Broadband Outdoor Radiometer Calibration
Longwave

BORCAL-LW
2019-06

Generated by

RCC

Radiometer Calibration and Characterization

Calibration Facility

Southern Great Plains

Latitude: 36.605°N

Longitude: 97.488°W

Elevation: 317.0 meters AMSL

Time Zone: -6.0

Calibration date

10/10/2019 to 11/18/2019

Report Date

November 20, 2019

Broadband Outdoor Radiometer Calibration Report

Table of contents

Introduction

This report compiles the calibration results from a Broadband Outdoor Radiometer Calibration (BORCAL). The work was accomplished at the Radiometer Calibration Facility shown on the front of this report. The calibration results reported here are traceable to the World Infrared Standard Group (WISG).

This report includes these sections:

- Control Instruments - a group of instruments included in each BORCAL event that provides a measure of process consistency.
- Results Summary - a table of all instruments included in this report summarizing their calibration results and uncertainty.
- Instrument Details - the calibration certificates for each instrument.
- Environmental and Sky Conditions - meteorological conditions and reference irradiance during the calibration event.

BORCAL Notes or Comments

PIR 32042F3 results were removed from this report due to bad data at the beginning of the calibration period.
PIR 32048F3 results were removed from this report due to intermittant bad case thermistor reporting throughout the calibration period.

Control Instrument History

Figure 1. Eppley PIR Control Instrument History (K0 Coefficient)

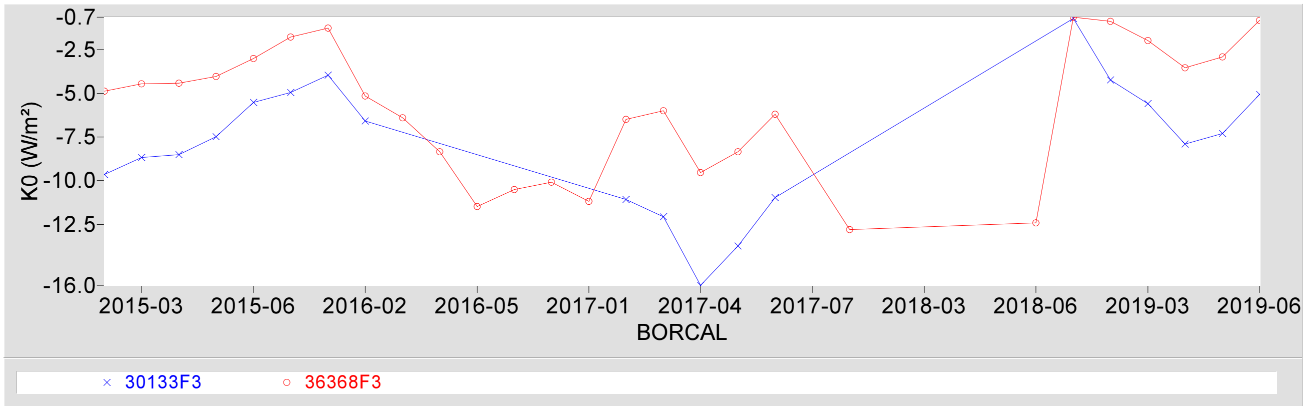


Figure 2. Eppley PIR Control Instrument History (K1 Coefficient)

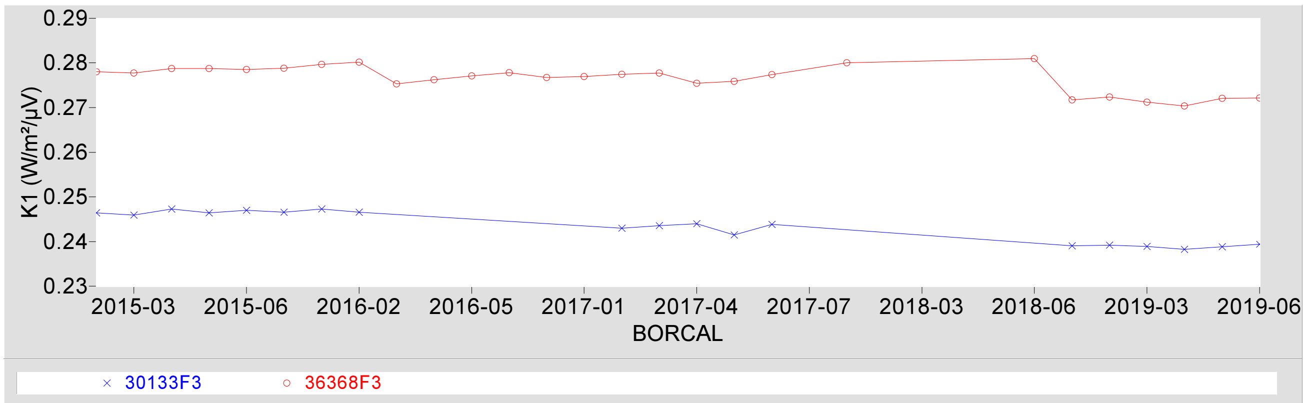


Figure 3. Eppley PIR Control Instrument History (K2 Coefficient)

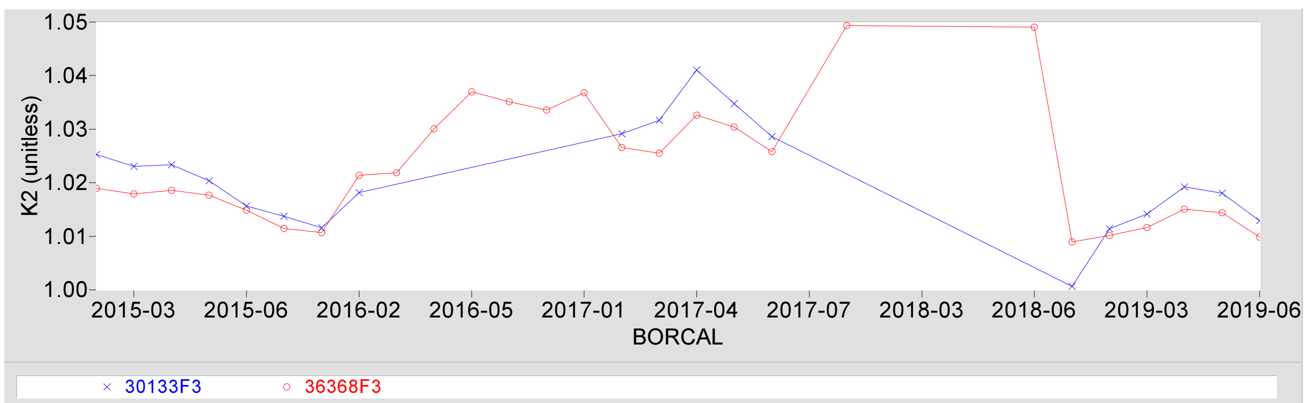
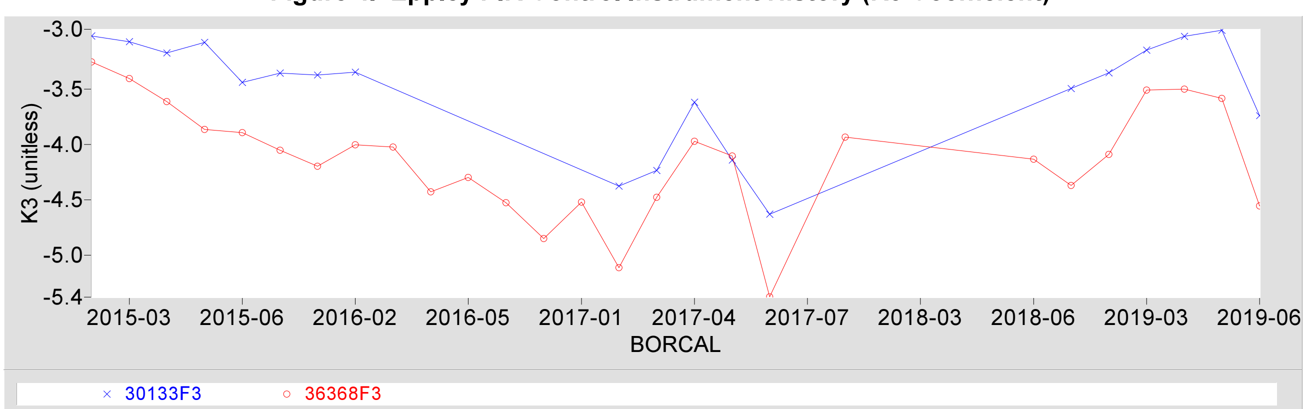


Figure 4. Eppley PIR Control Instrument History (K3 Coefficient)



Results Summary

Table 1. Results Summary

Instrument	Customer	K0 (W/m²)	K1 (W/m²/μV)	K2	K3	Kr * (K/μV)	U95 (W/m²)	Page
29592F3	SGP	2.2	0.24065	1.0003	-3.54	7.044e-4	±3.0	A1-2
29596F3	SGP	1.2	0.22550	1.0025	-4.07	7.044e-4	±3.0	A1-5
30010F3	SGP	0.5	0.27129	1.0039	-4.01	7.044e-4	±3.1	A1-8
30014F3	SGP	0.5	0.24316	1.0007	-4.41	7.044e-4	±3.0	A1-11
30084F3	TWP	-2.3	0.25728	1.0044	-4.07	7.044e-4	±3.0	A1-14
30133F3	SGP	-5.1	0.23940	1.0129	-3.74	7.044e-4	±3.0	A1-17
30345F3	SGP	-2.3	0.26150	1.0065	-4.27	7.044e-4	±3.0	A1-20
30356F3	SGP	-1.1	0.24643	1.0040	-3.45	7.044e-4	±3.0	A1-23
30682F3	SGP	-1.2	0.23361	1.0027	-3.68	7.044e-4	±3.1	A1-26
30684F3	SGP	-2.7	0.24990	1.0084	-3.42	7.044e-4	±3.0	A1-29
30685F3	SGP	-0.7	0.23703	1.0023	-3.39	7.044e-4	±3.0	A1-32
30687F3	SGP	-0.3	0.23596	1.0007	-3.21	7.044e-4	±3.0	A1-35
30688F3	SGP	-1.0	0.23244	1.0002	-3.02	7.044e-4	±3.0	A1-38
30689F3	SGP	-2.3	0.25411	1.0024	-3.11	7.044e-4	±3.0	A1-41
30780F3	SGP	0.0	0.24349	1.0008	-3.35	7.044e-4	±3.0	A1-44
30784F3	SGP	-0.6	0.23893	1.0067	-3.52	7.044e-4	±3.0	A1-47
30835F3	SGP	1.0	0.22615	0.9958	-3.38	7.044e-4	±3.0	A1-50
30837F3	SGP	-1.2	0.24194	1.0027	-4.24	7.044e-4	±3.0	A1-53
31639F3	SGP	2.4	0.21886	0.9953	-3.77	7.044e-4	±3.0	A1-56
32041F3	SGP	1.7	0.24258	1.0009	-4.35	7.044e-4	±3.1	A1-59
32043F3	NSA	2.7	0.22126	0.9915	-3.07	7.044e-4	±3.0	A1-62
34304F3	AMF	-1.2	0.22784	0.9967	-4.25	7.044e-4	±3.0	A1-65
36280F3	AMF	1.2	0.31379	1.0027	-4.39	7.044e-4	±3.0	A1-68
36368F3	SGP	-0.8	0.27217	1.0099	-4.56	7.044e-4	±3.0	A1-71
37325F3	AMF	-0.6	0.26269	0.9985	-7.32	7.044e-4	±3.1	A1-74
37327F3	AMF	0.1	0.23224	0.9988	-3.92	7.044e-4	±3.0	A1-77
37332F3	AMF	0.4	0.24506	1.0016	-5.73	7.044e-4	±3.0	A1-80
37334F3	NSA	4.9	0.22056	0.9903	-6.04	7.044e-4	±3.0	A1-83
38865F3	SGP	7.1	0.30701	0.9875	-5.82	7.044e-4	±3.1	A1-86
38866F3	SGP	3.7	0.32907	0.9827	-6.40	7.044e-4	±3.0	A1-89
38867F3	SGP	0.9	0.29324	0.9917	-5.40	7.044e-4	±3.1	A1-92
38868F3	SGP	5.4	0.29589	0.9843	-6.11	7.044e-4	±3.0	A1-95
38869F3	SGP	4.9	0.29758	0.9871	-5.41	7.044e-4	±3.0	A1-98
38870F3	SGP	3.2	0.26446	0.9855	-4.69	7.044e-4	±3.0	A1-101

Note: Environmental Conditions for BORCAL starts on page A1-104. * Kr used to derive K0,K1,K2, and K3

Appendix 1
Instrument Details

Calibration Certificates: 3 pages for each radiometer (4 including Environmental Conditions)
Environmental Conditions for BORCAL: Last Page of a Calibration Certificate. Note: This appears only once, at the end of Appendix 1.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	29592F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ _______________

Peter Gotseff, Technical Manager   Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

29592F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

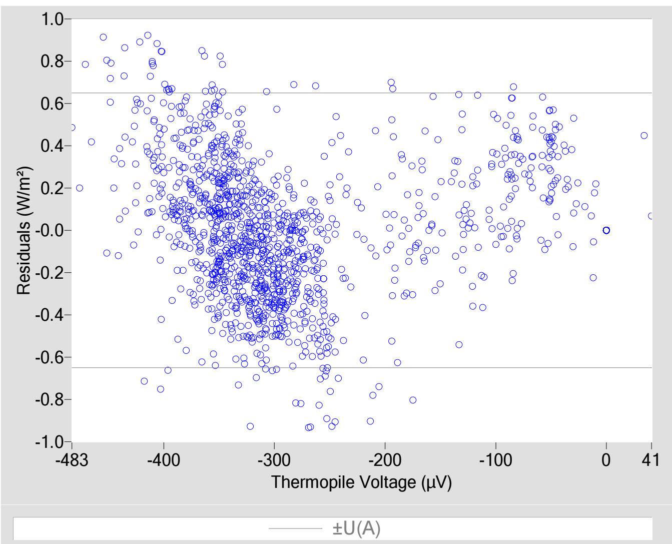


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

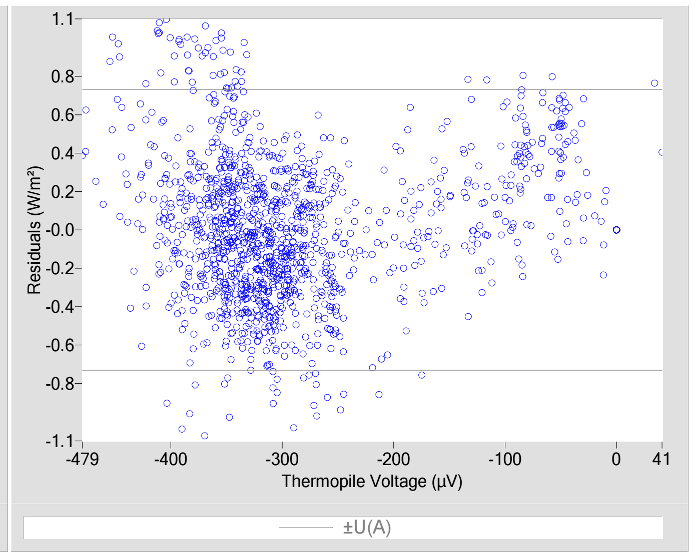


Table 2. Calibration Coefficients for K0<>0

K0	2.2
K1	0.24065
K2	1.0003
K3	-3.54
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24046
K2	1.0061
K3	-3.34
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.33
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.37
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

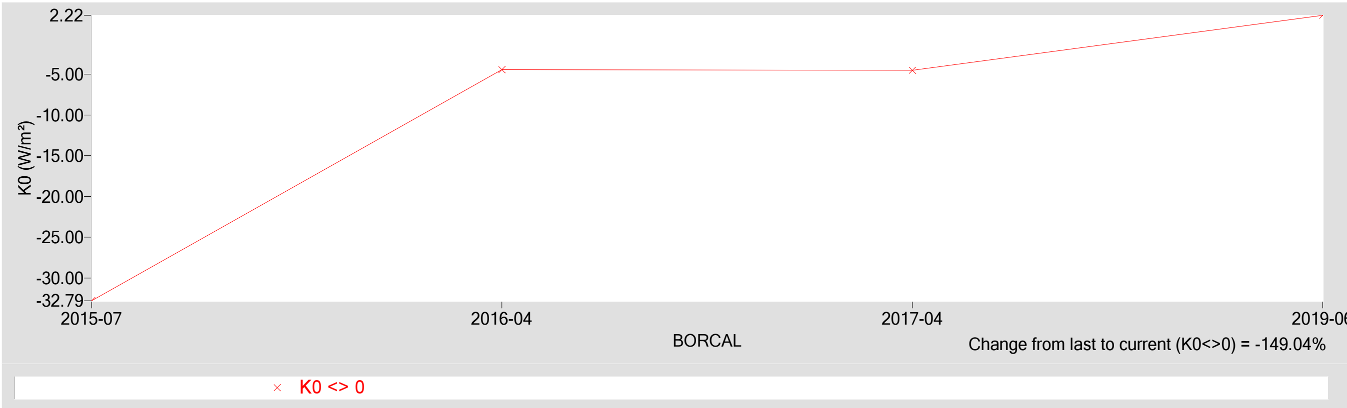


Figure 4. History of instrument (K1 Coefficient)

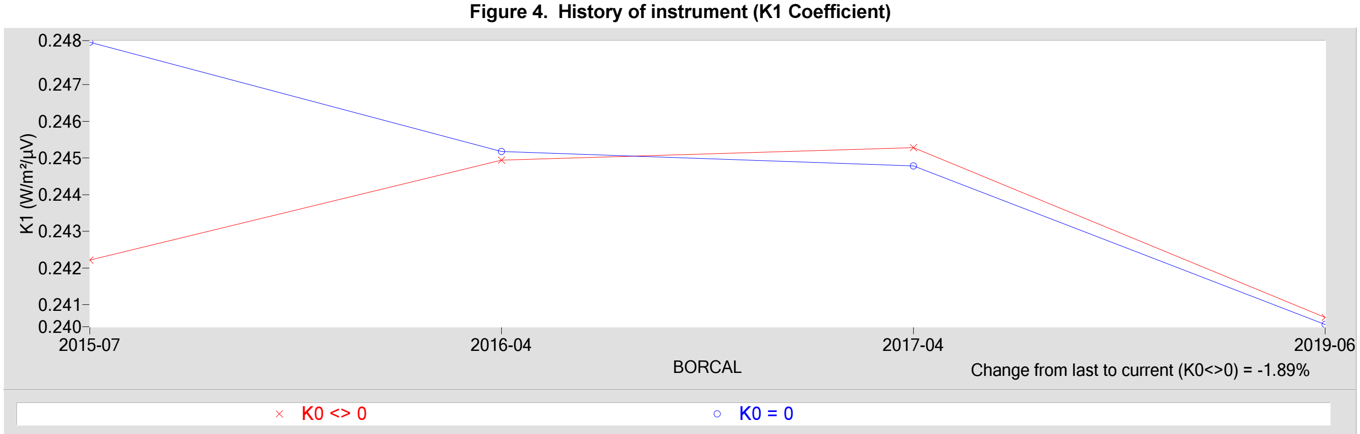


Figure 5. History of instrument (K2 Coefficient)

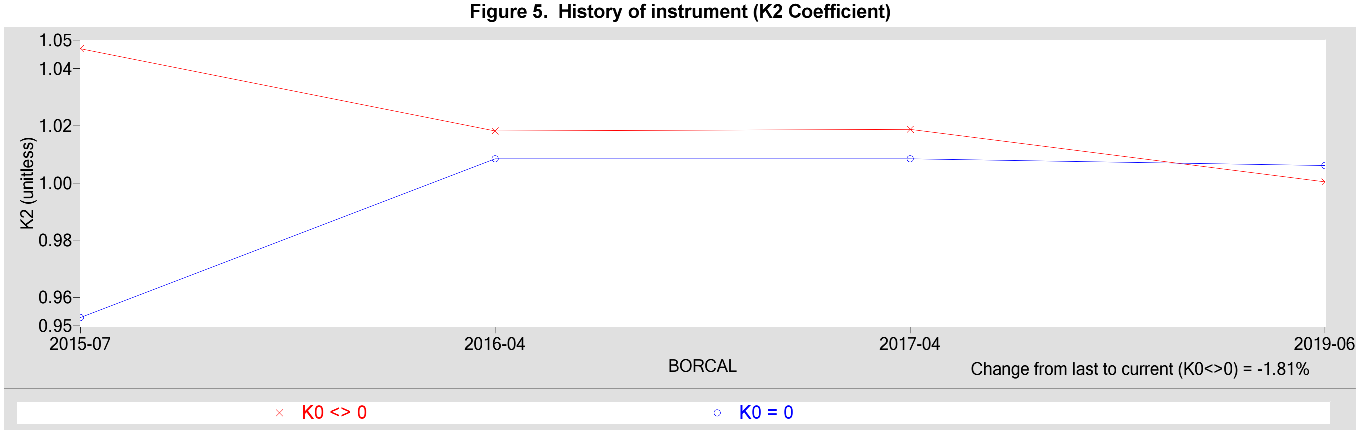
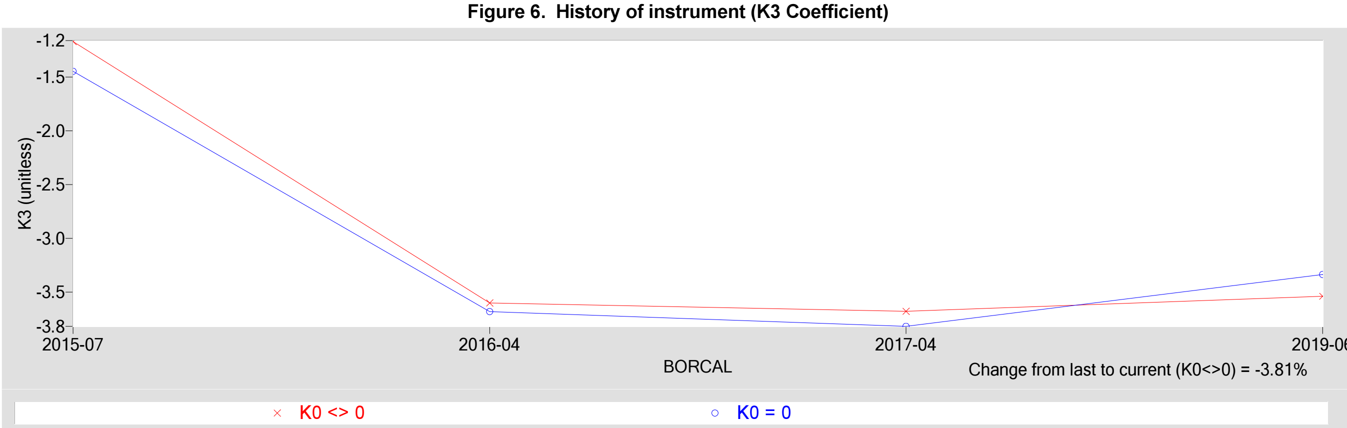


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	29596F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

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Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

29596F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1 \cdot V + K2 \cdot Wr + K3 \cdot (Wd - Wr) \qquad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
$Wd = \sigma \cdot Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma \cdot Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr \cdot V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

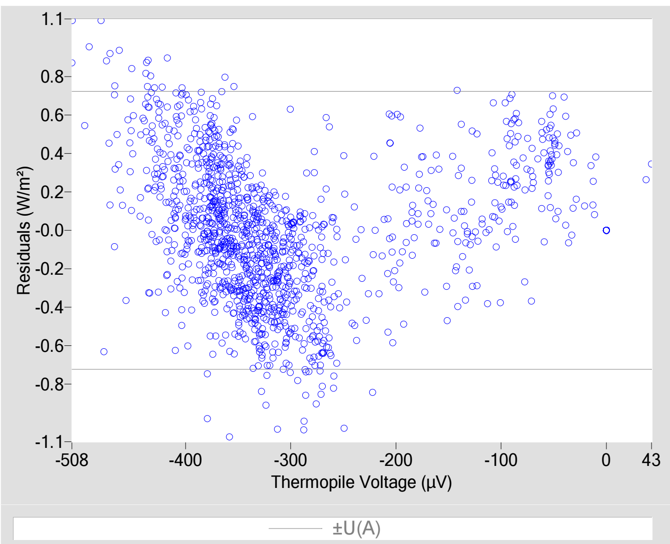


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

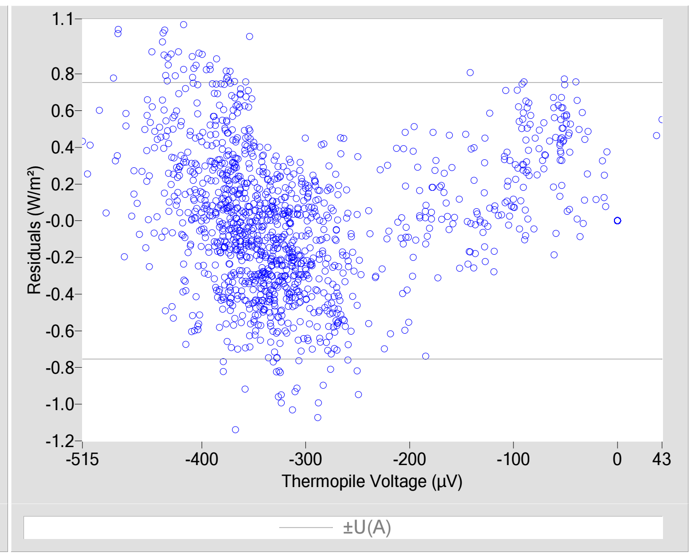


Table 2. Calibration Coefficients for K0<>0

K0	1.2
K1	0.22550
K2	1.0025
K3	-4.07
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.22536
K2	1.0057
K3	-3.97
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.37
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.38
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

