Calibration Report: Eppley PIR Pyrgeometer

Summary

Calibration Date: March 13, 2003   Calibration Due Date: March 13, 2005

Serial No.	C $\mu V/W/m^2$	k1	k2	k3		Cs $\mu V/W/m2$	K'
26168F3	4.39	0.0614	1.0088	3.36		4.22	3.04
27174F3	4.49	0.1385	1.0015	3.44		3.93	3.45
31606F3	3.81	0.0571	0.9974	3.35		3.53	3.49

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

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, $5.67 \times 10^{-8} \, W/m^2 \, K^4$

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.

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

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

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

Where:

E = Irradiance, W/m^2

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

U_{emf} = Thermopile output voltage μV

σ = Stephan-Boltzman Constant, $5.67 \times 10^{-8} \, W/m^2 \, K^4$

T_B = Output of body thermistor YSI 44031, K

K' = Dome heating constant

T_D = Output of dome thermistor YSI 44031, K

Calibration Report: Eppley PIR Pyrgeometer

Abstract

Three 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 1.0 1997. Physikalisch-Meteorolisches Observatorium Davos (PMOD) in Davos-Dorf, Switzerland performed the calibration. The calibration date is 13 March 2003. The serial numbers of the units calibrated were 26168F3, 27174F3 and 31606F3.

1. Introduction

Three Eppley Laboratory, Inc. PIR's were calibrated to meet the 1997 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 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 three sensors calibrated at PMOD are as follows:

26168F3

Mar. 2003   4.22 $\mu V/W/m^2$
Jan. 2002   4.18 $\mu V/W/m^2$
Sept. 2000 4.07 $\mu V/W/m^2$
Apr. 1998   4.22 $\mu V/W/m^2$

27174F3

Mar. 2003   3.93 $\mu V/W/m^2$
Sept. 2000 3.77 $\mu V/W/m^2$
Apr. 1998   4.03 $\mu V/W/m^2$

31606F3

Mar. 2003   3.53 $\mu V/W/m^2$
Sept. 2000 3.30 $\mu V/W/m^2$
Apr. 1998   3.54 $\mu V/W/m^2$

Calibration histories of other PIR's calibrated at PMOD:

26181F3

Jan. 2002 3.48 $\mu V/W/m^2$
Dec. 1999 3.47 $\mu V/W/m^2$

24323F3

Jan. 2002   3.87 $\mu V/W/m^2$
Sept. 2000 3.61 $\mu V/W/m^2$
Apr. 1998   3.79 $\mu V/W/m^2$

26036F3

Jan. 2002   3.86 $\mu V/W/m^2$
Sept. 2000 3.61 $\mu V/W/m^2$
Apr. 1998   3.84 $\mu V/W/m^2$

31605F3

Dec. 1999 3.54 $\mu V/W/m^2$

26169F3

Dec. 1999 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 three 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 three instruments from 13 March 2003.

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 1.0. June 1997.

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Weltstrahlungszentrum   Centre Mondial de Rayonnement   World Radiation Center
Physikalisch-Meteorologisches Observatorium Davos

Calibration Certificate for Pyrgeometer

Model :   Eppley PIR Pyrgeometer

Serial No. :   26168F3 (with 3 dome thermistors)

Owner: SAIC

Calibration measurements were performed in the black body radiation source of PMOD/WRC at Davos. Measurements are made at three body temperatures of $t_B = 25°$ C, $10°$ C and $-5°$ C and the black body temperature was set at about $10°$ C and $25°$ C below the body temperature of the instrument. Four different dome temperatures are chosen for the measurements with $t_B = 10°$C. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors.

From these measurements the sensitivity factor C and three correction factors k_1, k_2 and k_3 are determined.

$$C \ = \ 4.39 \quad \mu V/Wm^{-2}$$
$$k_1 \ = \ 0.0614$$
$$k_2 \ = \ 1.0088$$
$$k_3 \ = \ 3.36$$

If the pyrgeometer is used without a shading disk the long-wave part of the direct sun has to be subtracted. For this a correction factor f has to be determined during clear days and this factor should be checked monthly.

The dome temperature is calculated as a mean value of the three dome temperature measurements. The instrument has to be positioned such that the cable points to the North. The South-North temperature difference of the dome is calculated using the following formula $\Delta T_{S-N} = (T_{SE} - T_N) + (T_{SW} - T_N)$. If necessary a constant value has to be added or subtracted in order to get ΔT_{S-N} equal to zero over night.
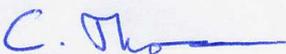
The long-wave downward irradiance E is calculated using the following equation.

$$E = \frac{U_{emf}}{C} \left(1 + k_1 \sigma T_B^3 \right) + k_2 \sigma T_B^4 - k_3 \sigma \left(T_D^4 - T_B^4 \right) - f \Delta T_{S-N}$$

