 and +10 °C and Pyrgeometer body temperatures between -10 and +25°C.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Radiation and temperature conditions during the calibration:

Longwave downward radiation (LDR):	201 to 330 Wm^{-2}
Net radiation:	-151 to -25 Wm^{-2}
Pyrgeometer body temperature:	-3.0 to 16.5 °C
Standard deviation of the residuals	0.44 Wm^{-2}
Measurement period:	March 23, 2007 to April 18, 2007
Measurement days used for the calibration:	23

Remarks:

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From the measurements the sensitivity factor **C** is determined by using the standard relation (shown below), which involves the pyrgeometer signal U_{emf}, the dome temperature T_D and body temperature T_B of the pyrgeometer. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors. The dome temperature T_D is calculated from the average of the three dome temperature measurements (N, SE, and SW). The longwave downward irradiance *E* is calculated using the following equation:

$$E = \frac{U_{emf}}{C} + \sigma T_B^4 - \mathrm{K}\sigma(T_D^4 - T_B^4)$$

Sensitivity: **C = 4.15 µV/Wm^{-2}**
u = 0.08 µV/Wm^{-2}

coefficient in use: **K = 3.9**

The coefficient **K** was determined in the reference blackbody source of PMOD/WRC using blackbody temperatures between -30 and +10 °C and Pyrgeometer body temperatures between -10 and +25°C.

The reported expanded uncertainty of measurement **u** is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

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