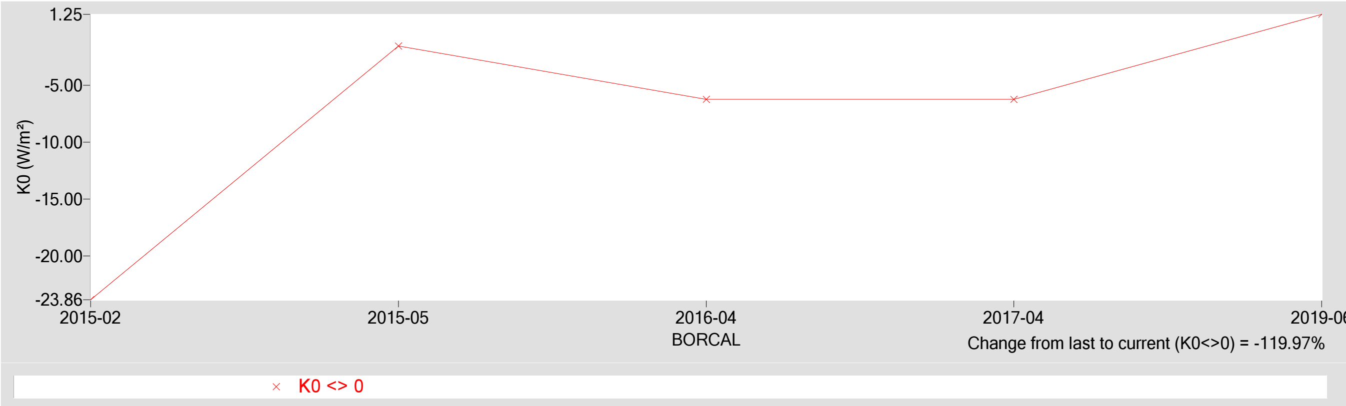


Figure 4. History of instrument (K1 Coefficient)

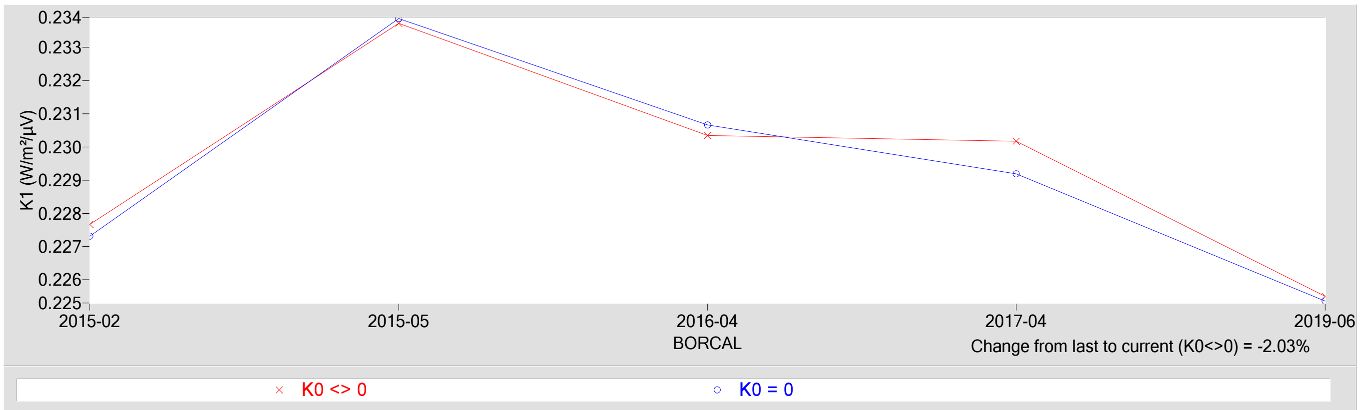


Figure 5. History of instrument (K2 Coefficient)

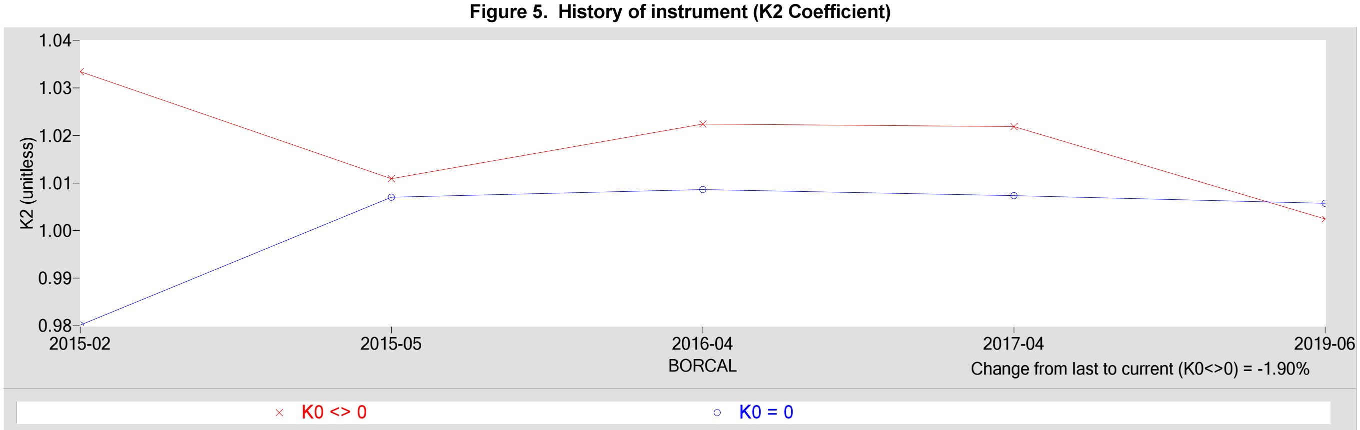
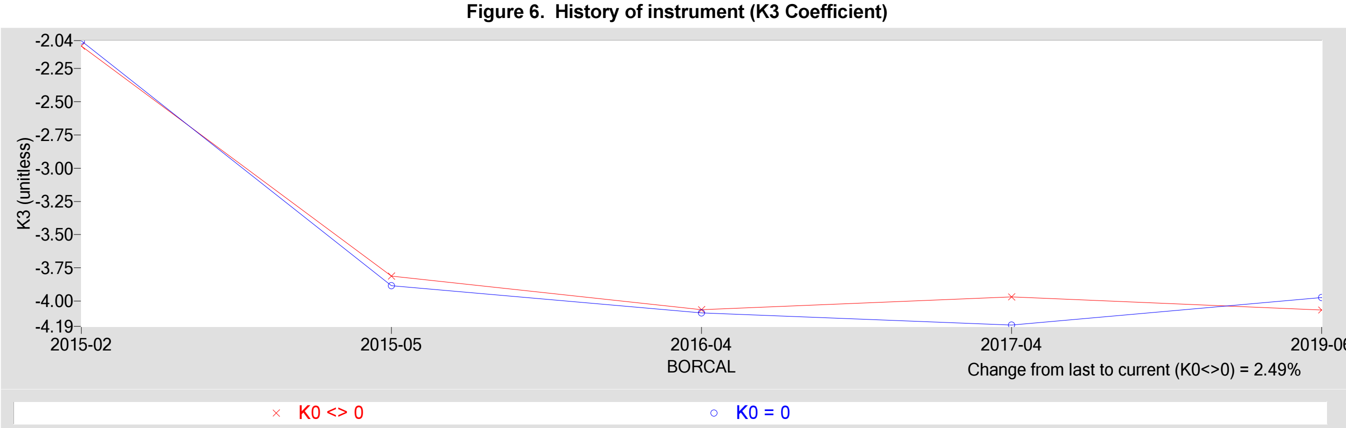


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30010F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

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Measurement Type	Instrument	Calibration Date	Calibration Due Date
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Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________________ __________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30010F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

*Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr)* [1]

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

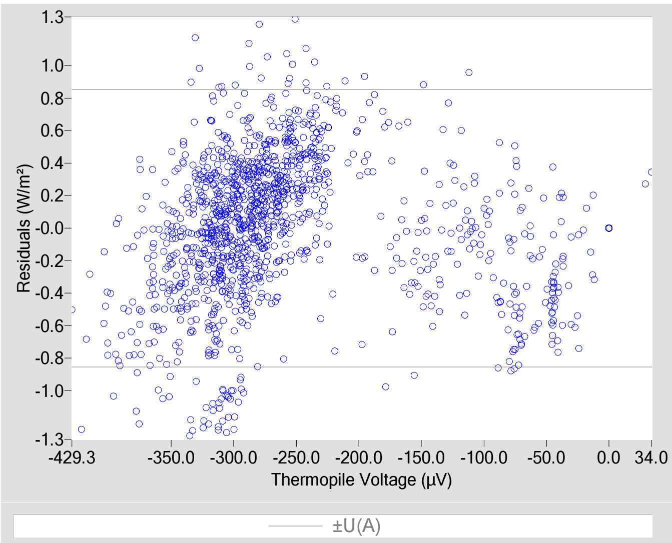


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

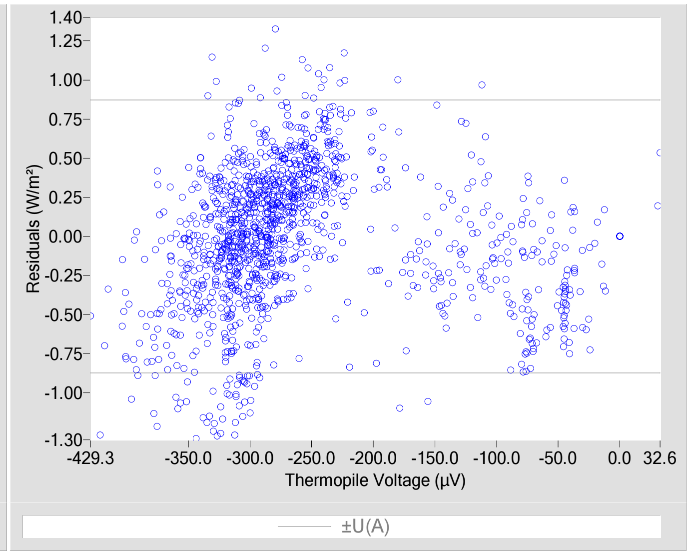


Table 2. Calibration Coefficients for K0<>0

K0	0.5
K1	0.27129
K2	1.0039
K3	-4.01
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.27135
K2	1.0052
K3	-3.97
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.44
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.44
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

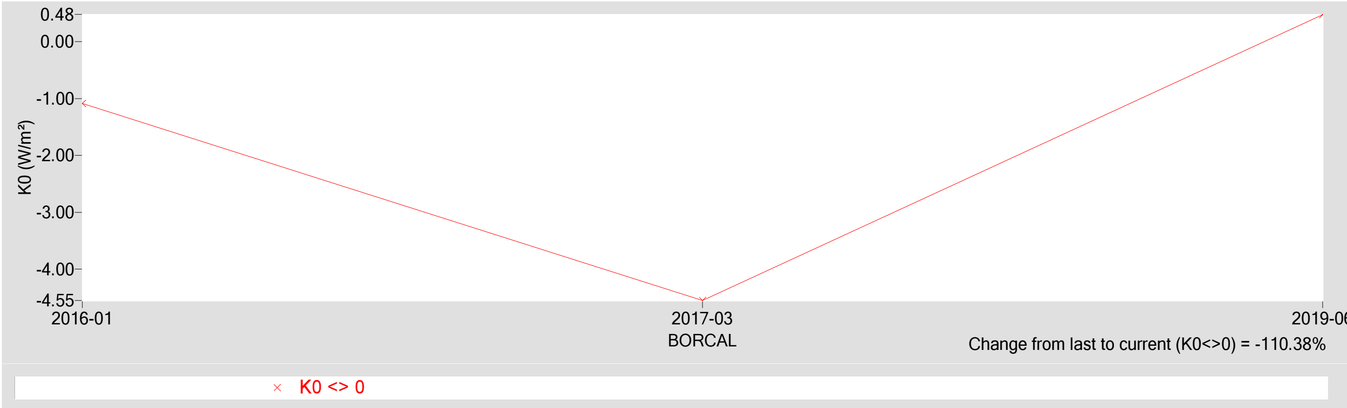


Figure 4. History of instrument (K1 Coefficient)

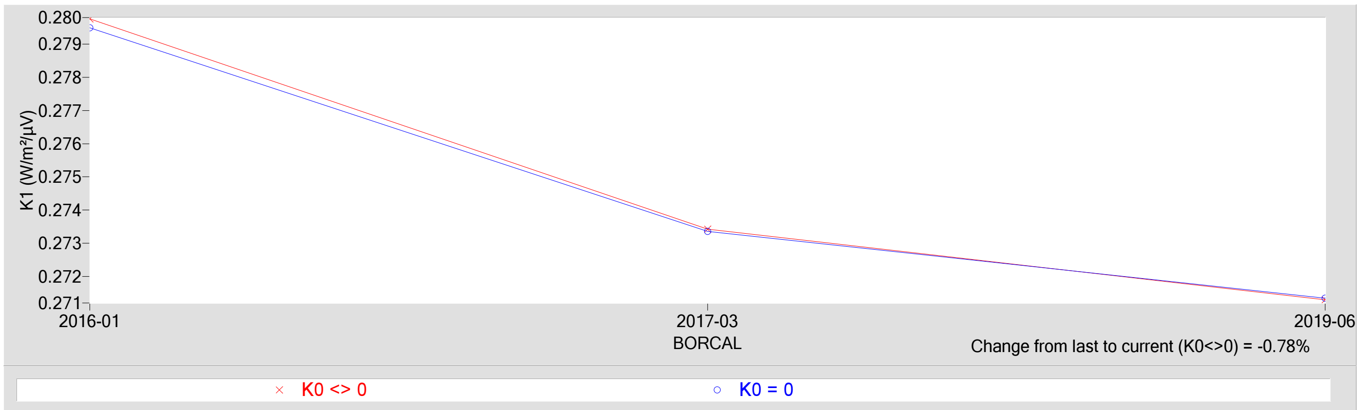


Figure 5. History of instrument (K2 Coefficient)

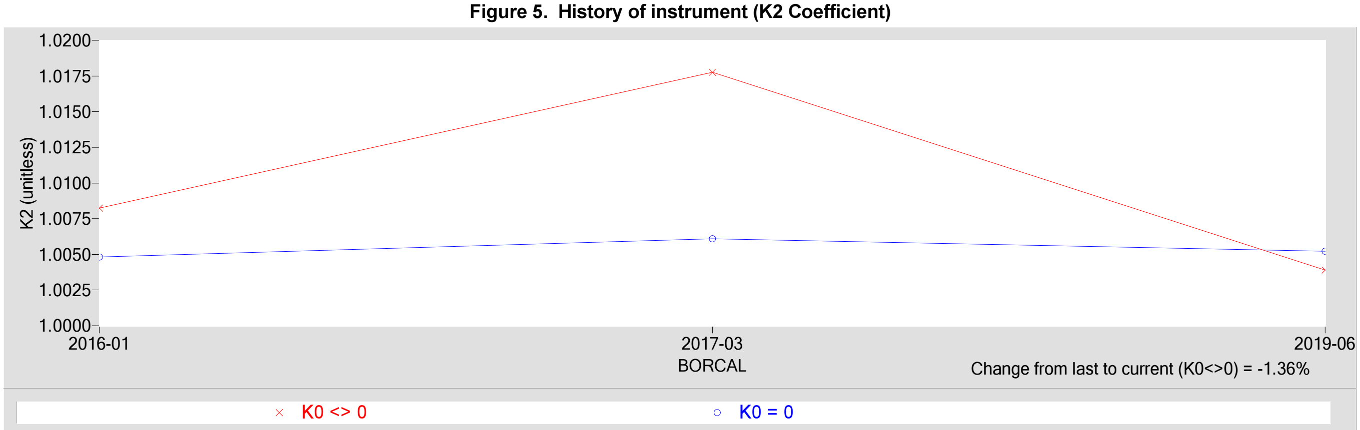
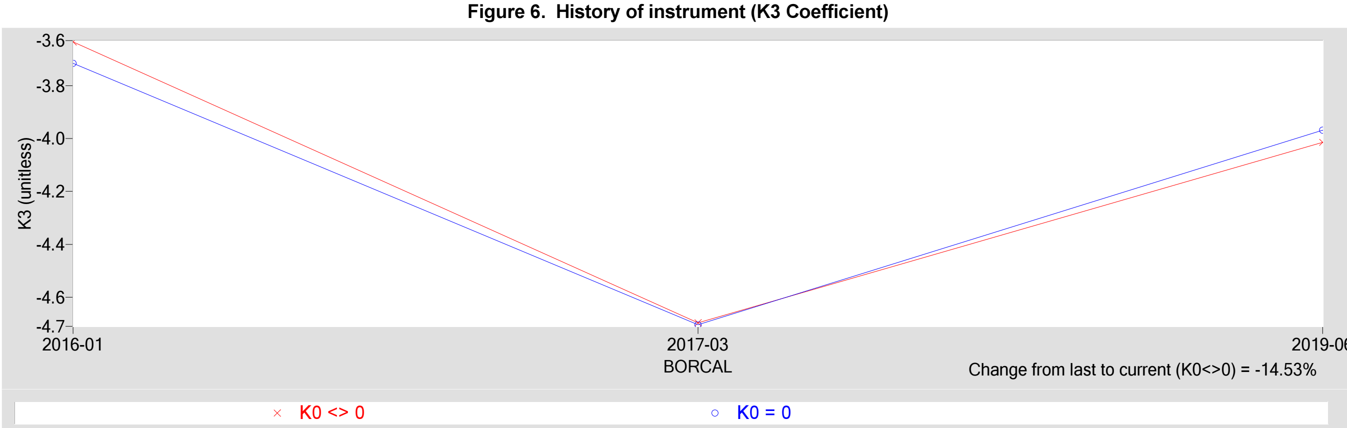


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30014F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

__________________________________ ________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30014F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

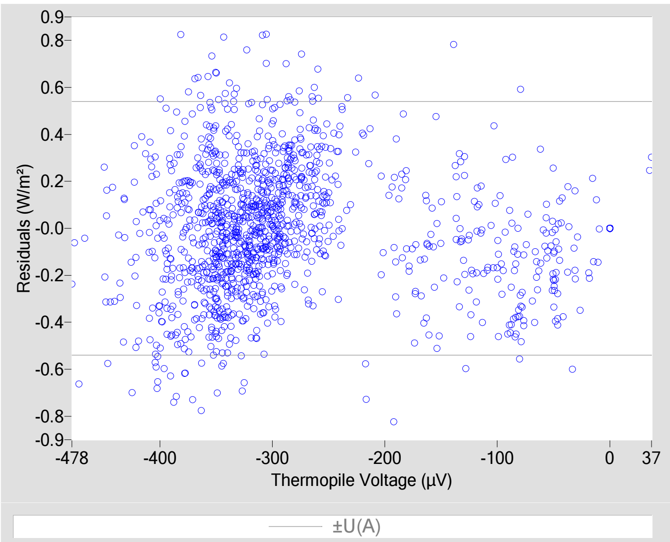


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

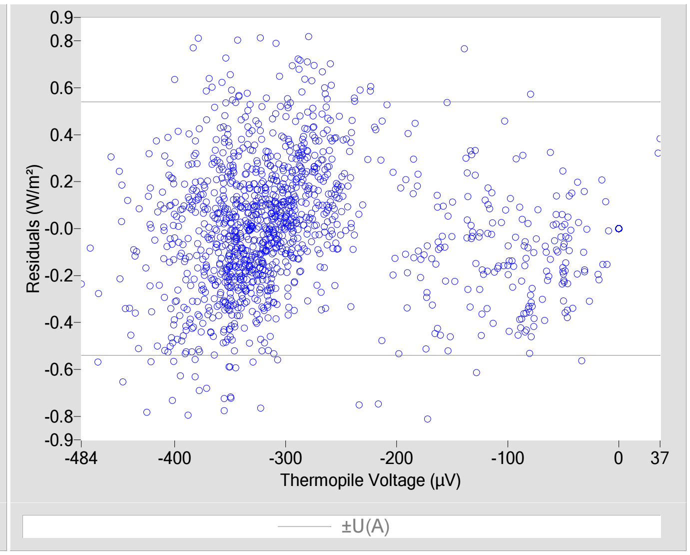


Table 2. Calibration Coefficients for K0<>0

K0	0.5
K1	0.24316
K2	1.0007
K3	-4.41
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24311
K2	1.0020
K3	-4.35
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.28
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.28
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

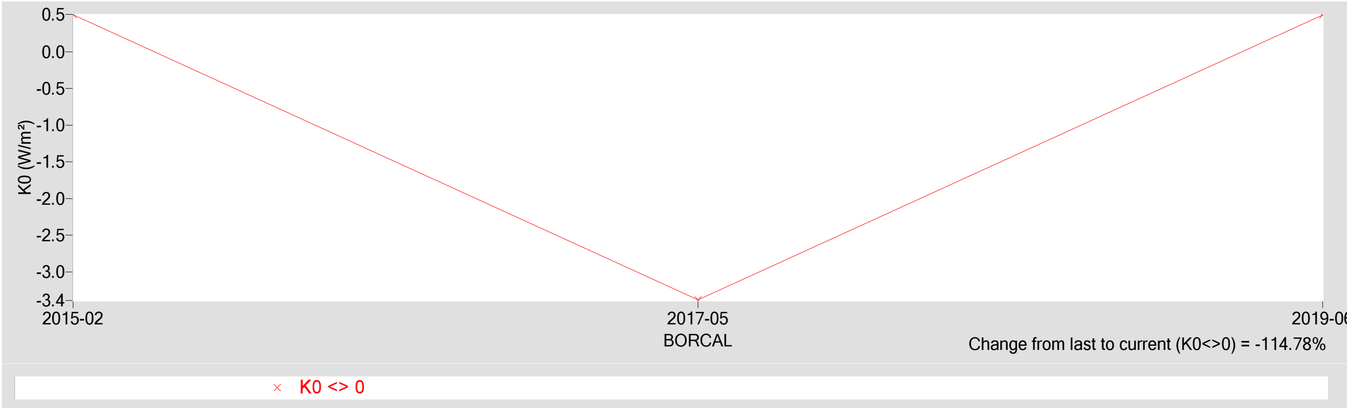


Figure 4. History of instrument (K1 Coefficient)

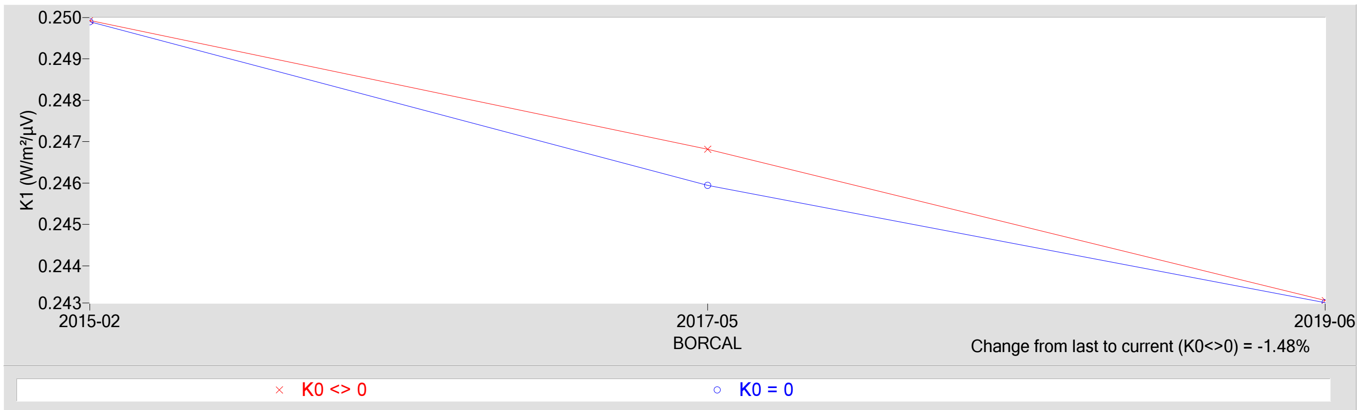


Figure 5. History of instrument (K2 Coefficient)

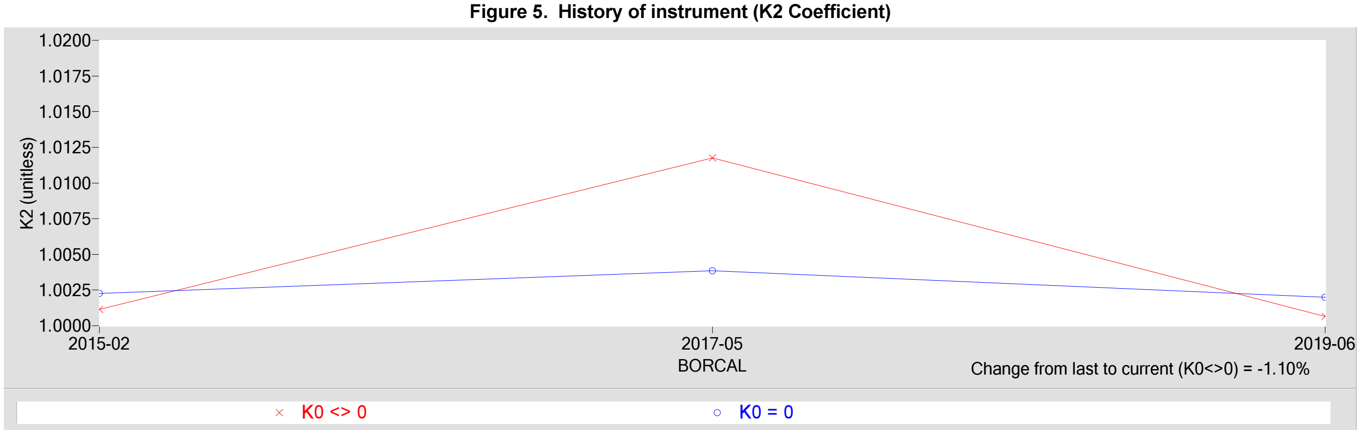
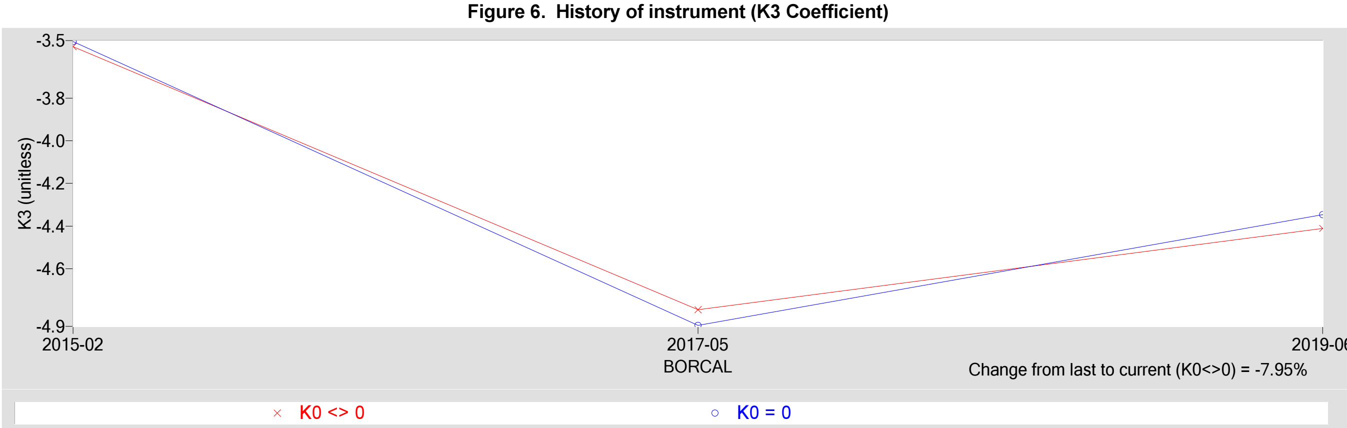