For calculations with the old pyrgeometer formula after Albrecht et al. the sensitivity factor C and the correction factor K are also calculated from the same calibration measurements.

$$C \ = \ 4.22 \ \mu V/Wm^{-2} \qquad K = 3.04$$

Davos Dorf, 13. March 2003

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(In charge of calibration)

Dr. R. Philipona
(Scientist resp. for calibration)

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Weltstrahlungszentrum Centre Mondial de Rayonnement World Radiation Center
Physikalisch-Meteorologisches Observatorium Davos

Calibration Certificate for Pyrgeometer

Model : Eppley PIR Pyrgeometer

Serial No. : 27174F3 (with 3 dome thermistors)

Owner: SAIC

Calibration measurements were performed in the black body radiation source of PMOD/WRC at Davos. Measurements are made at three body temperatures of $t_B = 25°$ C, $10°$ C and $-5°$ C and the black body temperature was set at about $10°$ C and $25°$ C below the body temperature of the instrument. Four different dome temperatures are chosen for the measurements with $t_B = 10°$C. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors.

From these measurements the sensitivity factor C and three correction factors k_1, k_2 and k_3 are determined.

$$C = 4.49 \quad \mu V/Wm^{-2}$$
$$k_1 = 0.1385$$
$$k_2 = 1.0015$$
$$k_3 = 3.44$$

If the pyrgeometer is used without a shading disk the long-wave part of the direct sun has to be subtracted. For this a correction factor f has to be determined during clear days and this factor should be checked monthly.

The dome temperature is calculated as a mean value of the three dome temperature measurements. The instrument has to be positioned such that the cable points to the North. The South-North temperature difference of the dome is calculated using the following formula $\Delta T_{S-N} = (T_{SE} - T_N) + (T_{SW} - T_N)$. If necessary a constant value has to be added or subtracted in order to get ΔT_{S-N} equal to zero over night.

The long-wave downward irradiance E is calculated using the following equation.

$$E = \frac{U_{emf}}{C}\left(1 + k_1 \sigma T_B^3\right) + k_2 \sigma T_B^4 - k_3 \sigma\left(T_D^4 - T_B^4\right) - f \Delta T_{S-N}$$
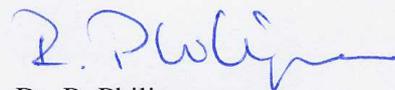
For calculations with the old pyrgeometer formula after Albrecht et al. the sensitivity factor C and the correction factor K are also calculated from the same calibration measurements.

$$C = 3.93 \ \mu V/Wm^{-2} \qquad K = 3.45$$

Davos Dorf, 13. March 2003

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Weltstrahlungszentrum   Centre Mondial de Rayonnement   World Radiation Center
Physikalisch-Meteorologisches Observatorium Davos

Calibration Certificate for Pyrgeometer

Model :   Eppley PIR Pyrgeometer

Serial No. :   31606F3 (with 3 dome thermistors)

Owner: SAIC

Calibration measurements were performed in the black body radiation source of PMOD/WRC at Davos. Measurements are made at three body temperatures of $t_B = 25°$ C, 10° C and -5° C and the black body temperature was set at about 10° C and 25° C below the body temperature of the instrument. Four different dome temperatures are chosen for the measurements with $t_B = 10°$C. Body and dome temperatures are determined using the Steinhart and Hart equation and the YSI coefficients of the YSI 44031 thermistors.

From these measurements the sensitivity factor C and three correction factors k_1, k_2 and k_3 are determined.

$$C = 3.81 \quad \mu V/Wm^{-2}$$
$$k_1 = 0.0571$$
$$k_2 = 0.9974$$
$$k_3 = 3.35$$

If the pyrgeometer is used without a shading disk the long-wave part of the direct sun has to be subtracted. For this a correction factor f has to be determined during clear days and this factor should be checked monthly.

The dome temperature is calculated as a mean value of the three dome temperature measurements. The instrument has to be positioned such that the cable points to the North. The South-North temperature difference of the dome is calculated using the following formula $\Delta T_{S-N} = (T_{SE} - T_N) + (T_{SW} - T_N)$. If necessary a constant value has to be added or subtracted in order to get ΔT_{S-N} equal to zero over night.

The long-wave downward irradiance E is calculated using the following equation.

$$E = \frac{U_{emf}}{C}\left(1 + k_1 \sigma T_B^3\right) + k_2 \sigma T_B^4 - k_3 \sigma\left(T_D^4 - T_B^4\right) - f\,\Delta T_{S-N}$$

For calculations with the old pyrgeometer formula after Albrecht et al. the sensitivity factor C and the correction factor K are also calculated from the same calibration measurements.

$$C = 3.53\ \mu V/Wm^{-2} \qquad K = 3.49$$

Davos Dorf, 13. March 2003

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