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30084F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	TWP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ____________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results
30084F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coeffiiceints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

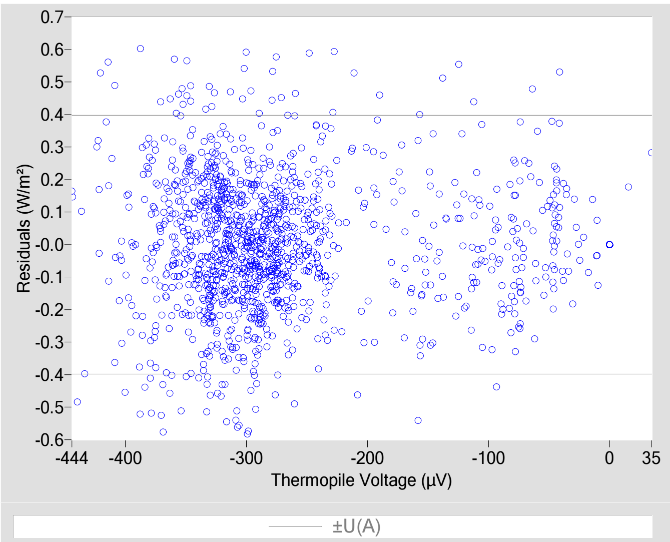


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

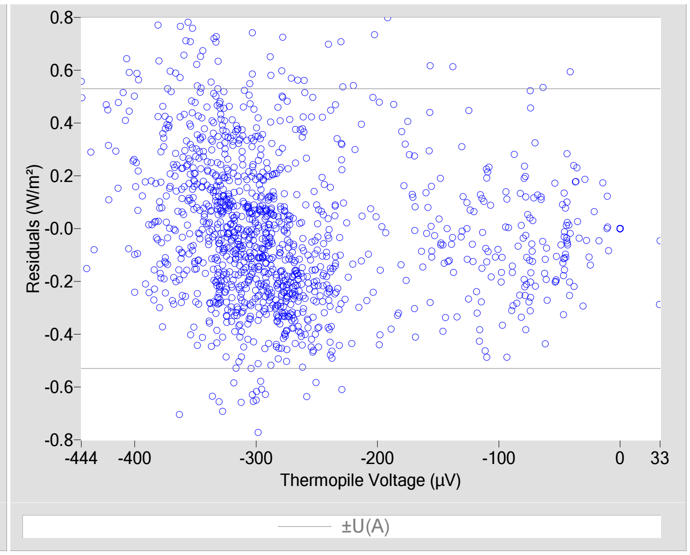


Table 2. Calibration Coefficients for K0<>0

K0	-2.3
K1	0.25728
K2	1.0044
K3	-4.07
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.25772
K2	0.9980
K3	-4.00
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.20
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.27
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

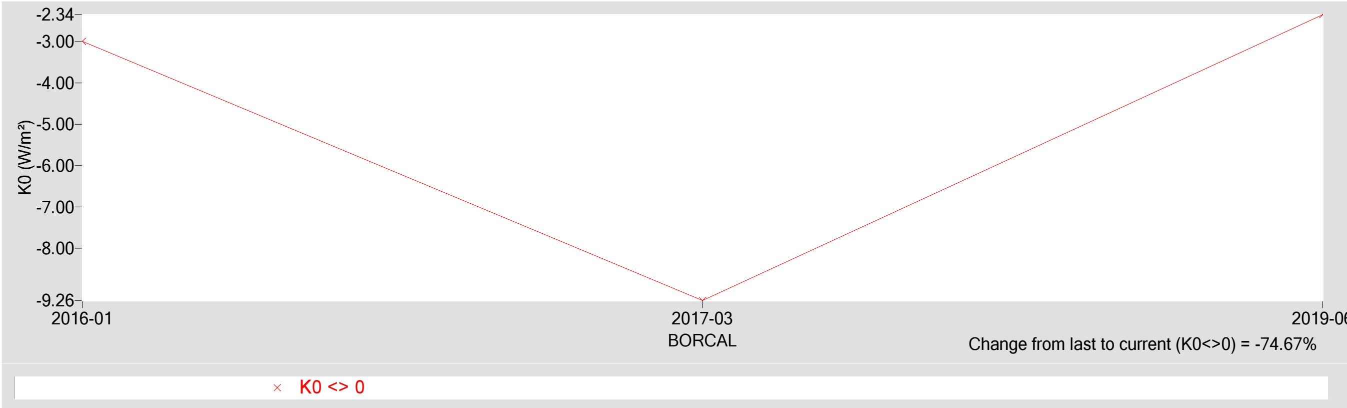


Figure 4. History of instrument (K1 Coefficient)

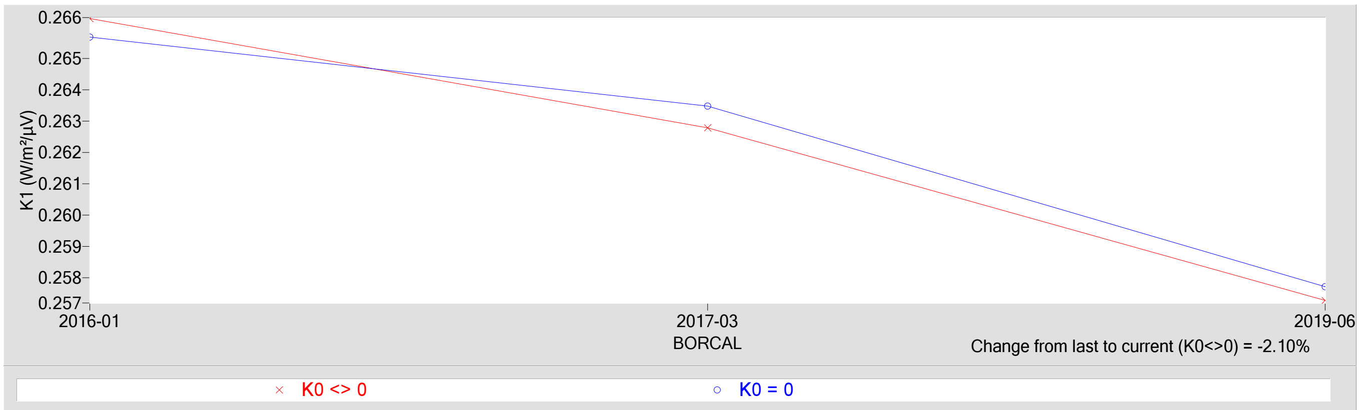


Figure 5. History of instrument (K2 Coefficient)

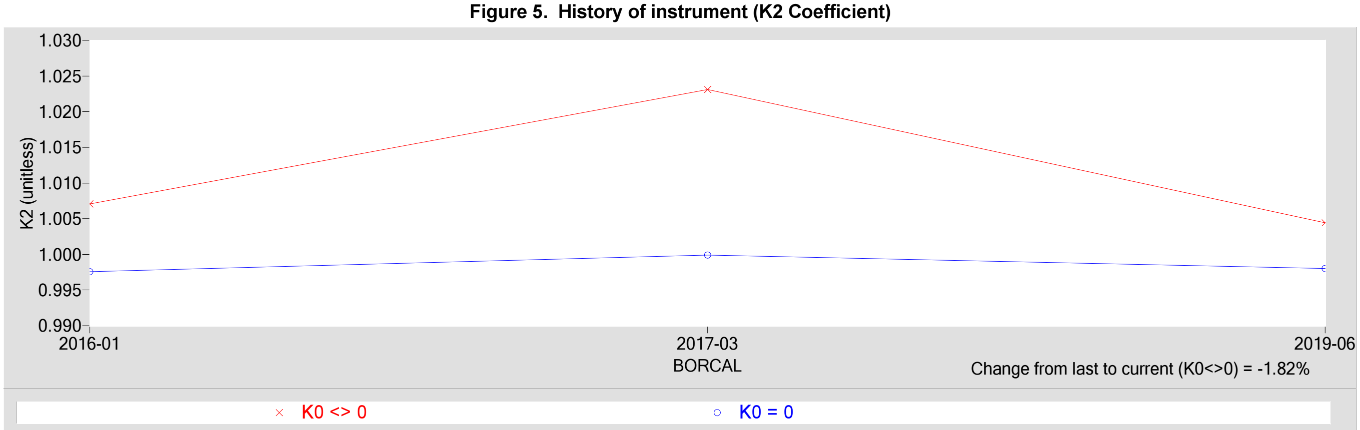
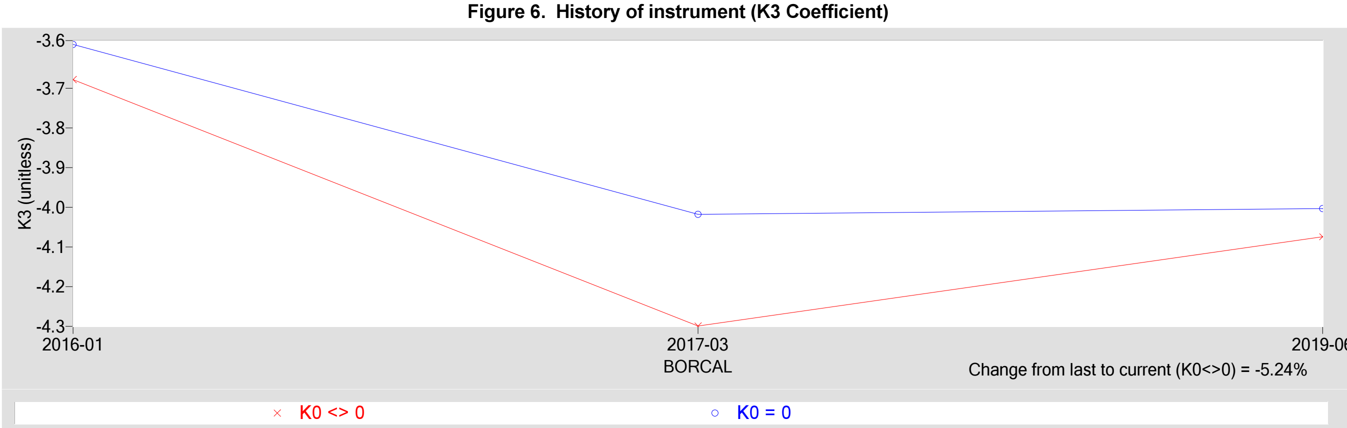


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30133F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ _______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30133F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

*Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr)* [1]

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

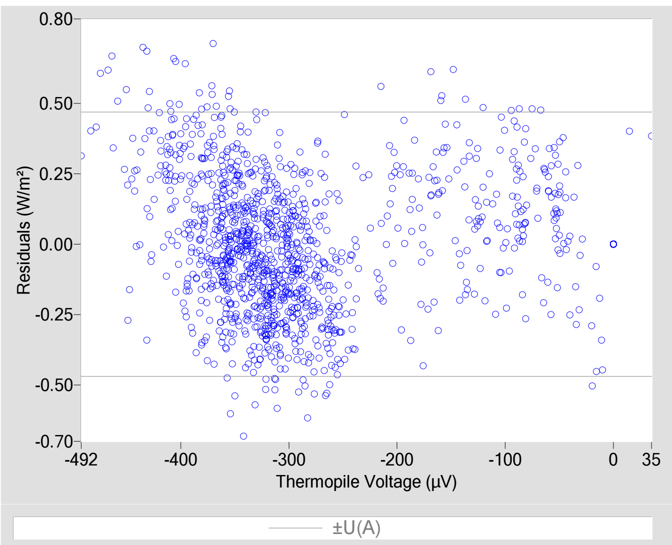


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

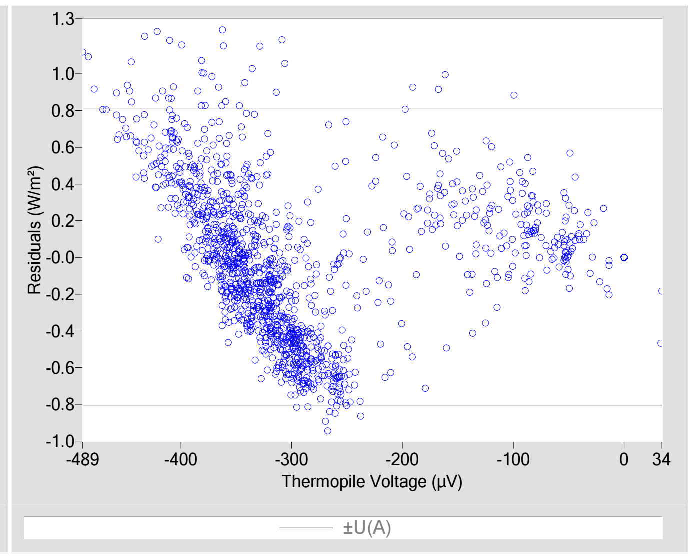


Table 2. Calibration Coefficients for K0<>0

K0	-5.1
K1	0.23940
K2	1.0129
K3	-3.74
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23944
K2	0.9985
K3	-3.55
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.41
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

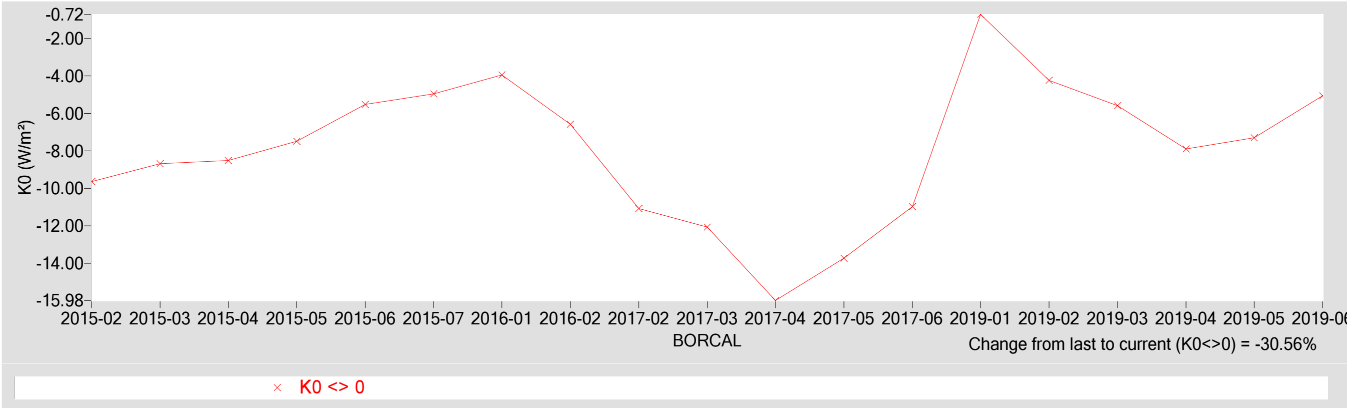


Figure 4. History of instrument (K1 Coefficient)

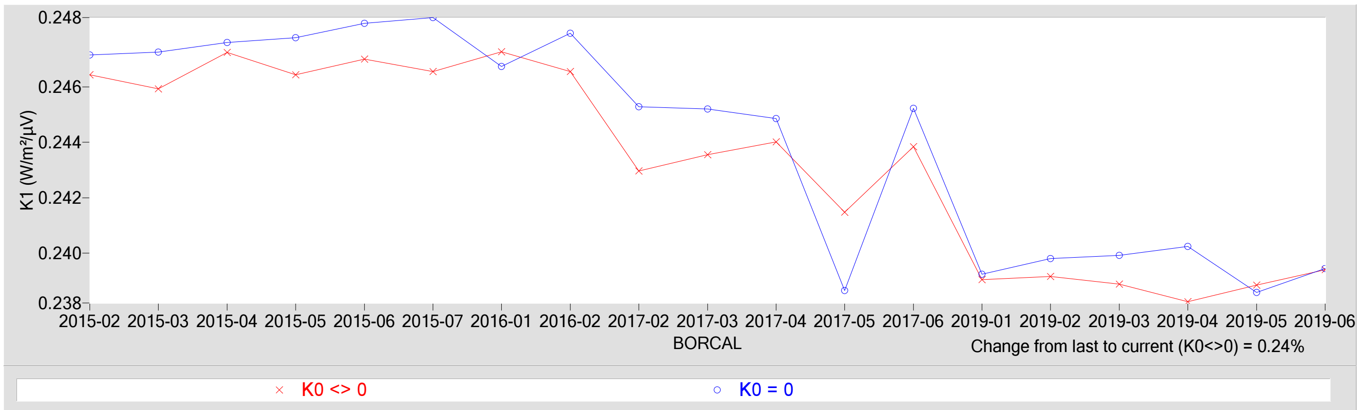


Figure 5. History of instrument (K2 Coefficient)

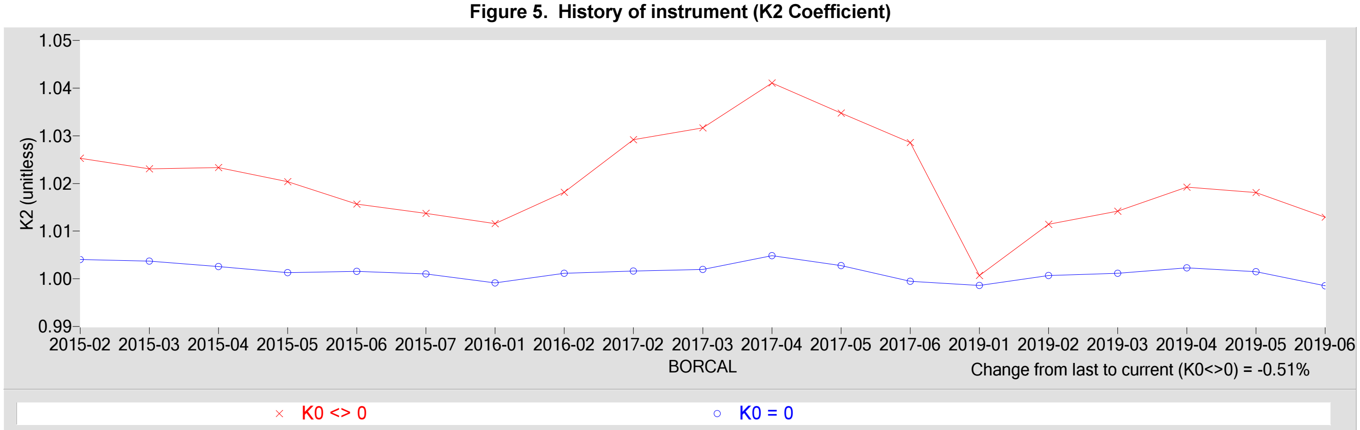
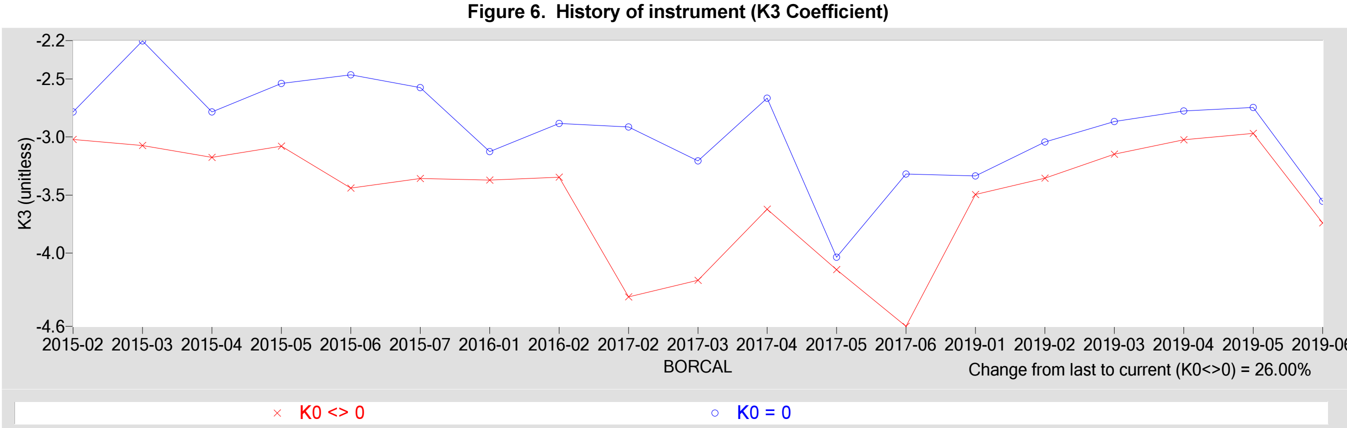


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30345F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ____________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30345F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1 * V + K2 * Wr + K3 * (Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

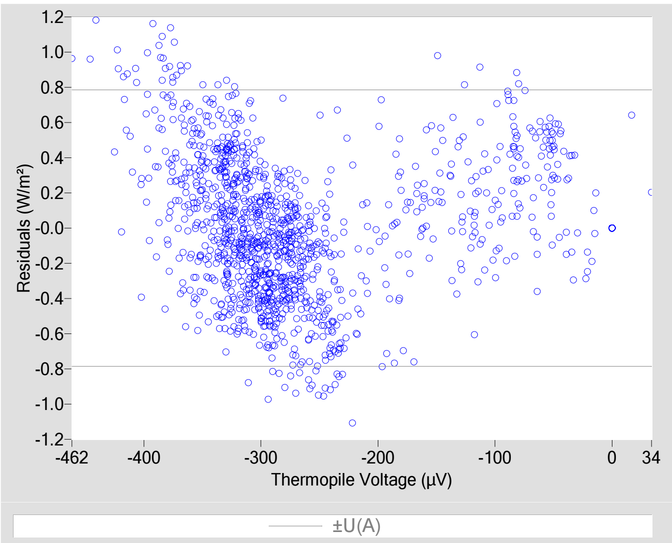


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

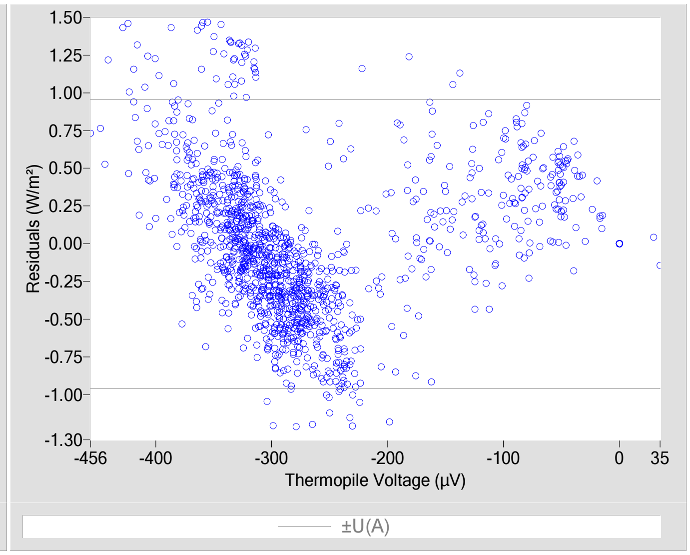


Table 2. Calibration Coefficients for K0<>0

K0	-2.3
K1	0.26150
K2	1.0065
K3	-4.27
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.26093
K2	0.9996
K3	-4.35
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.40
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.49
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

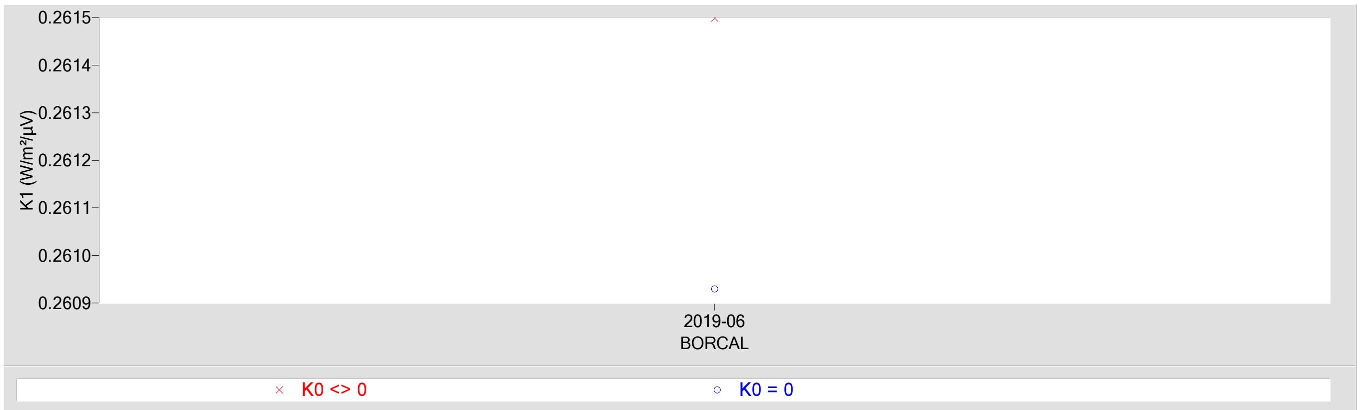


Figure 5. History of instrument (K2 Coefficient)

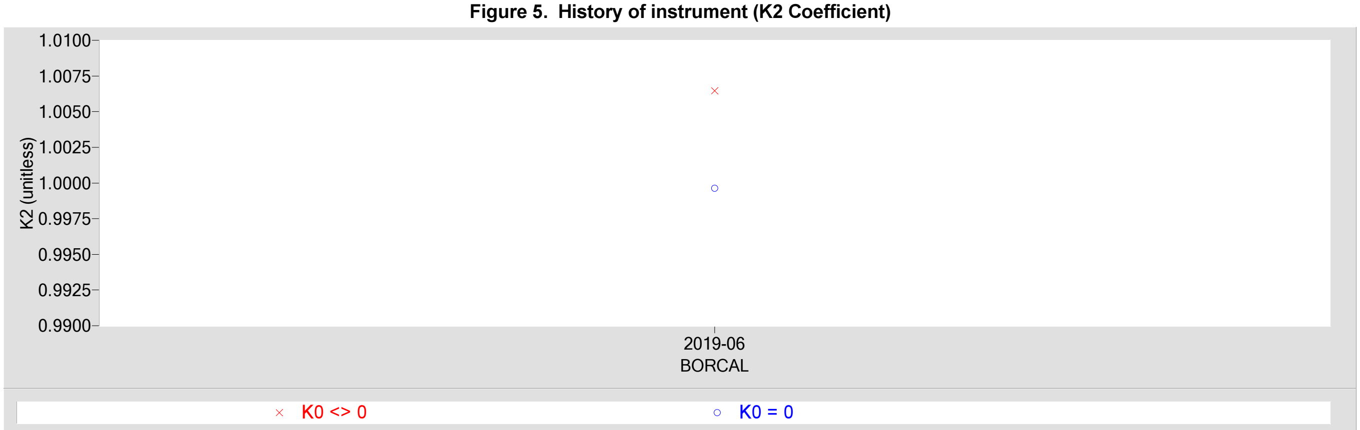
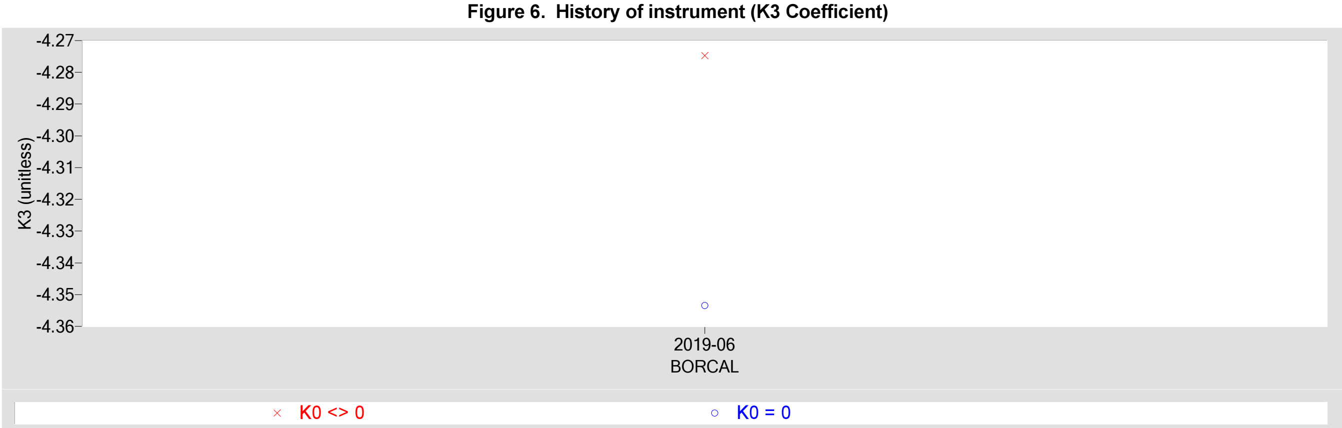


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30356F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____________________________________ __________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30356F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
Wd = *σ* * *Td*^4 = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = *σ* * *Tr*^4 = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

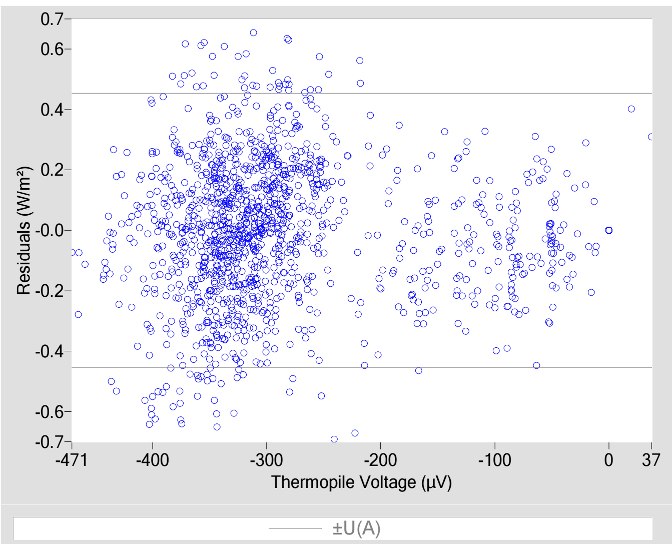


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

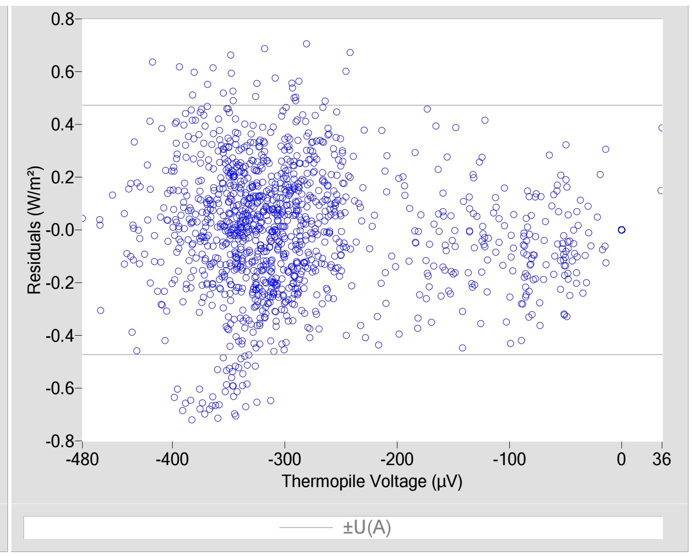


Table 2. Calibration Coefficients for K0<>0

K0	-1.1
K1	0.24643
K2	1.0040
K3	-3.45
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24651
K2	1.0009
K3	-3.50
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.23
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

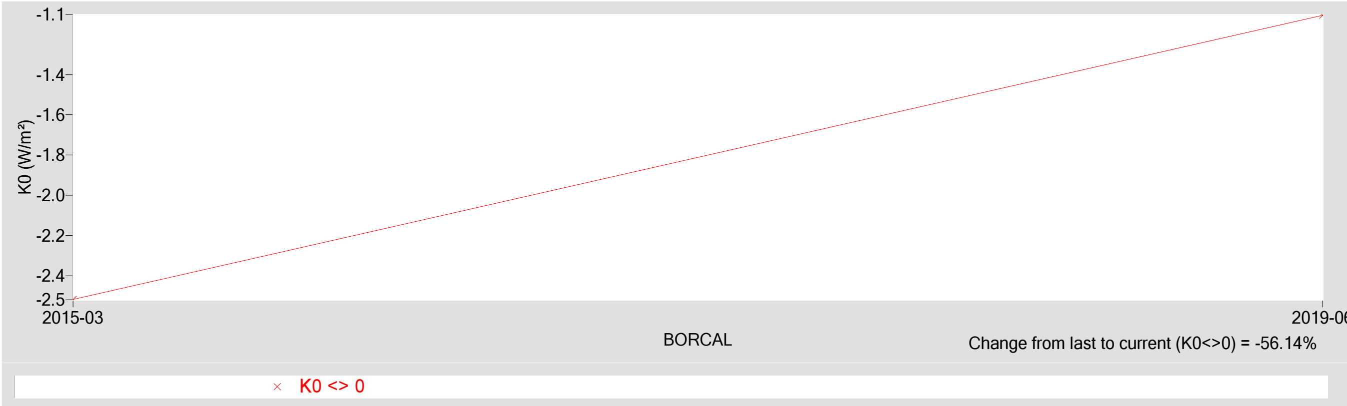


Figure 4. History of instrument (K1 Coefficient)

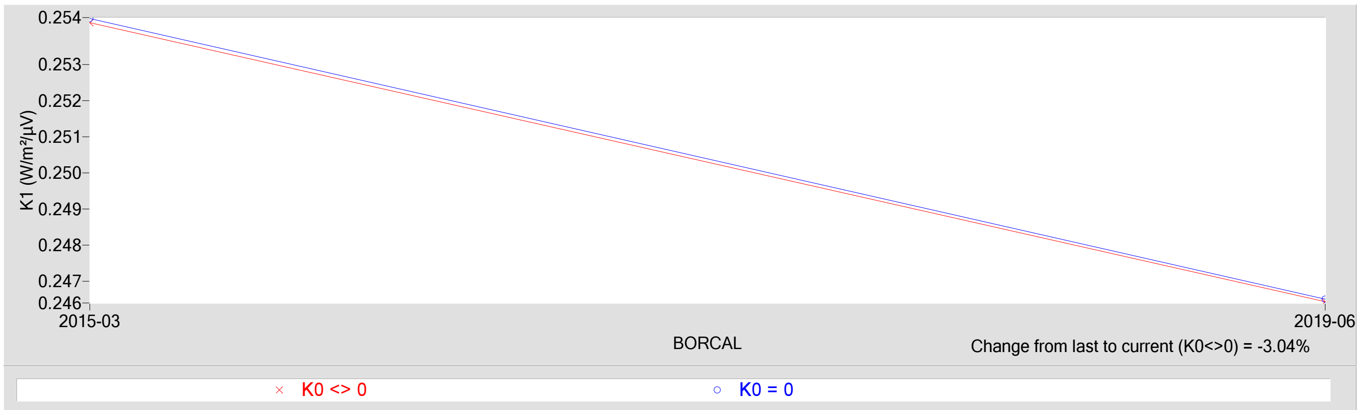


Figure 5. History of instrument (K2 Coefficient)

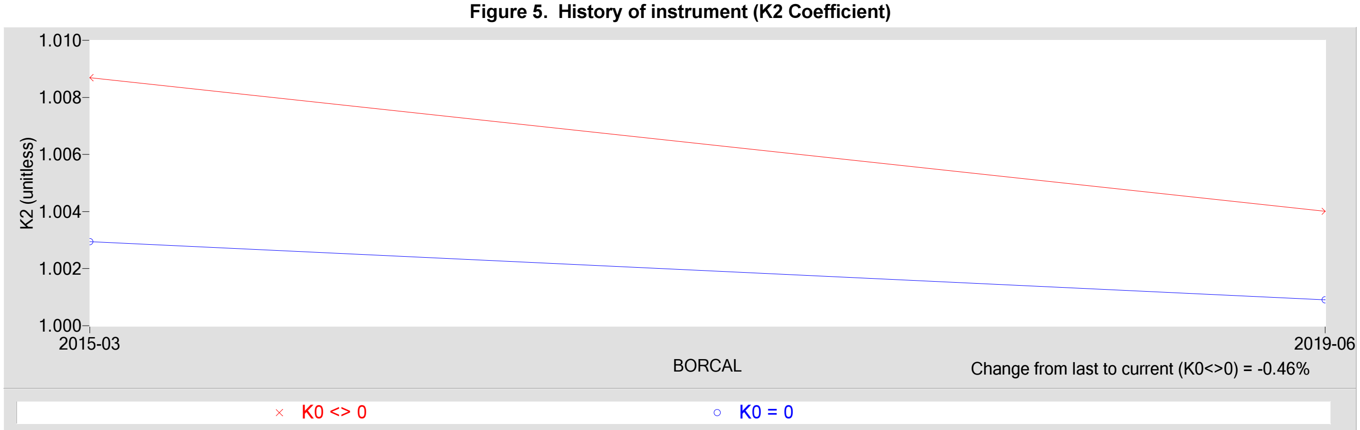
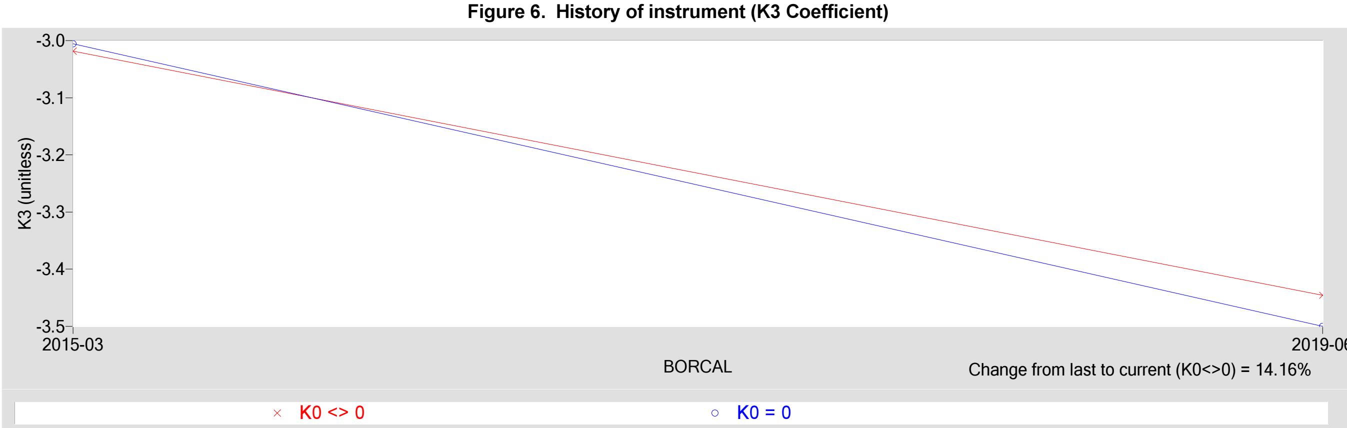


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30682F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30682F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1 \cdot V + K2 \cdot Wr + K3 \cdot (Wd - Wr) \qquad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma \cdot Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma \cdot Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr \cdot V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

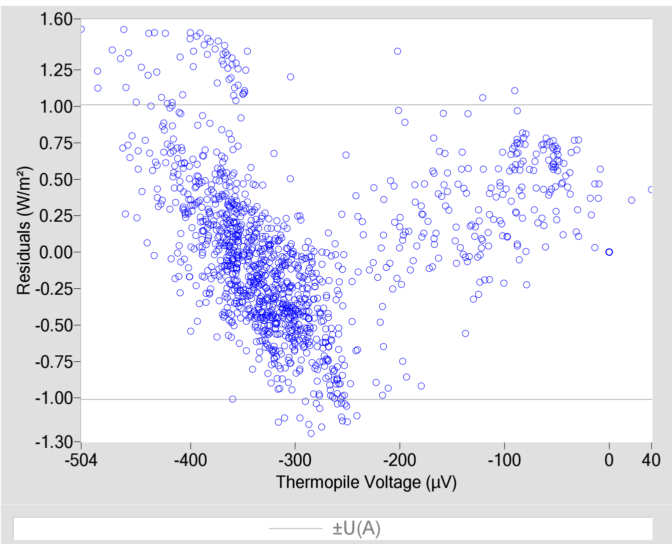


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

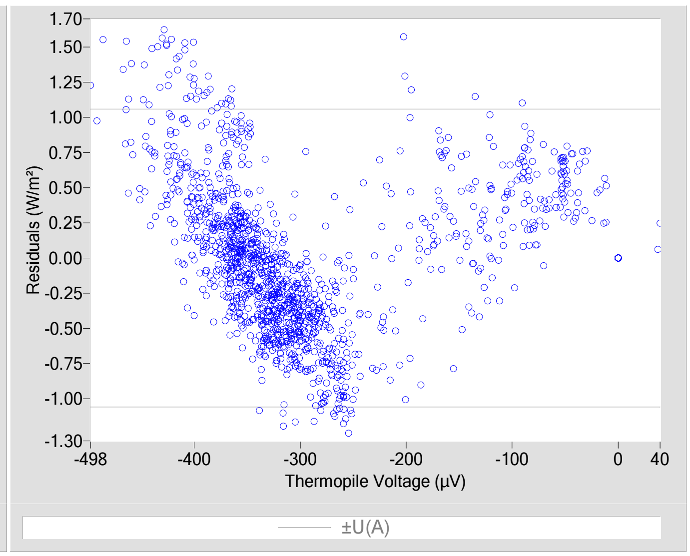


Table 2. Calibration Coefficients for K0<>0

K0	-1.2
K1	0.23361
K2	1.0027
K3	-3.68
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23353
K2	0.9994
K3	-3.70
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.52
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.54
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

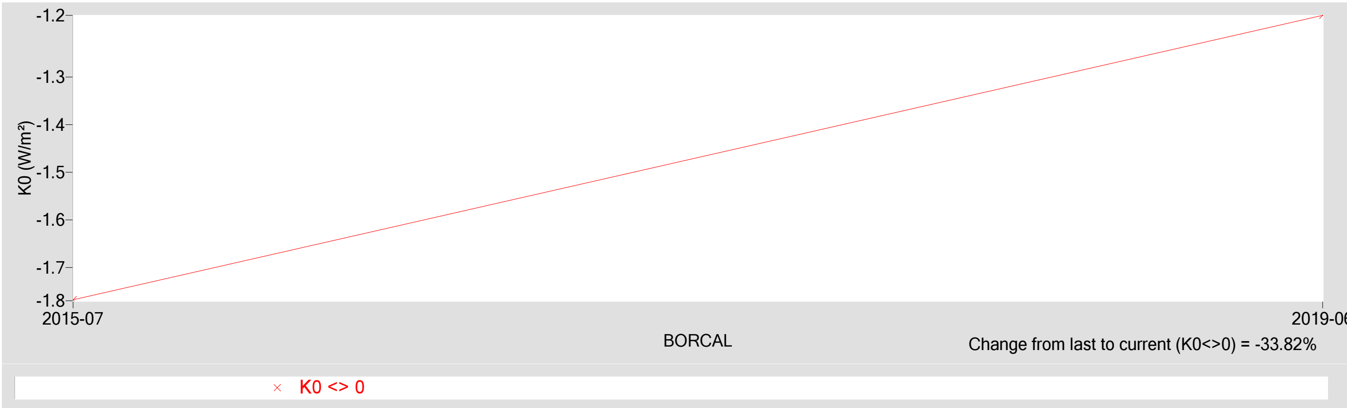


Figure 4. History of instrument (K1 Coefficient)

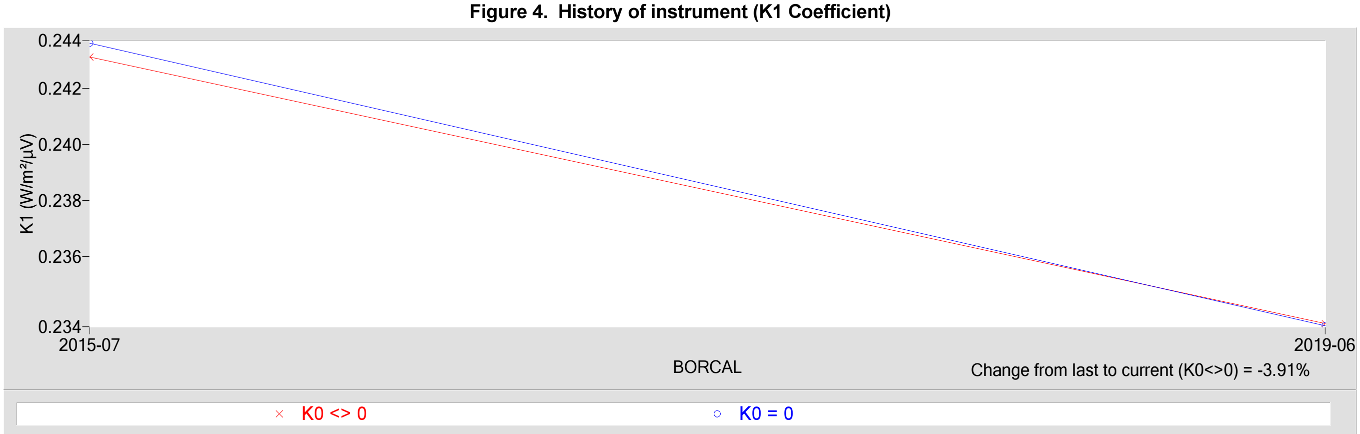


Figure 5. History of instrument (K2 Coefficient)

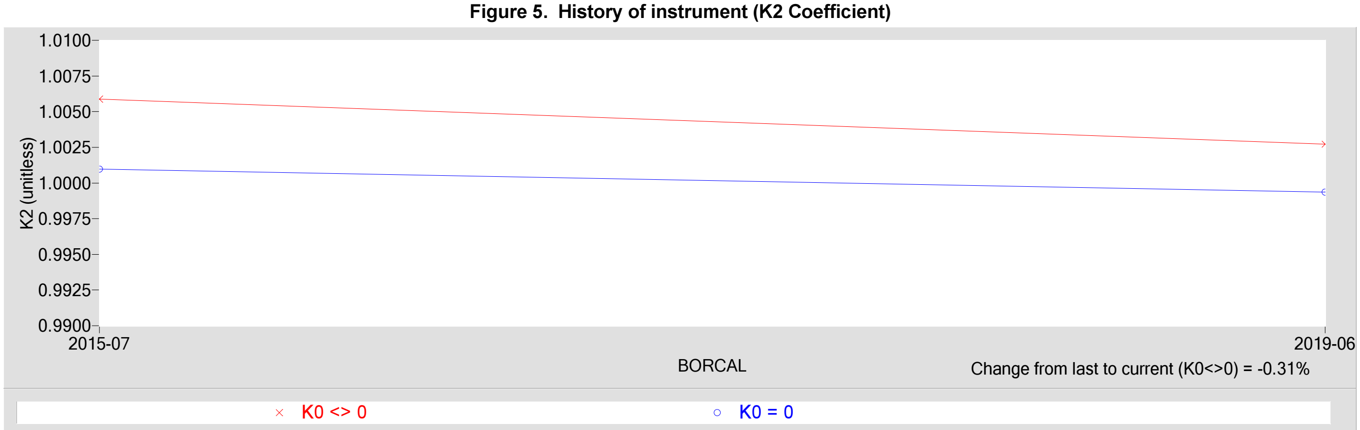
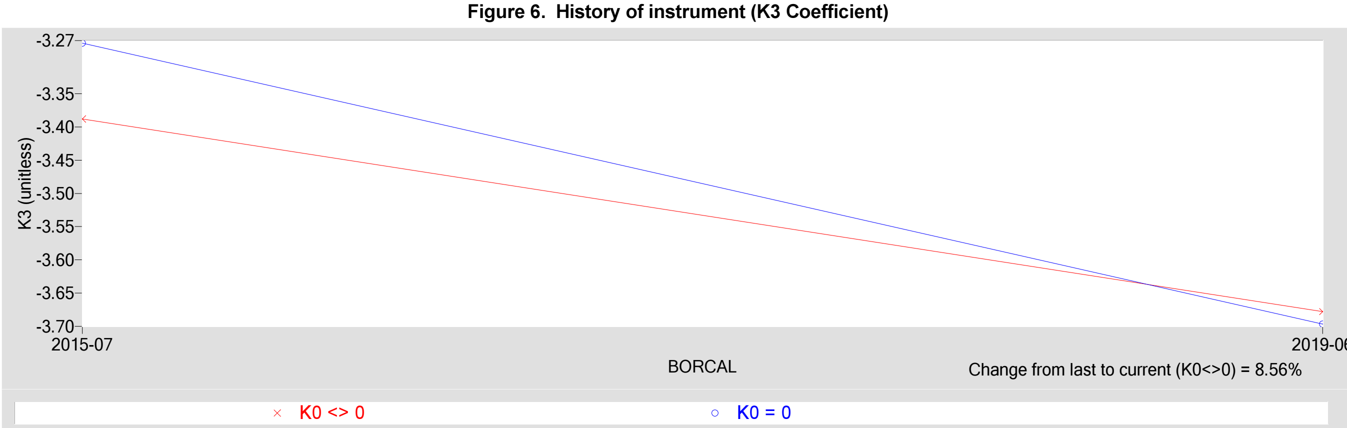


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30684F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____ ________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30684F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
Wd = σ * *Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr^4* = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

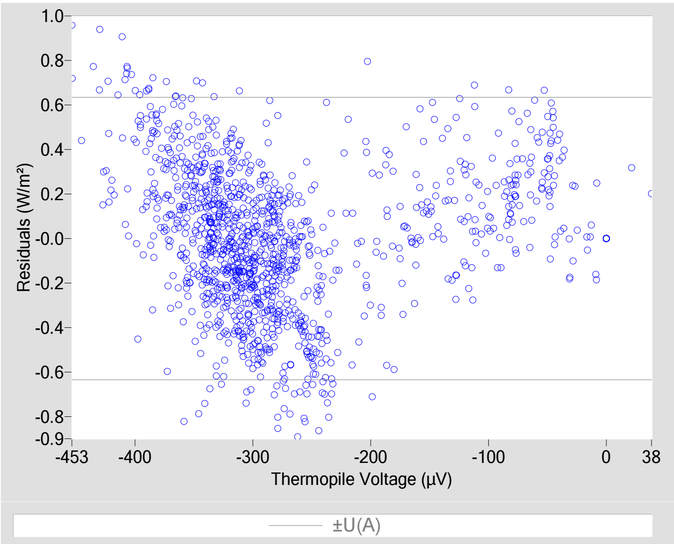


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

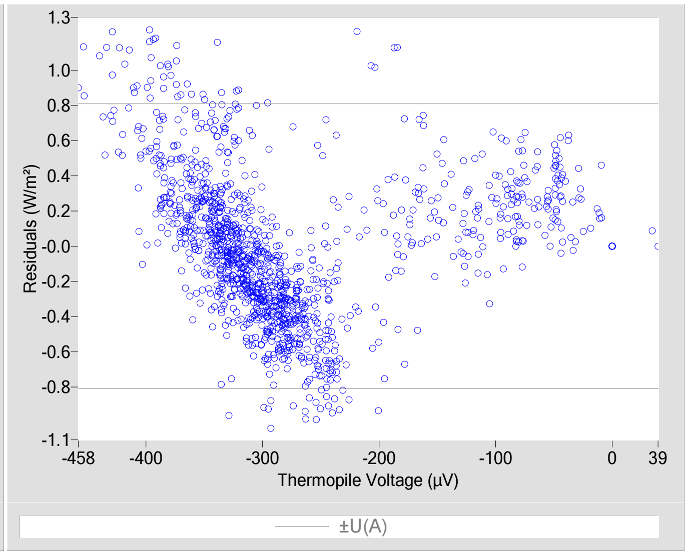


Table 2. Calibration Coefficients for K0<>0

K0	-2.7
K1	0.24990
K2	1.0084
K3	-3.42
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24938
K2	1.0005
K3	-3.45
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.32
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.41
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

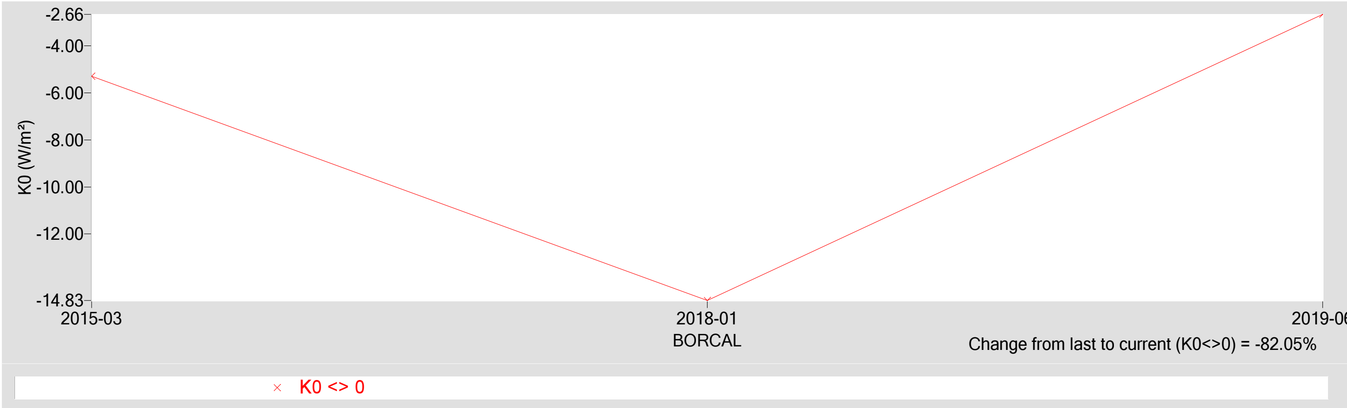


Figure 4. History of instrument (K1 Coefficient)

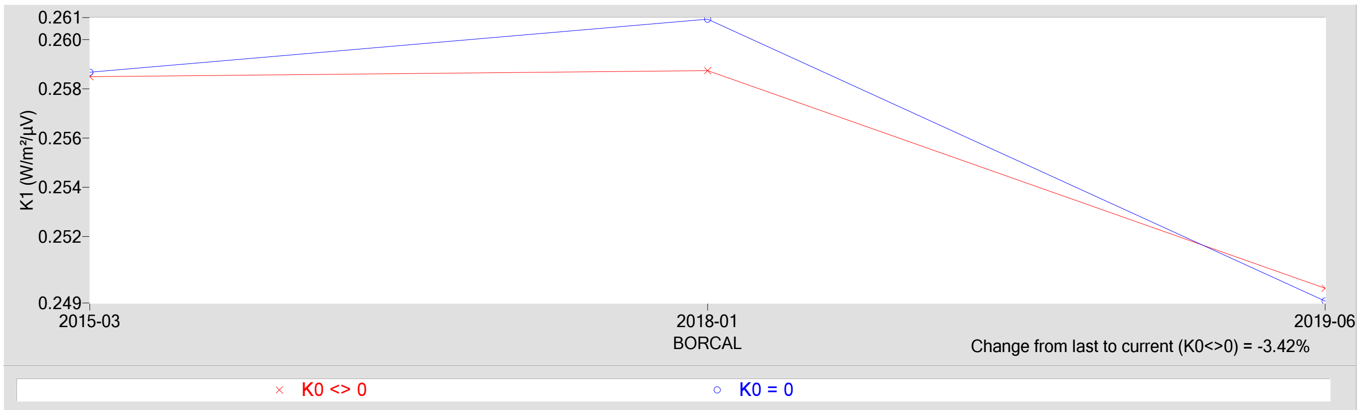


Figure 5. History of instrument (K2 Coefficient)

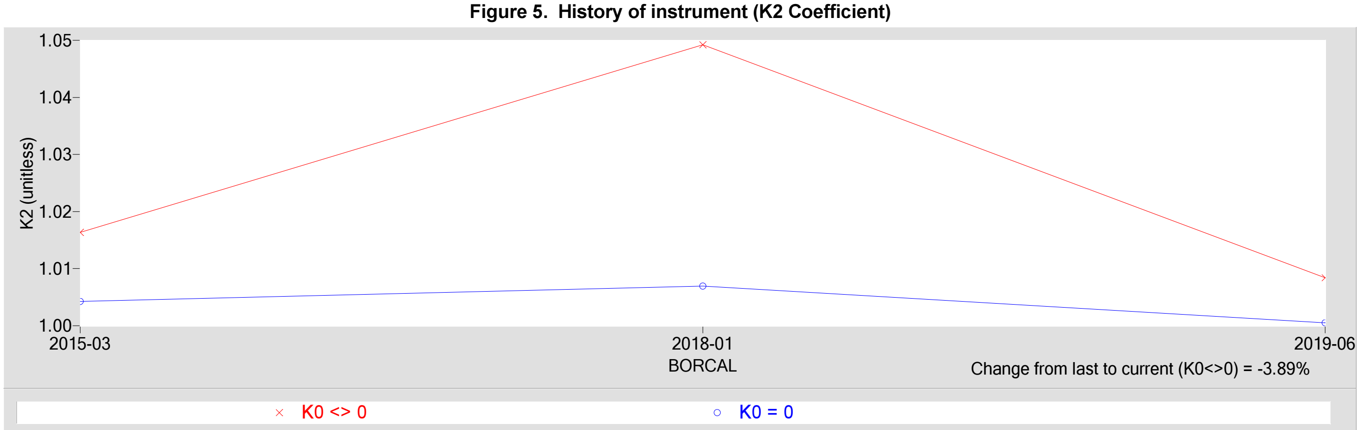
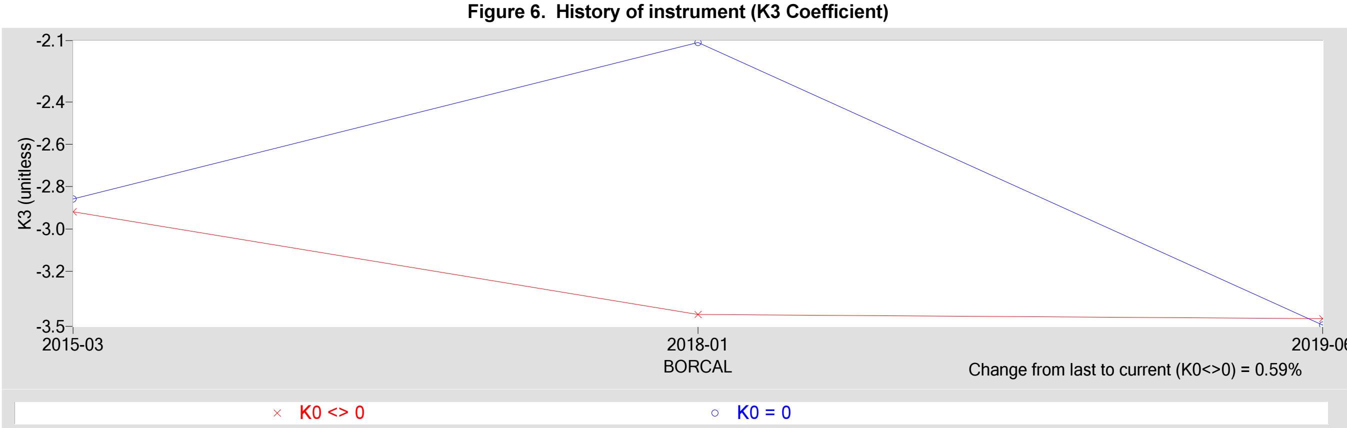


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30685F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30685F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

- *K0,K1,K2,K3* = calibration coefficeints,
- *V* = thermopile output voltage (µV),
- $Wd = \sigma * Td^4$ = dome irradiance (W/m²),
  - where, *Td* = dome temperature (K),
- $Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
  - where, σ = 5.6704e-8 W·m-2·K-4,
  - $Tr = Tc + Kr * V$ = receiver temperature (K),
  - *Tc* = case temperature (K),
  - *Kr* = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

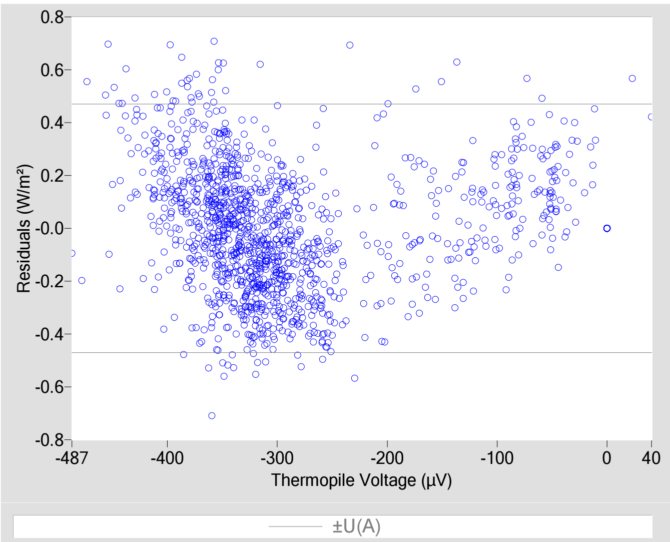


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

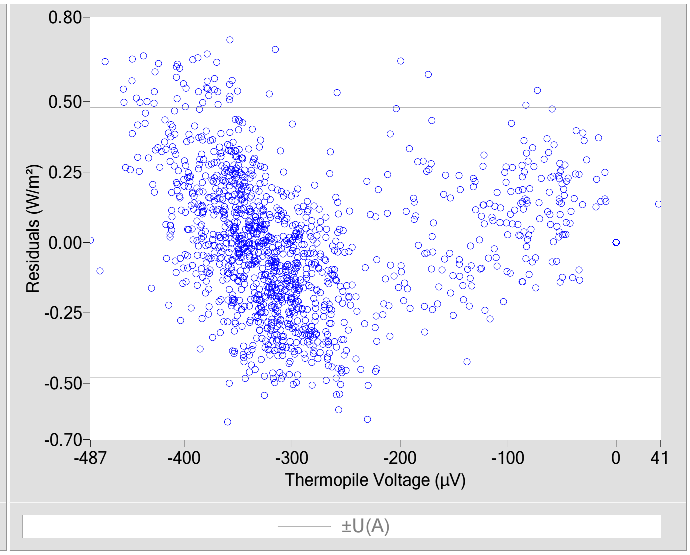


Table 2. Calibration Coefficients for K0<>0

K0	-0.7
K1	0.23703
K2	1.0023
K3	-3.39
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23714
K2	1.0004
K3	-3.40
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

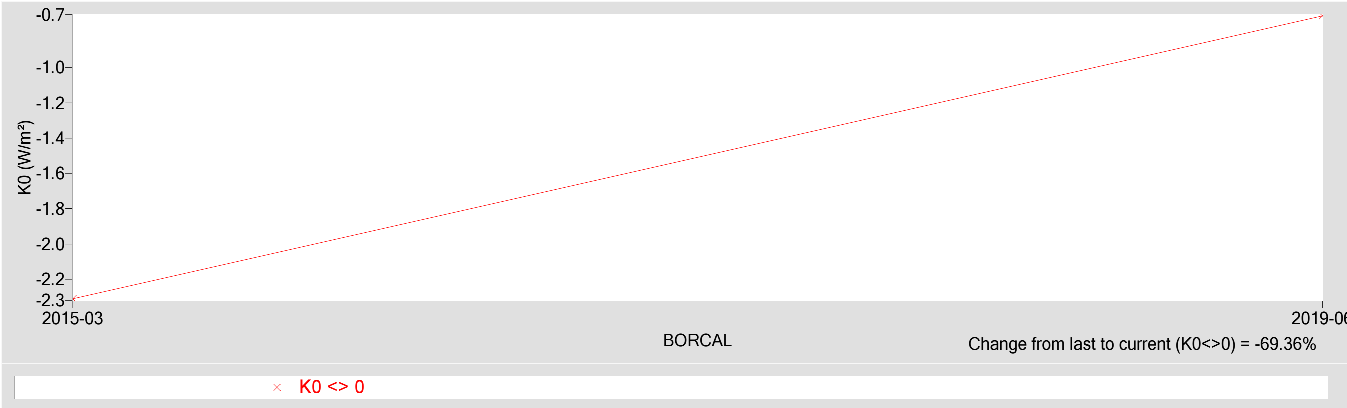


Figure 4. History of instrument (K1 Coefficient)

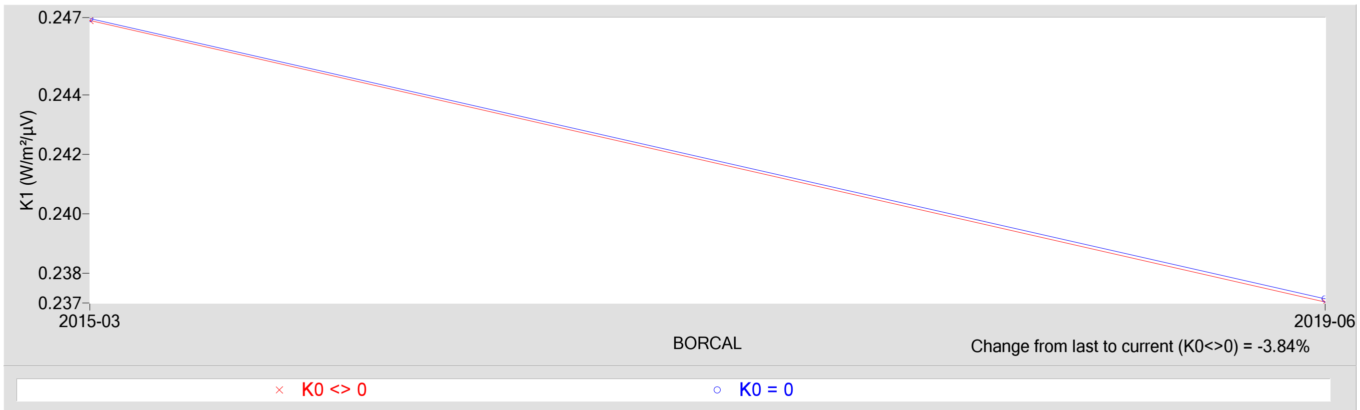


Figure 5. History of instrument (K2 Coefficient)

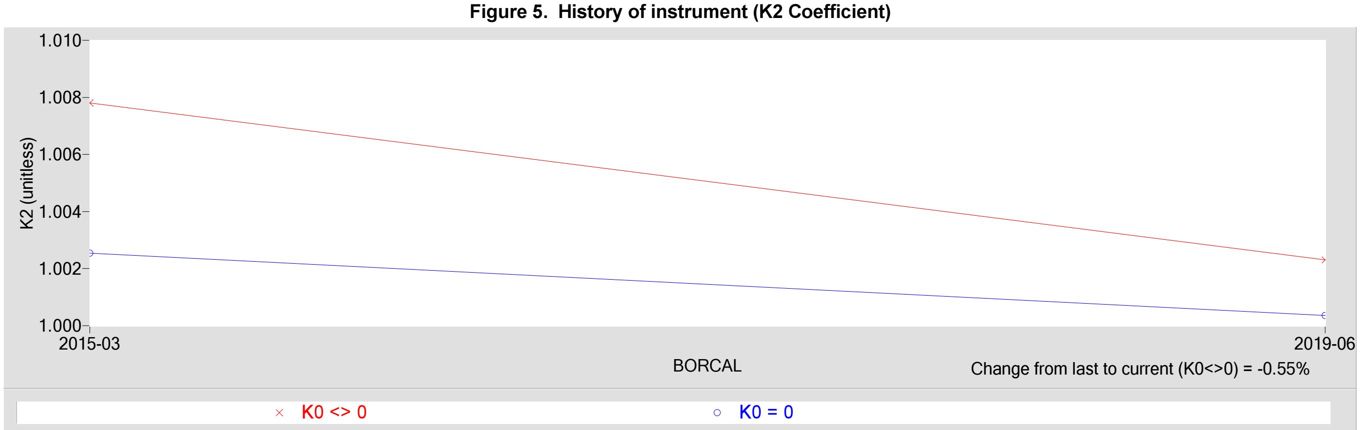
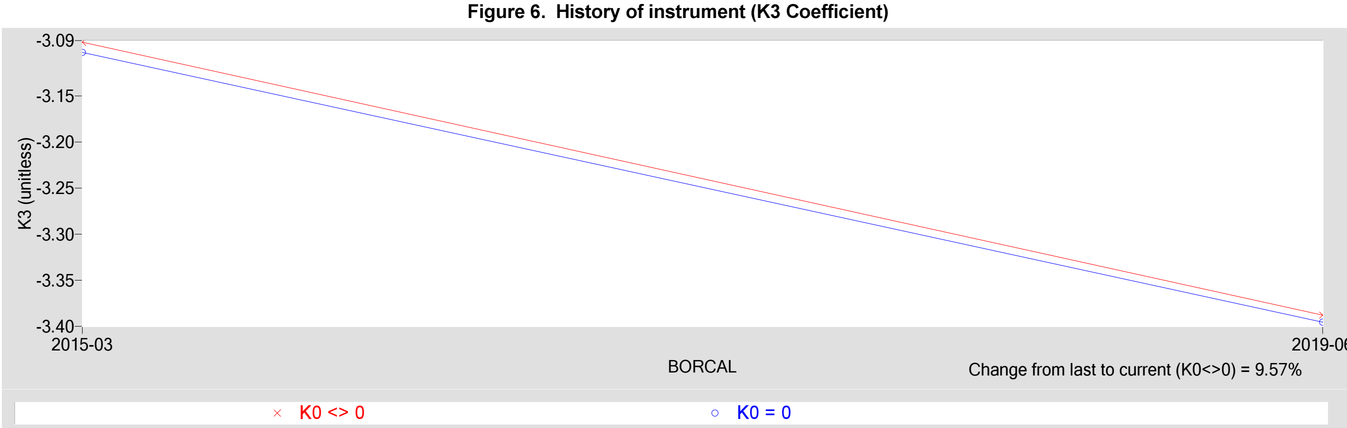


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30687F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ____________

Peter Gotseff, Technical Manager   Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30687F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
Wd = *σ* * *Td*^4 = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = *σ* * *Tr*^4 = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

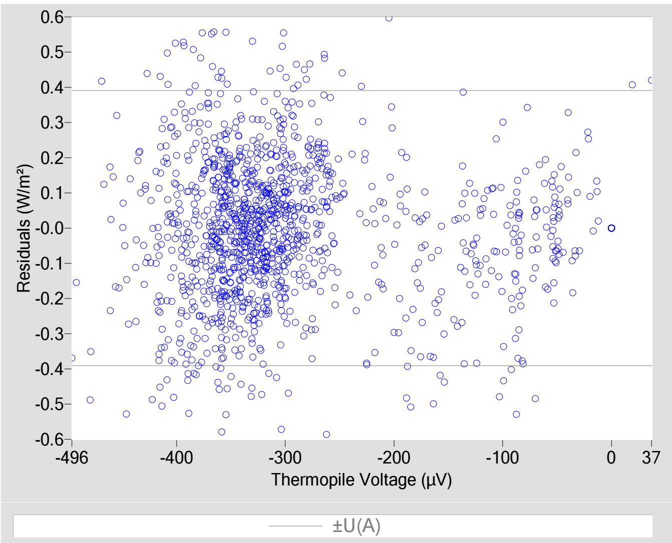


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

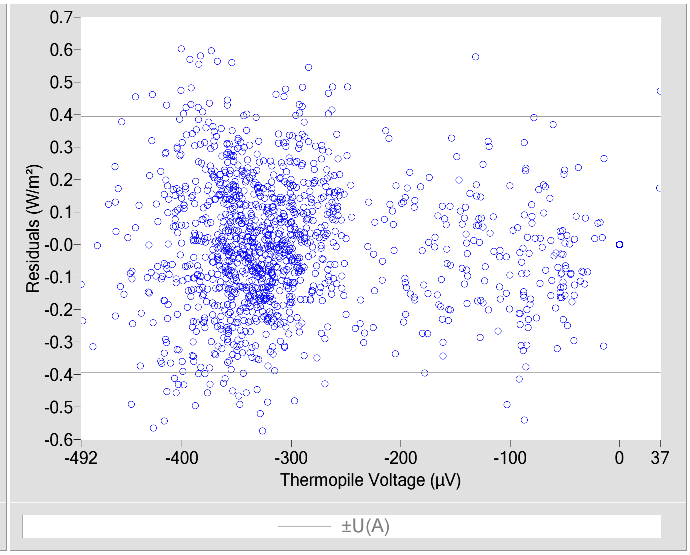


Table 2. Calibration Coefficients for K0<>0

K0	-0.3
K1	0.23596
K2	1.0007
K3	-3.21
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23599
K2	0.9998
K3	-3.22
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.20
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.20
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

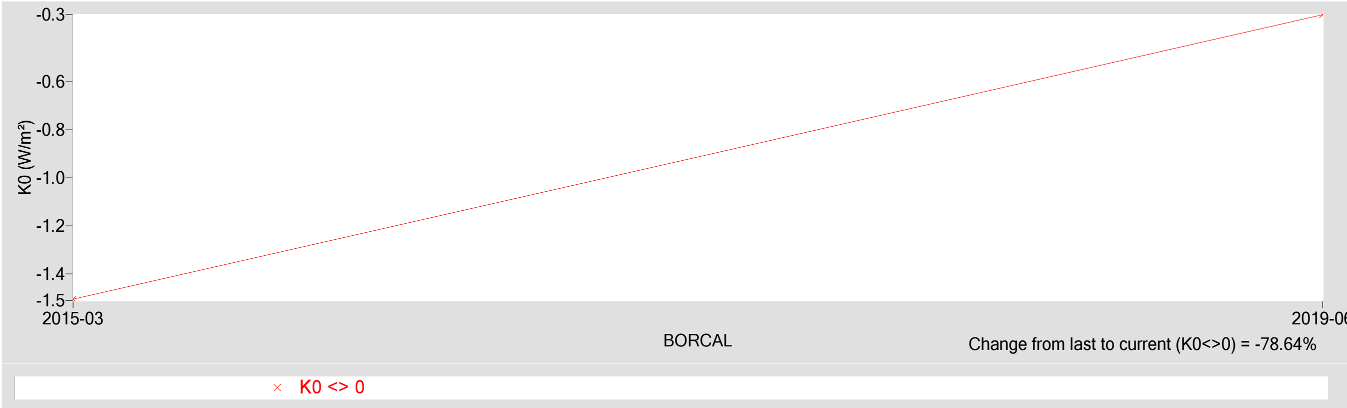


Figure 4. History of instrument (K1 Coefficient)

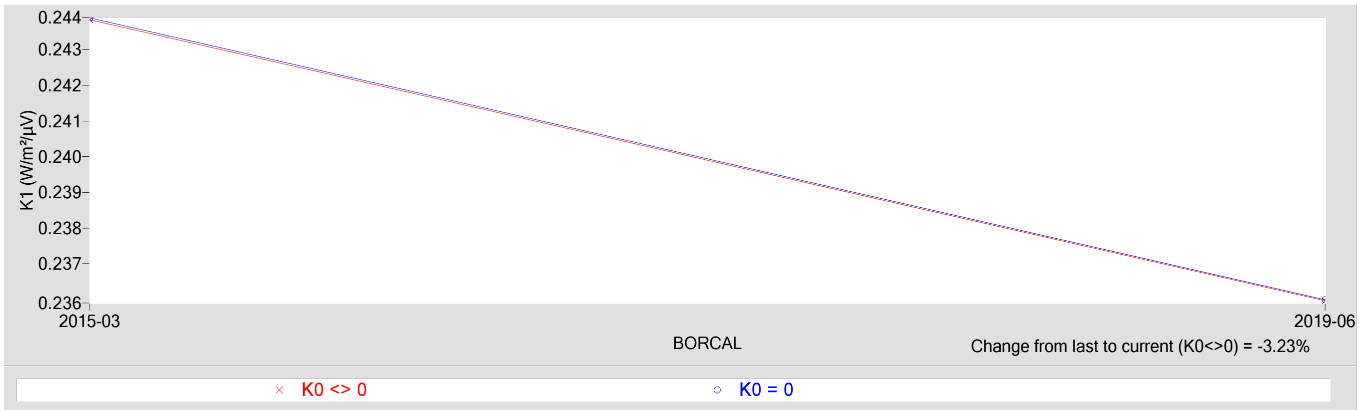


Figure 5. History of instrument (K2 Coefficient)

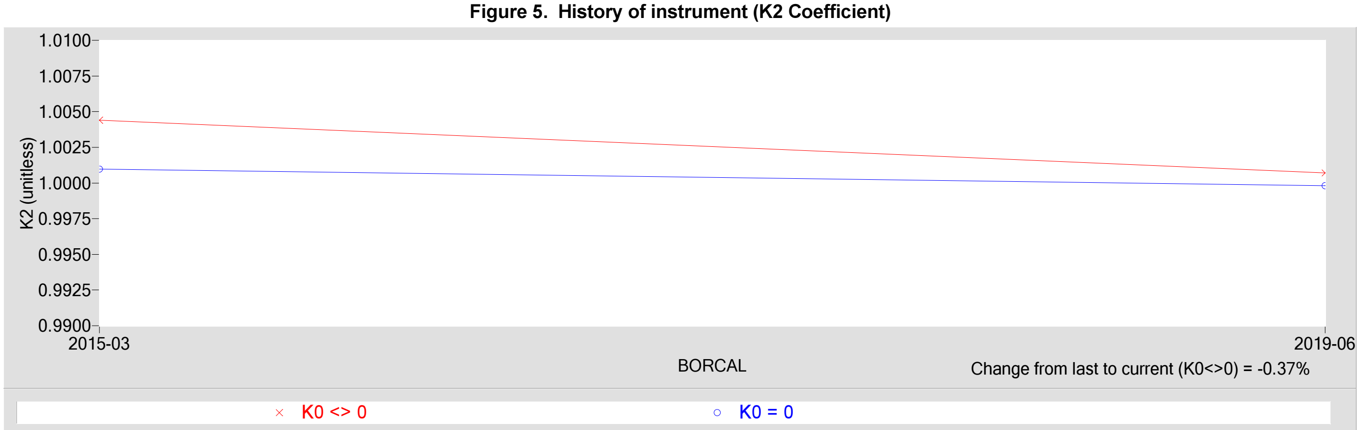
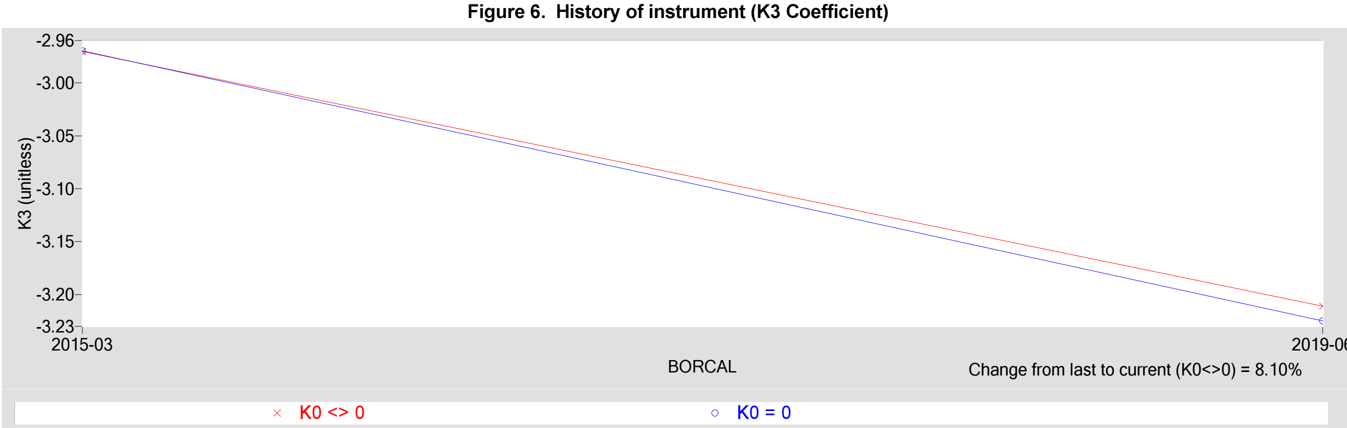


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30688F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results
30688F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
Wd = σ * *Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr^4* = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

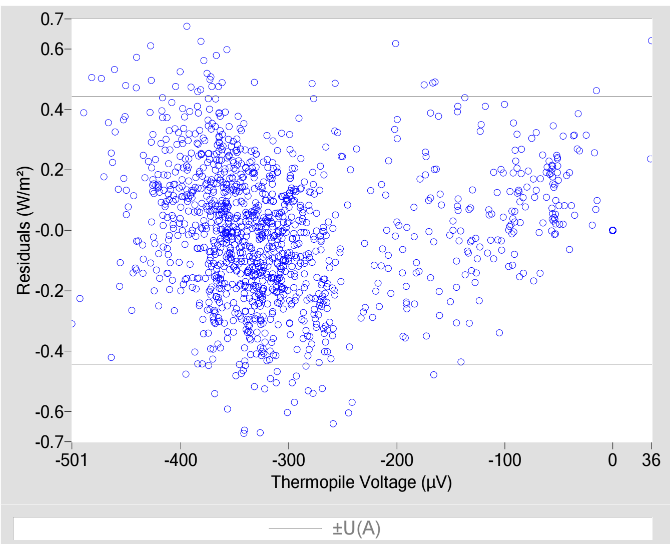


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

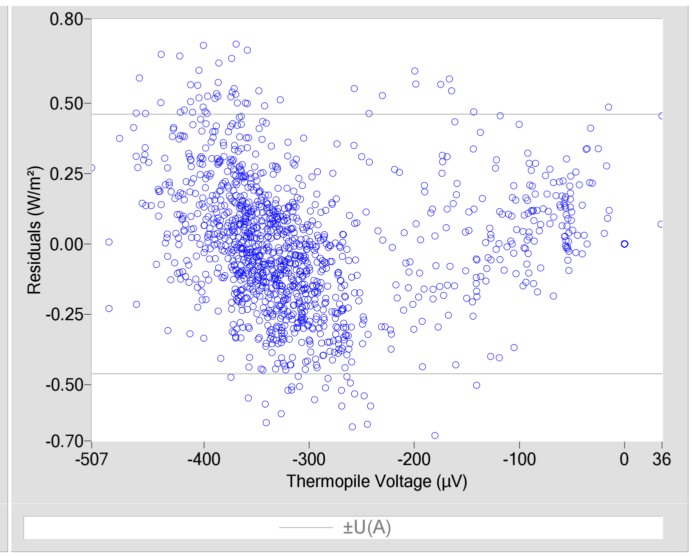


Table 2. Calibration Coefficients for K0<>0

K0	-1.0
K1	0.23244
K2	1.0002
K3	-3.02
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23258
K2	0.9974
K3	-3.03
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.23
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

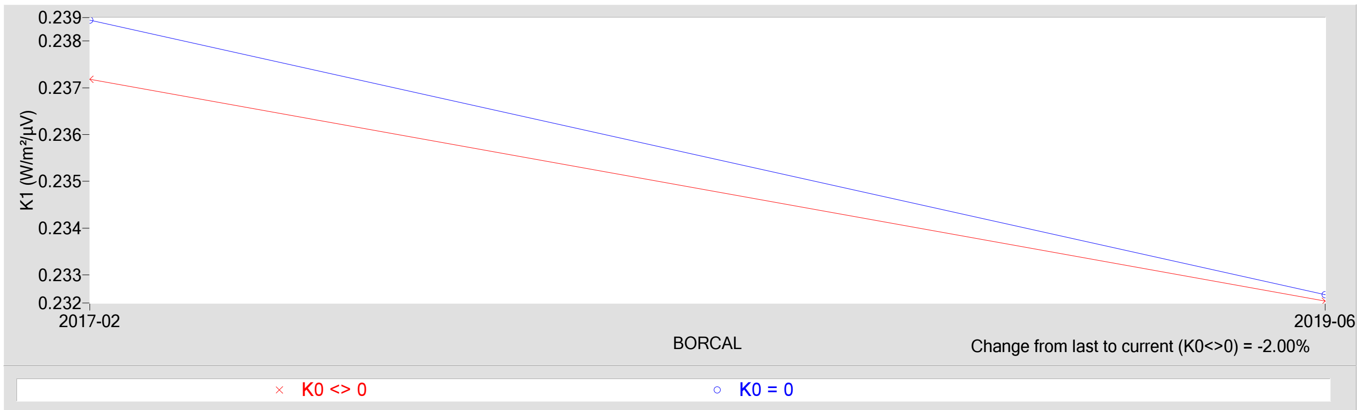


Figure 5. History of instrument (K2 Coefficient)

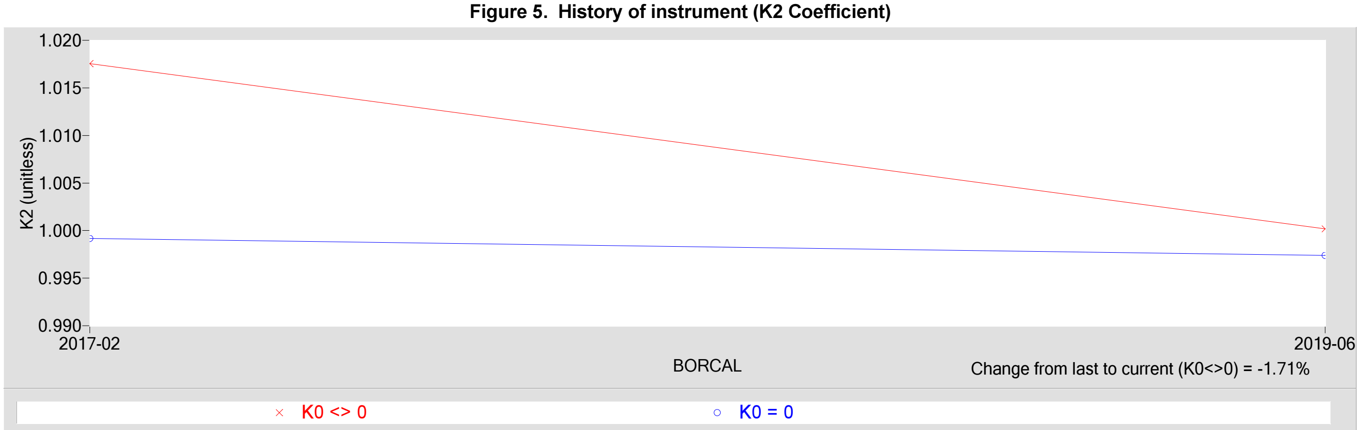
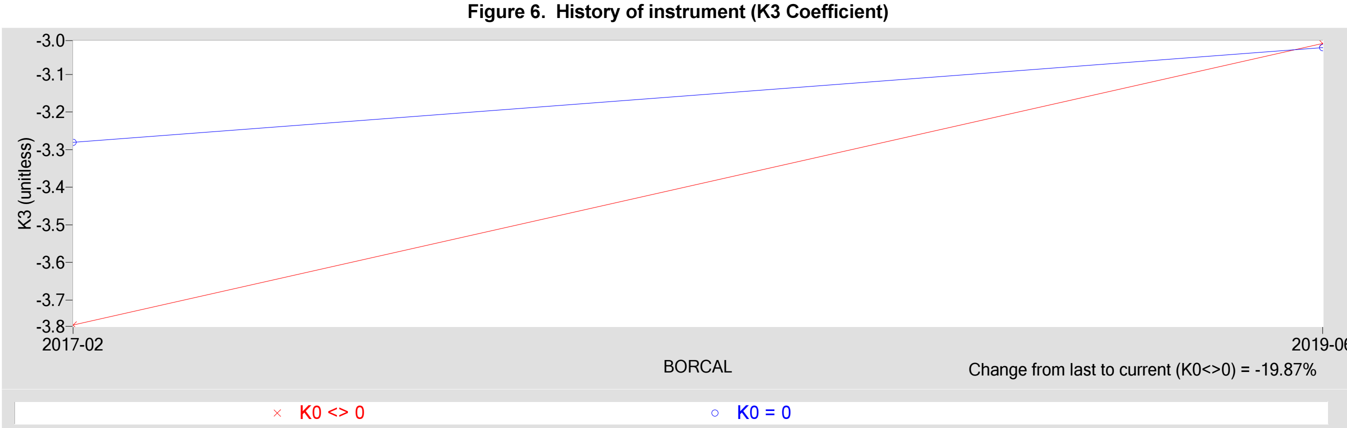


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30689F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

________________________________ ____________

Peter Gotseff, Technical Manager   Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30689F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

*Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr)* [1]

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

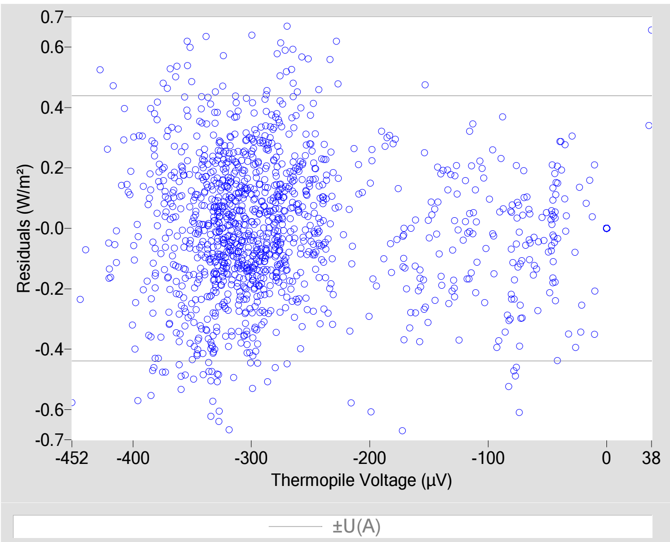


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

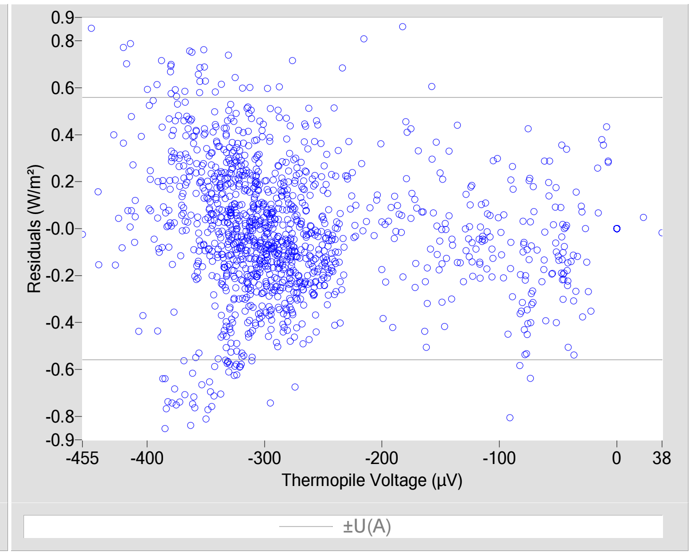


Table 2. Calibration Coefficients for K0<>0

K0	-2.3
K1	0.25411
K2	1.0024
K3	-3.11
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.25449
K2	0.9962
K3	-3.07
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.22
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.29
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

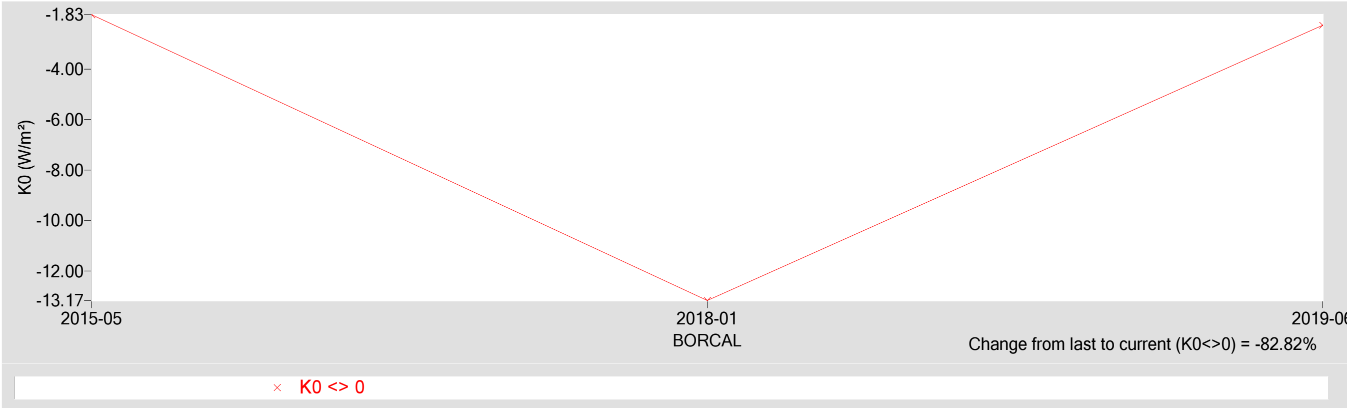


Figure 4. History of instrument (K1 Coefficient)

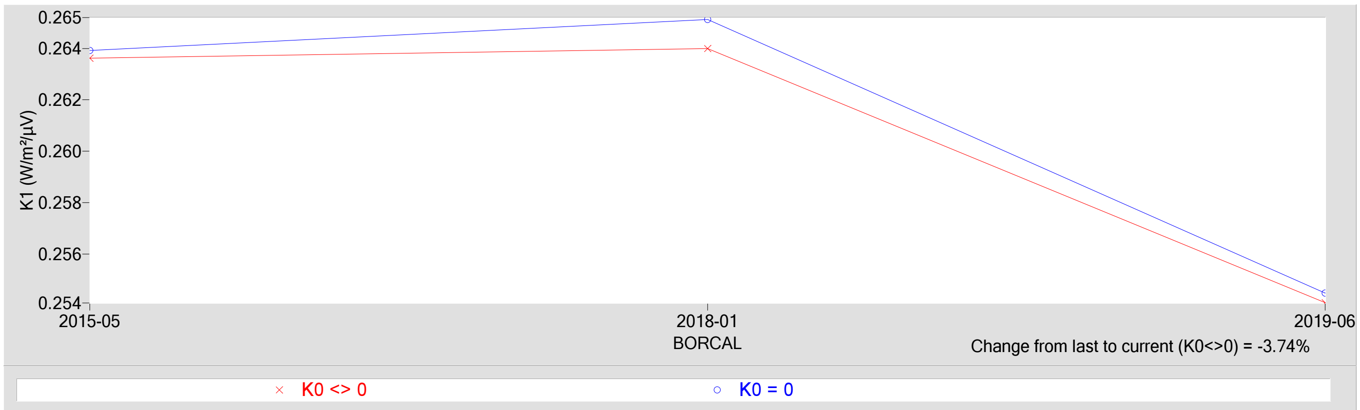


Figure 5. History of instrument (K2 Coefficient)

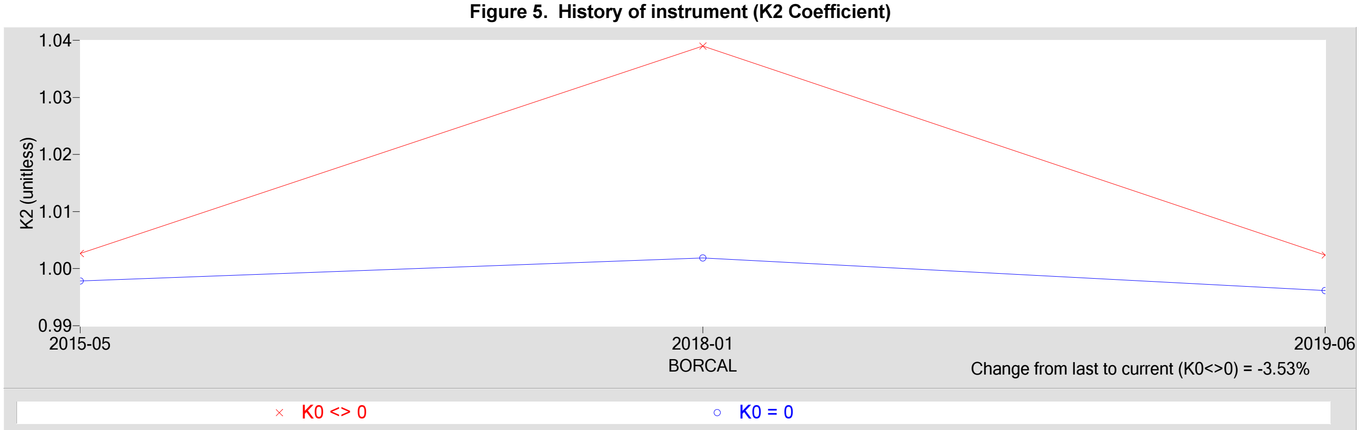
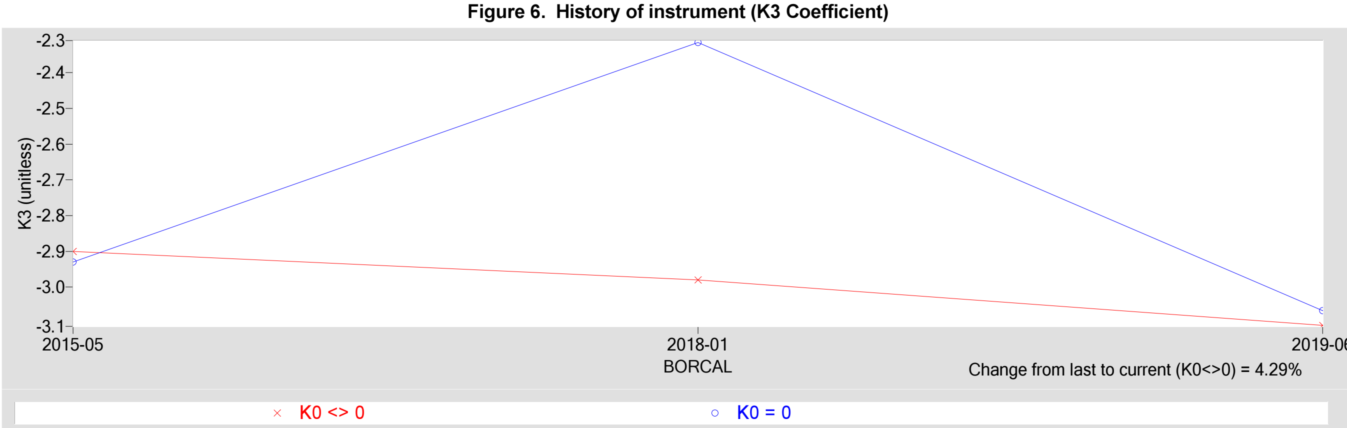


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30780F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

________________________________ ________________

Peter Gotseff, Technical Manager   Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30780F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

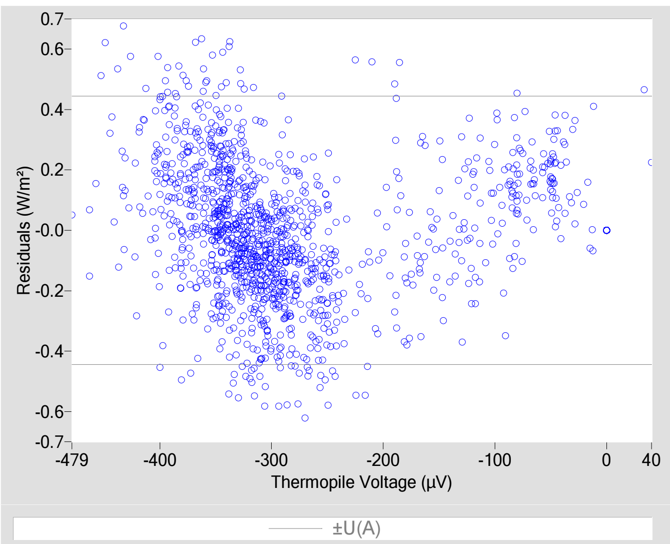


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

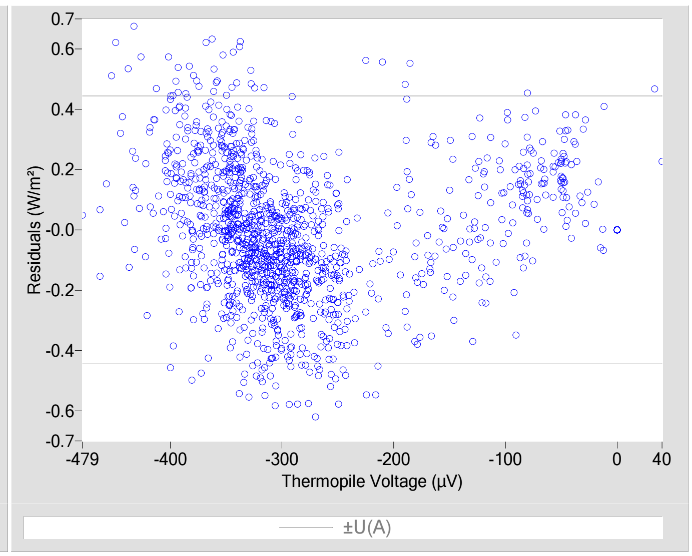


Table 2. Calibration Coefficients for K0<>0

K0	0.0
K1	0.24349
K2	1.0008
K3	-3.35
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24349
K2	1.0008
K3	-3.35
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.23
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.23
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

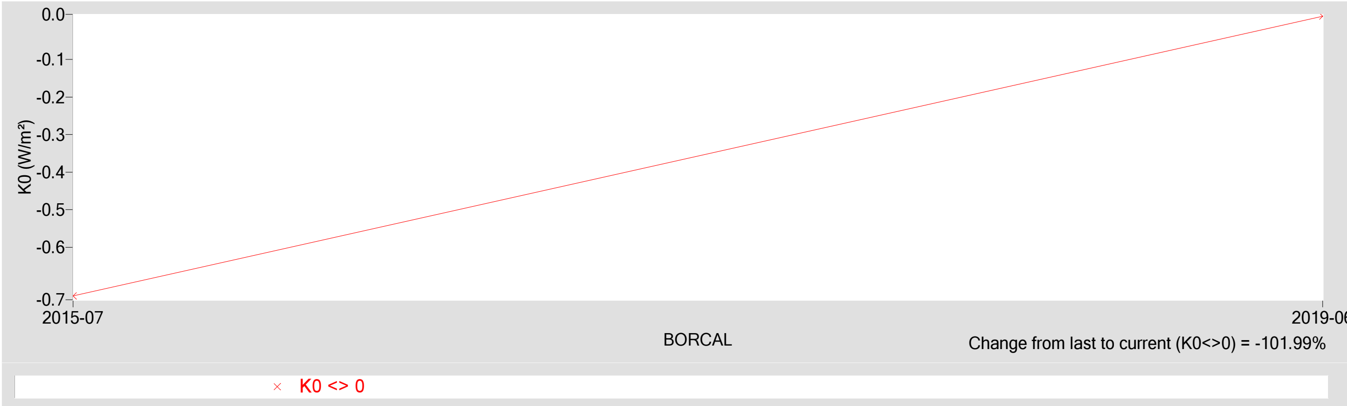


Figure 4. History of instrument (K1 Coefficient)

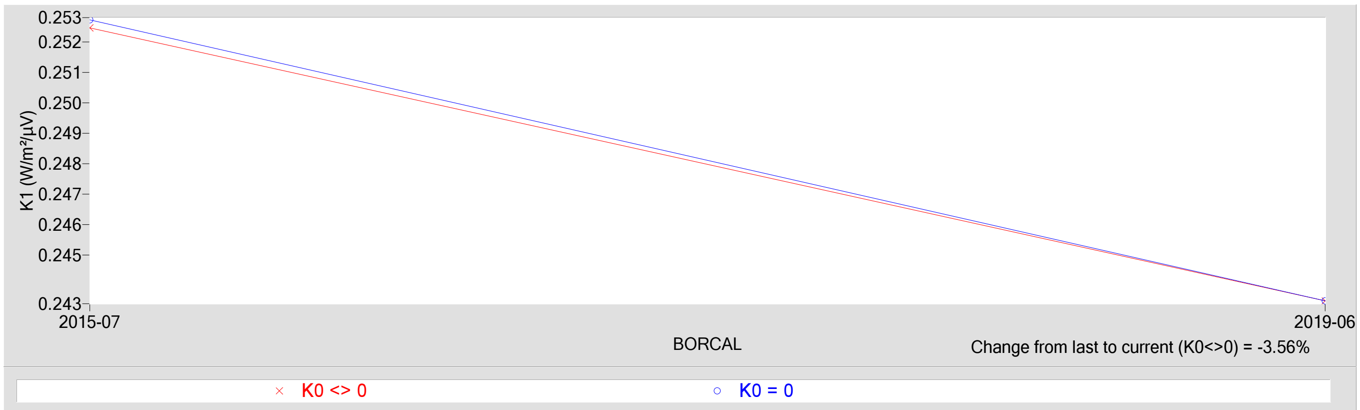


Figure 5. History of instrument (K2 Coefficient)

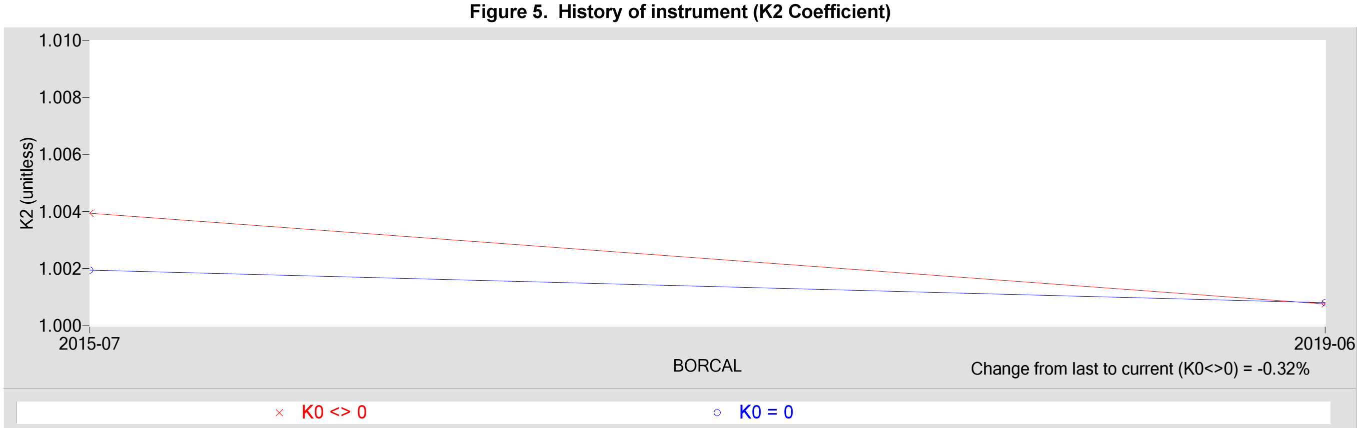
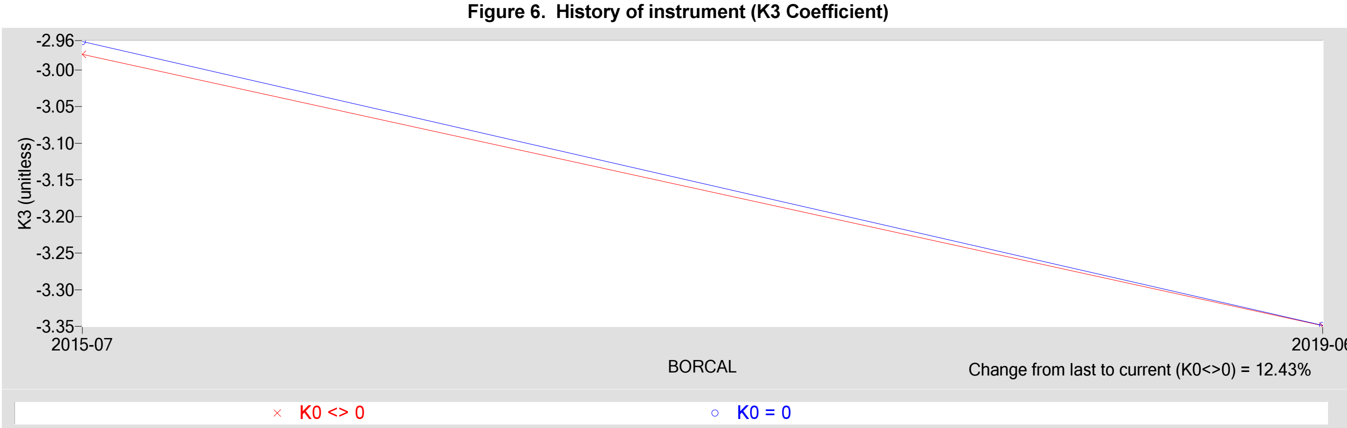


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30784F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____________________________________ ________________

Peter Gotseff, Technical Manager   Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30784F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

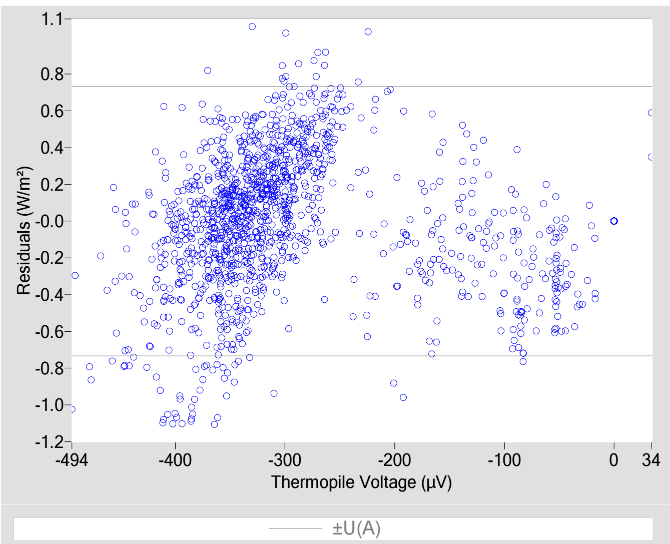


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

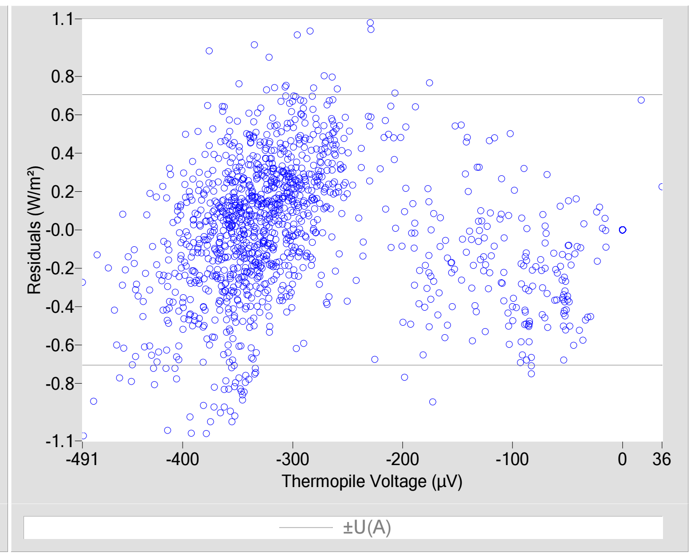


Table 2. Calibration Coefficients for K0<>0

K0	-0.6
K1	0.23893
K2	1.0067
K3	-3.52
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23882
K2	1.0049
K3	-3.55
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.37
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.36
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

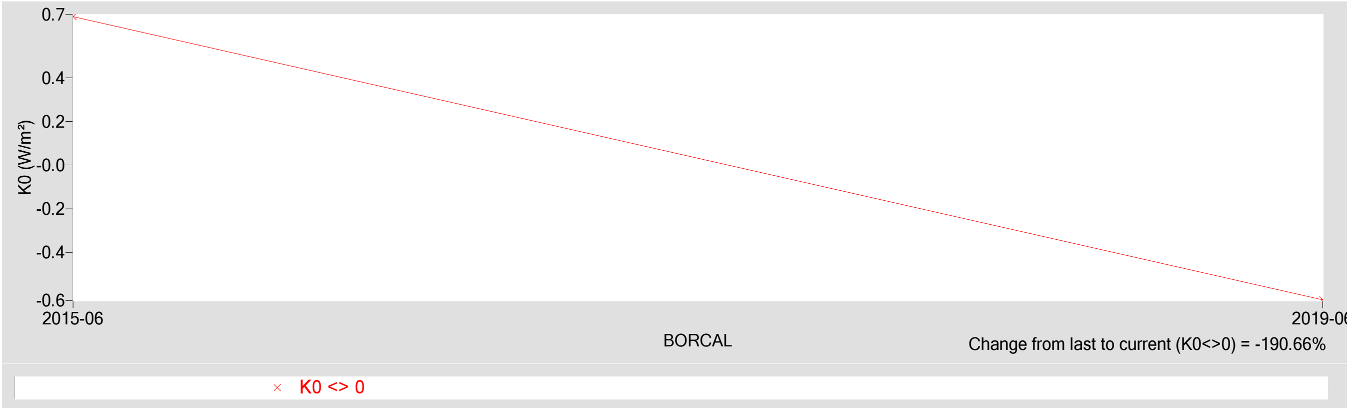


Figure 4. History of instrument (K1 Coefficient)

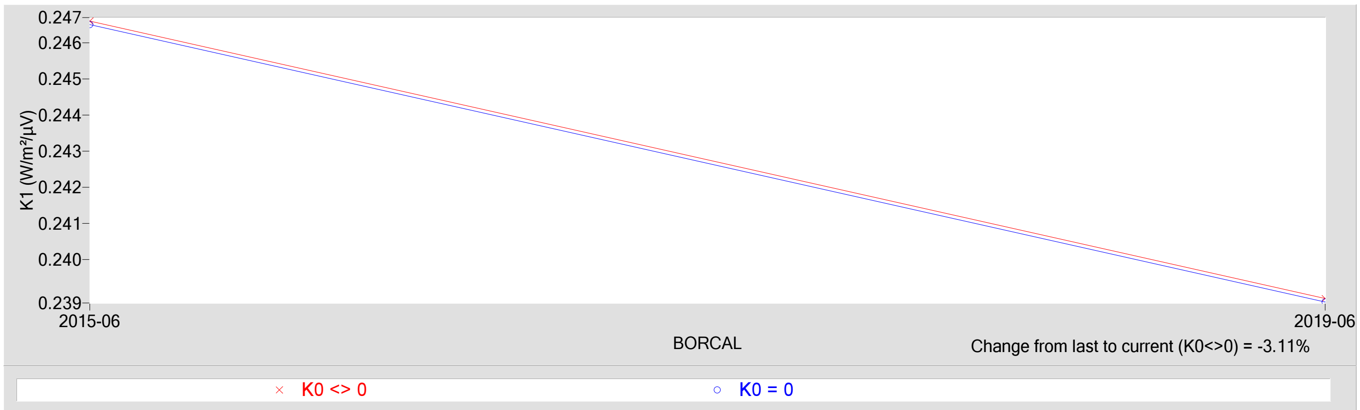


Figure 5. History of instrument (K2 Coefficient)

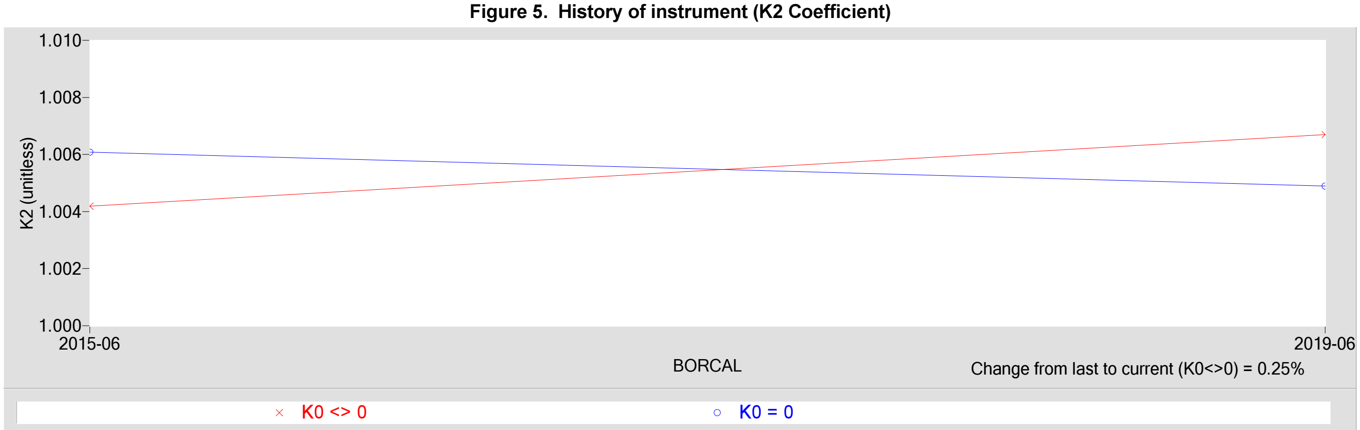
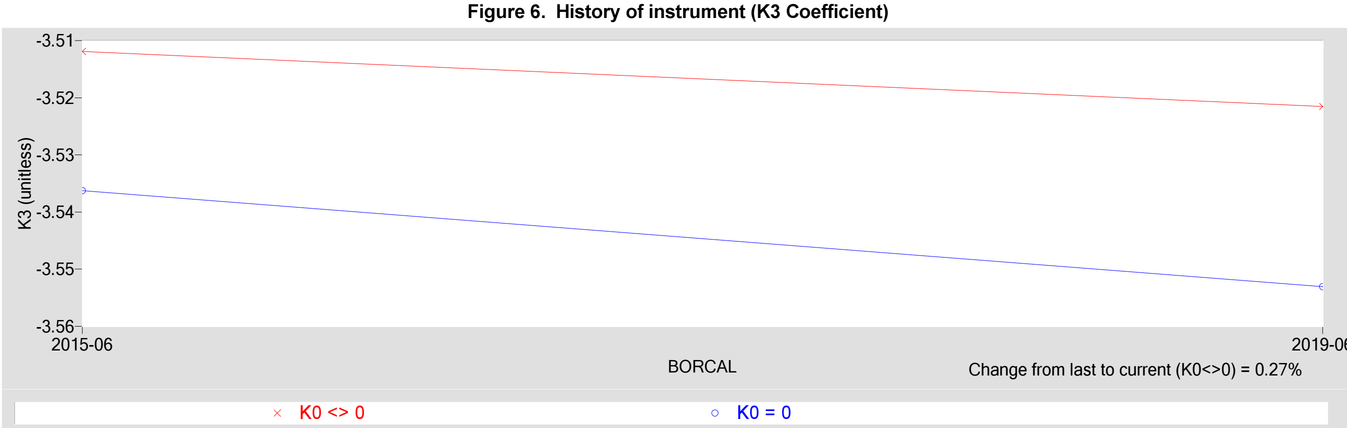


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30835F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ____________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30835F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

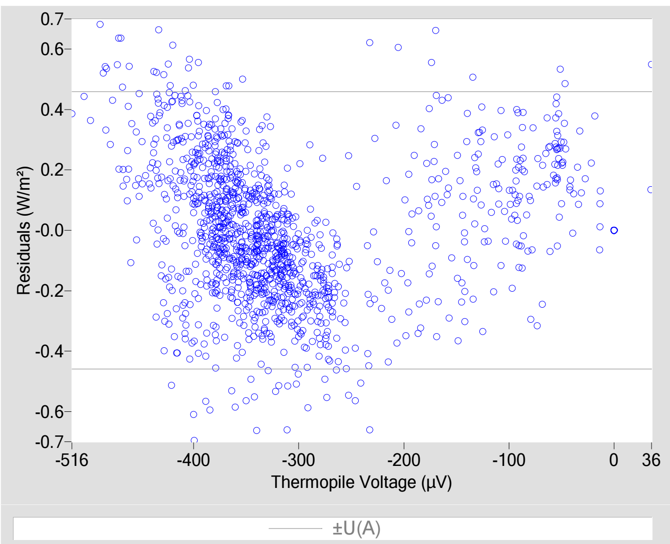


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

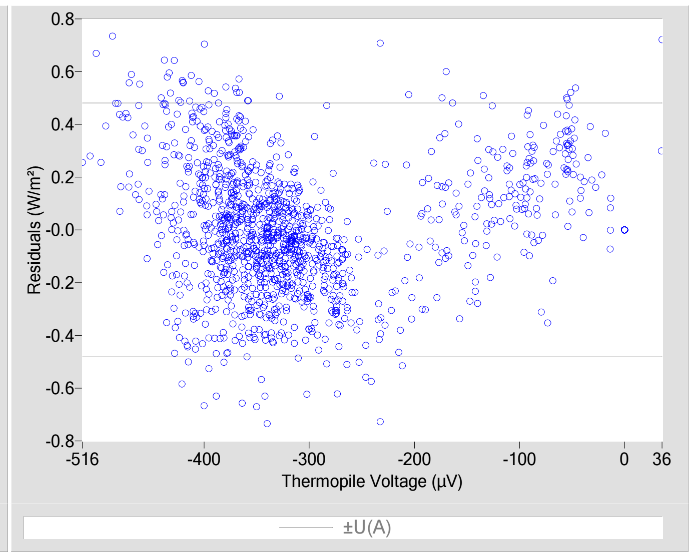


Table 2. Calibration Coefficients for K0<>0

K0	1.0
K1	0.22615
K2	0.9958
K3	-3.38
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.22601
K2	0.9985
K3	-3.34
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.23
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.25
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

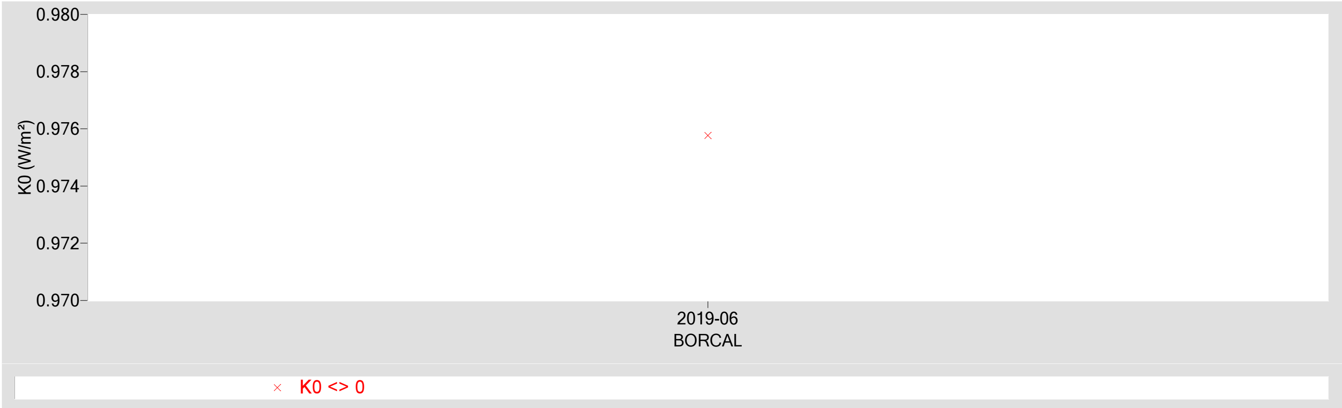


Figure 4. History of instrument (K1 Coefficient)

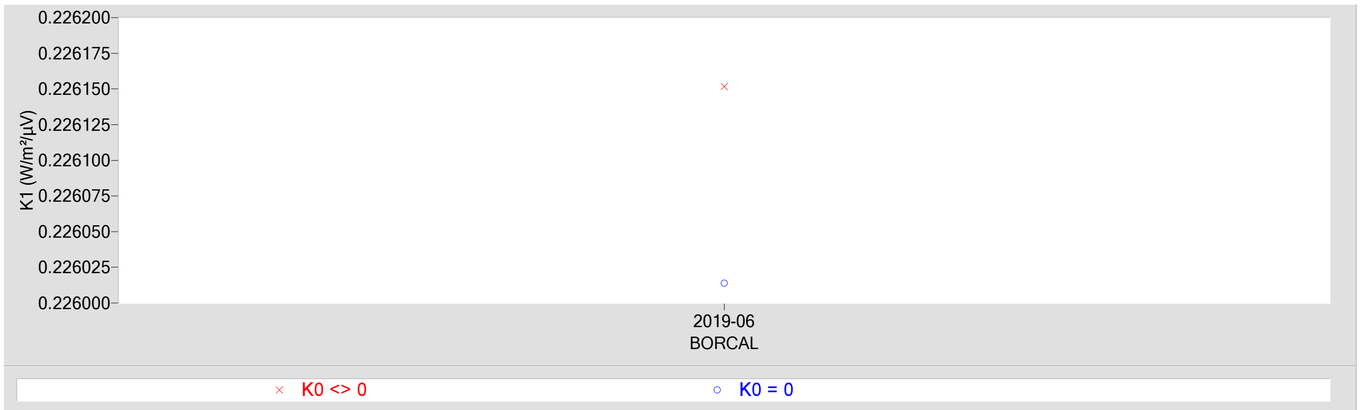


Figure 5. History of instrument (K2 Coefficient)

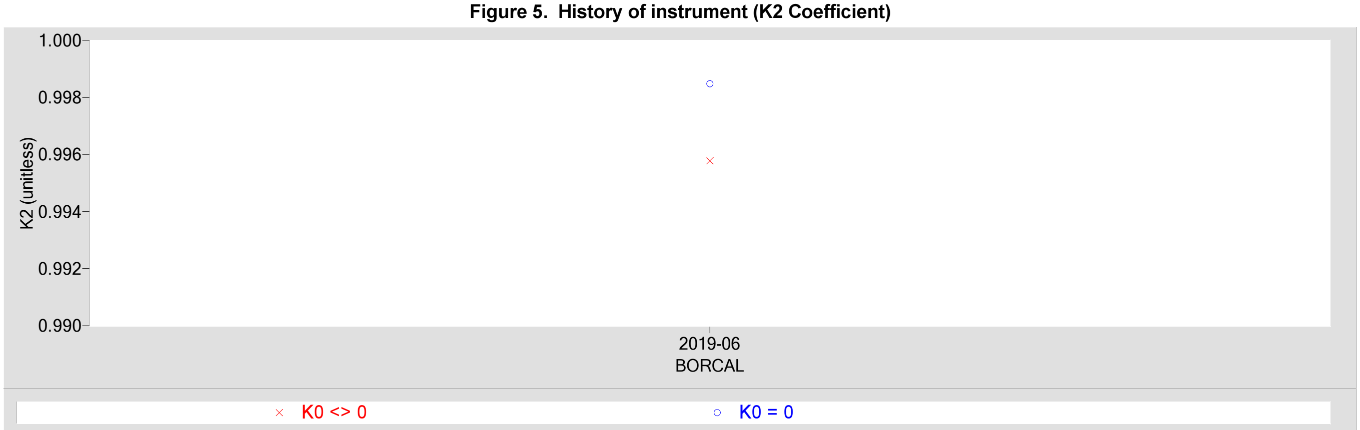
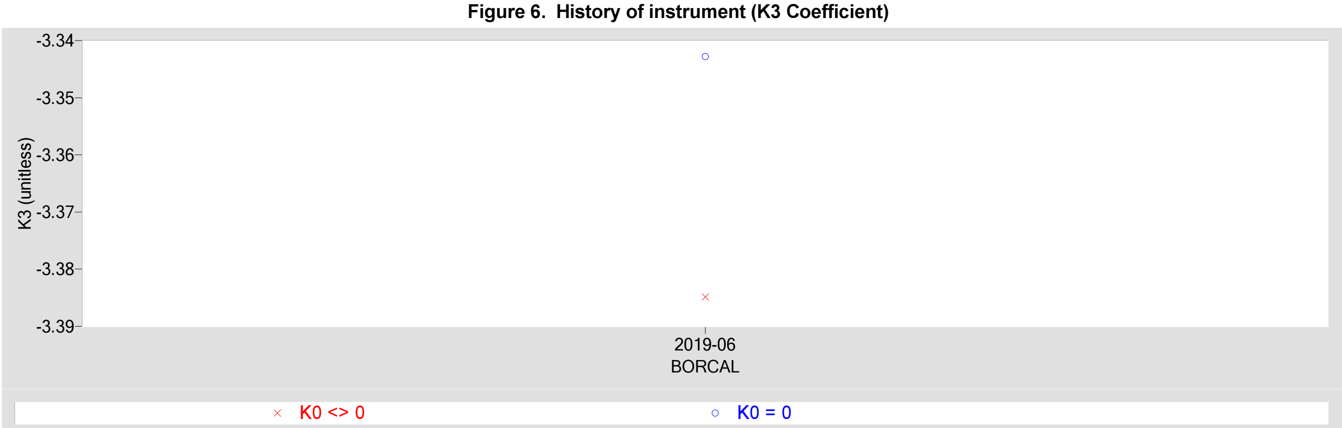


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	30837F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ____________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

30837F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coeffiecints,
V = thermopile output voltage (μV),
Wd = σ * *Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr^4* = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

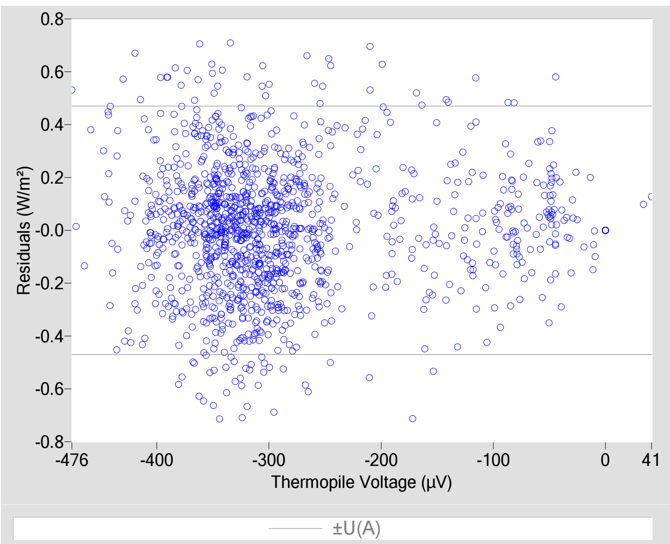


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

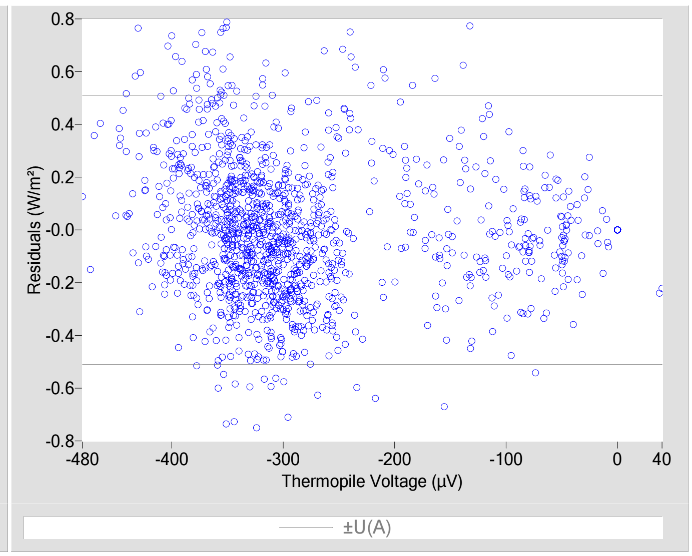


Table 2. Calibration Coefficients for K0<>0

K0	-1.2
K1	0.24194
K2	1.0027
K3	-4.24
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24212
K2	0.9992
K3	-4.25
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.26
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

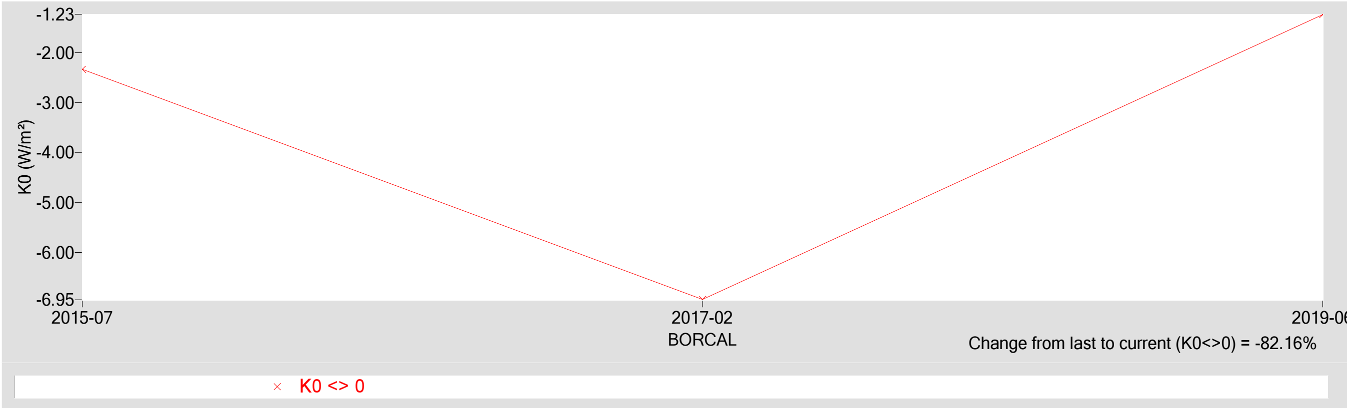


Figure 4. History of instrument (K1 Coefficient)

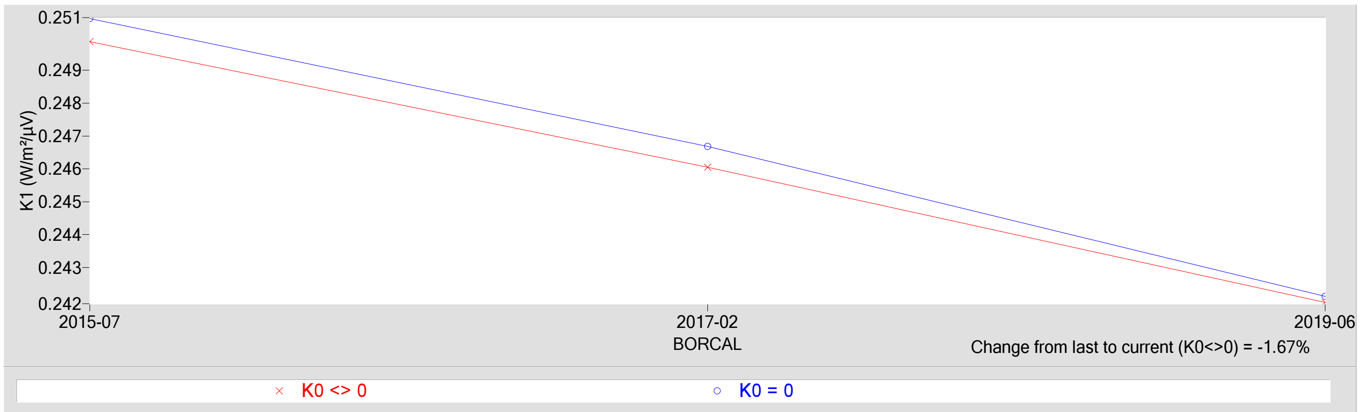


Figure 5. History of instrument (K2 Coefficient)

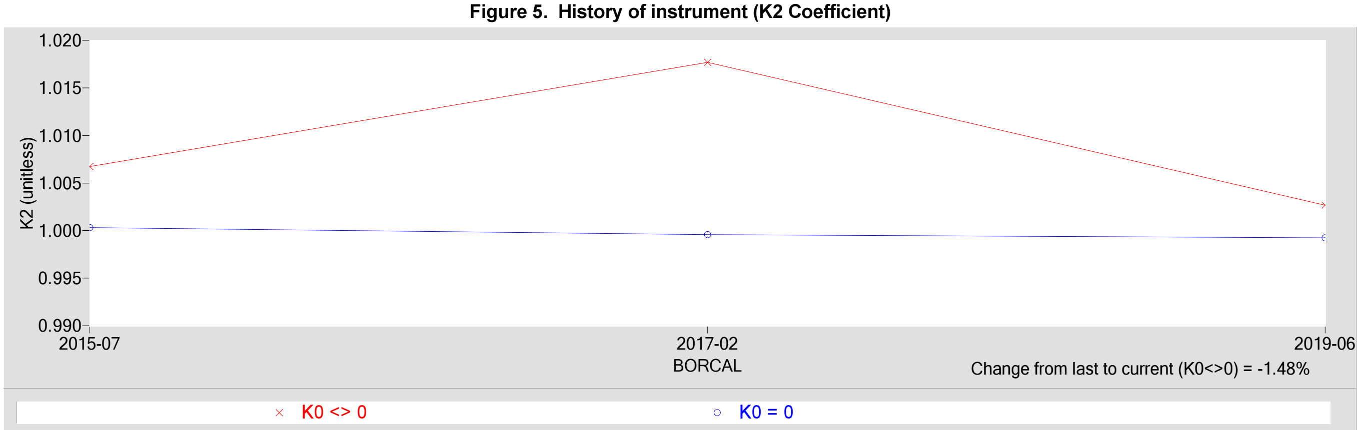
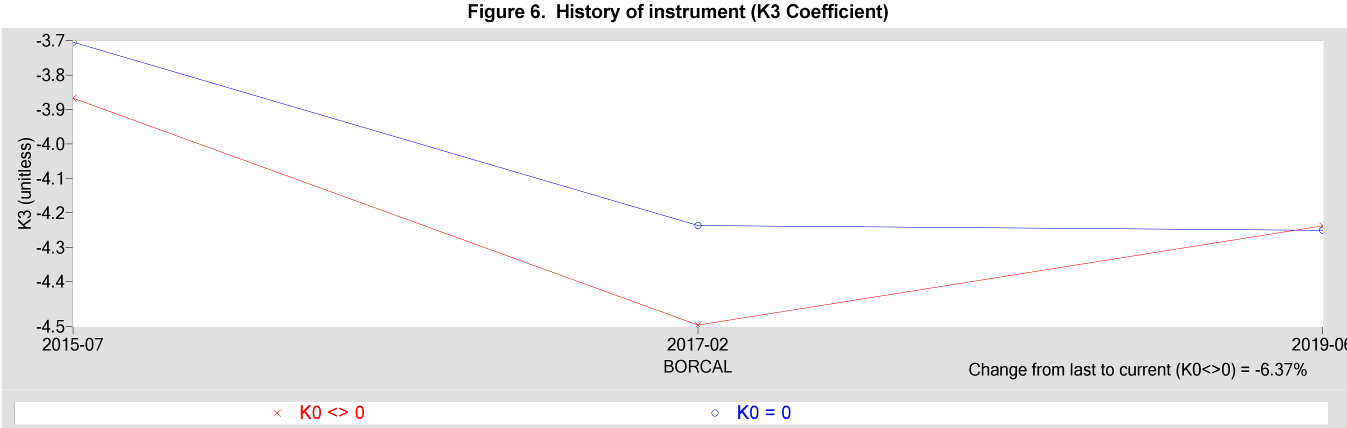


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	31639F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ _____________

Peter Gotseff, Technical Manager   Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

31639F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \qquad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

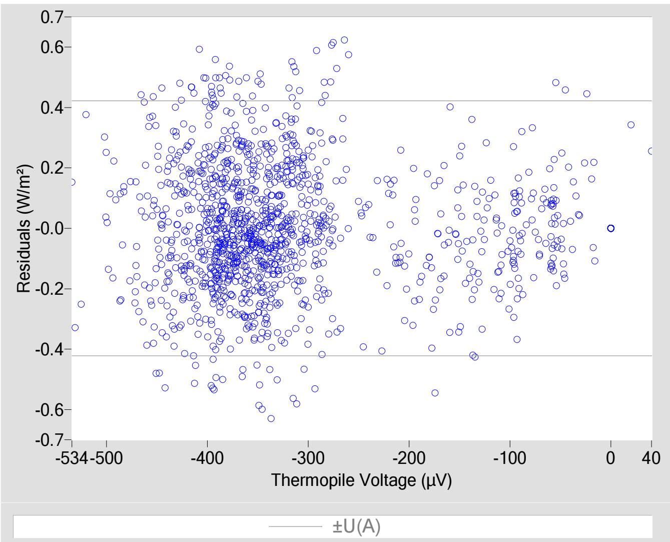


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

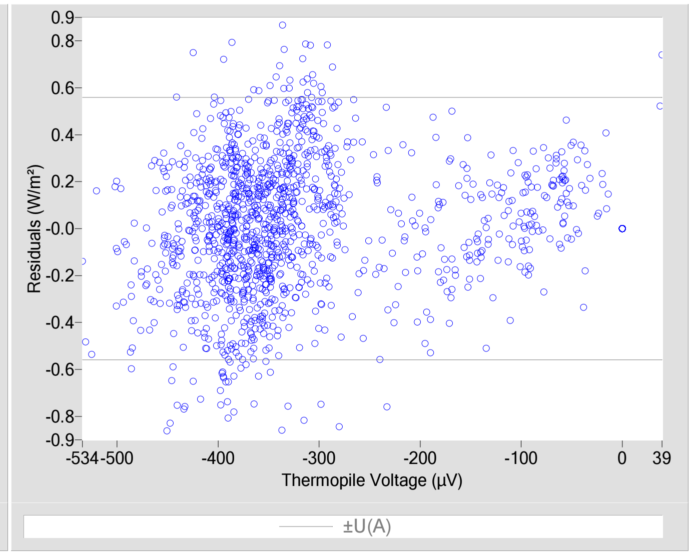


Table 2. Calibration Coefficients for K0<>0

K0	2.4
K1	0.21886
K2	0.9953
K3	-3.77
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.21855
K2	1.0018
K3	-3.57
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.22
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.29
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

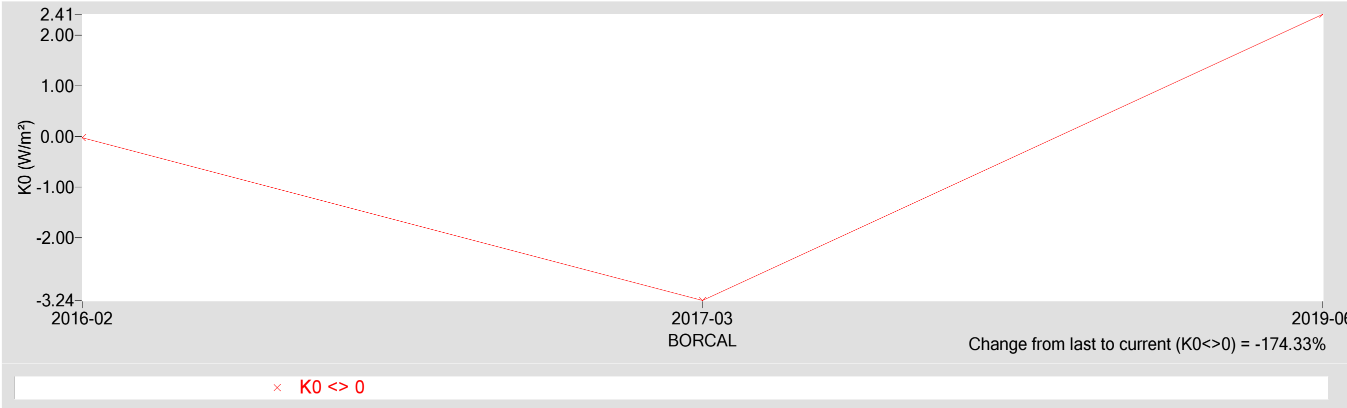


Figure 4. History of instrument (K1 Coefficient)

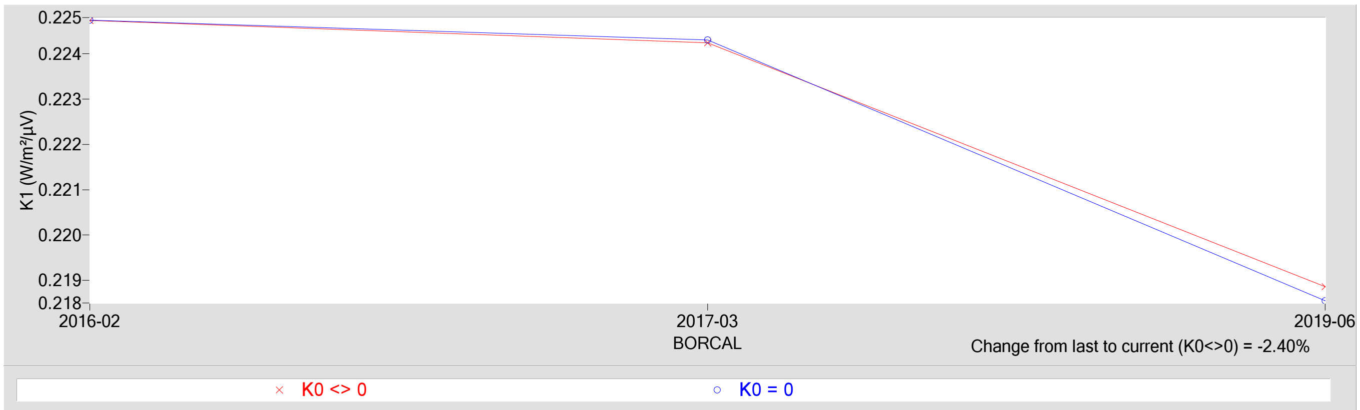


Figure 5. History of instrument (K2 Coefficient)

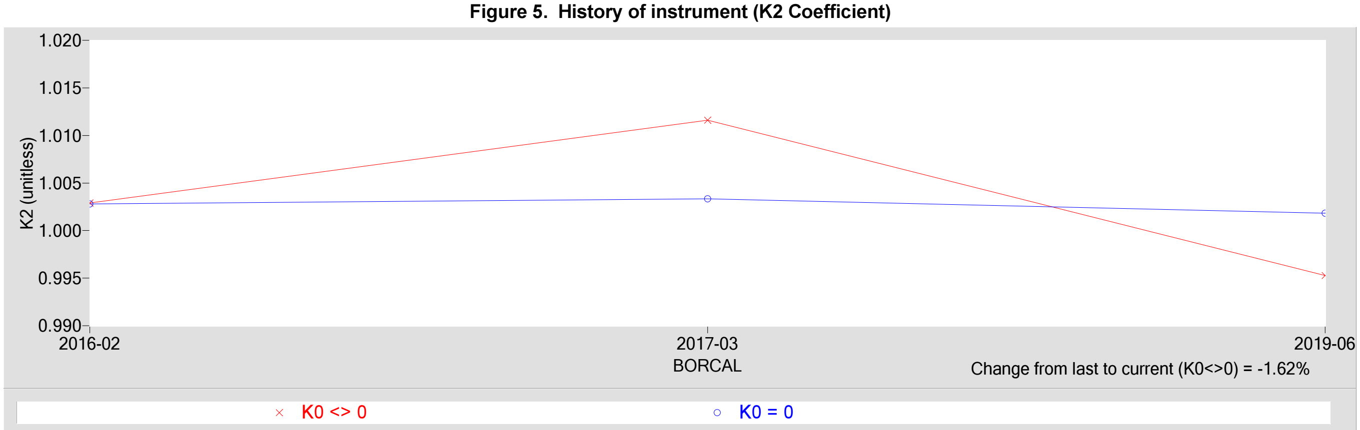
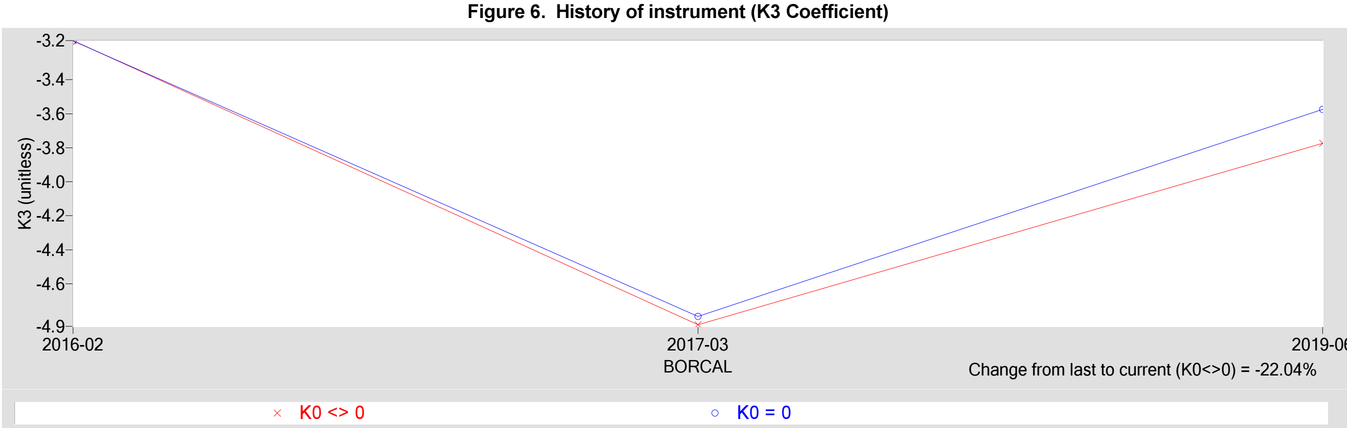


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	32041F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____________________________ ____________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

32041F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coeffiicents,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

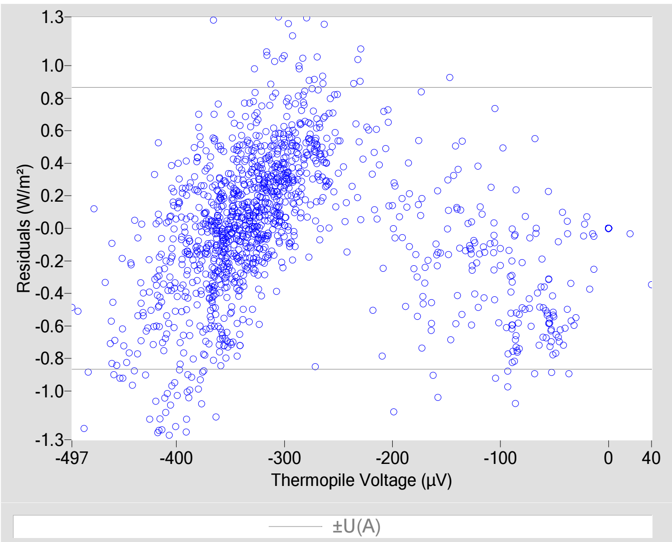


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

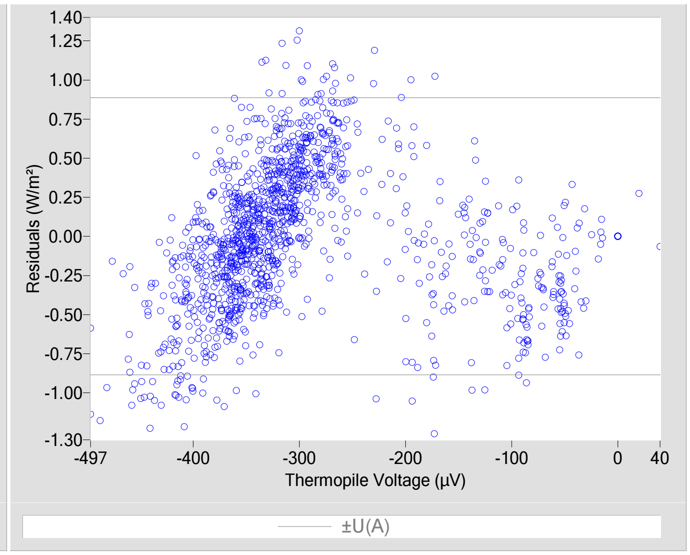


Table 2. Calibration Coefficients for K0<>0

K0	1.7
K1	0.24258
K2	1.0009
K3	-4.35
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24210
K2	1.0056
K3	-4.19
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.44
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.45
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

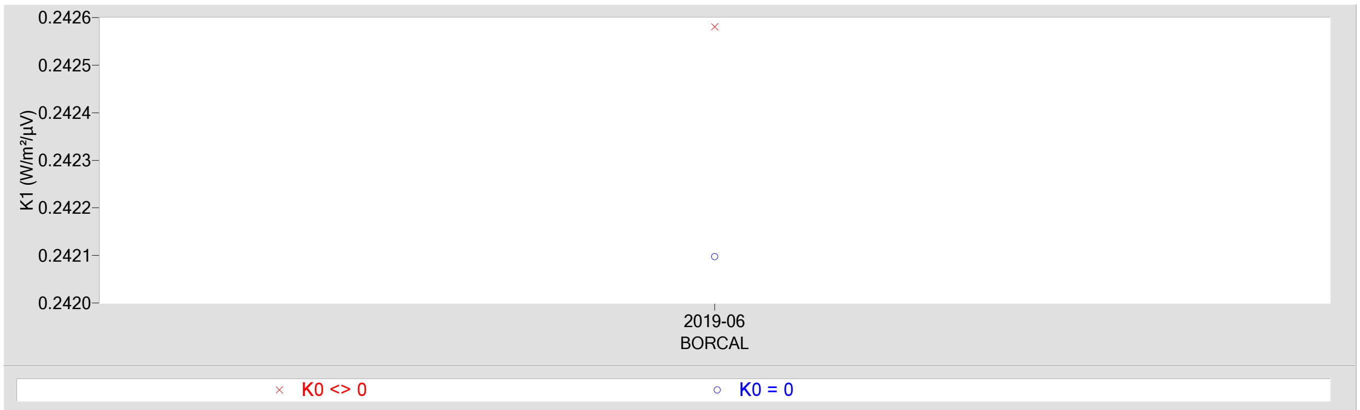


Figure 5. History of instrument (K2 Coefficient)

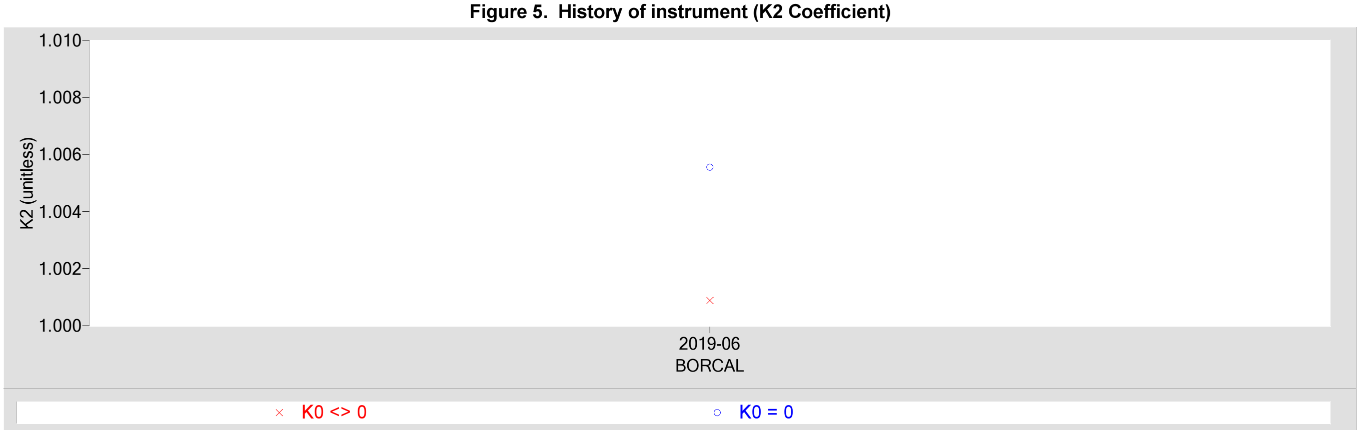
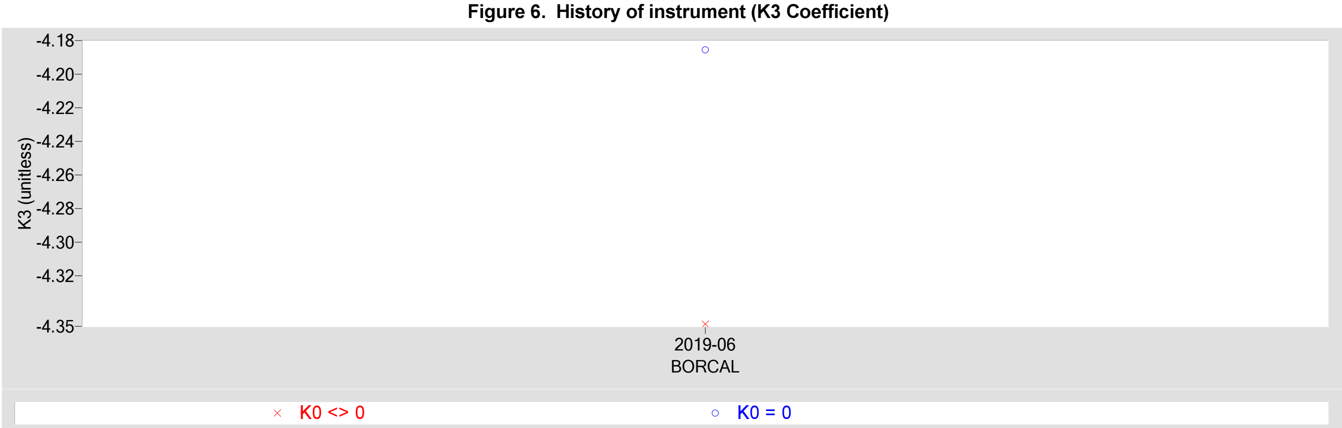


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	32043F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	NSA	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

________________________________ ________________

Peter Gotseff, Technical Manager — Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

32043F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

- *K0,K1,K2,K3* = calibration coefficeints,
- *V* = thermopile output voltage (μV),
- $Wd = \sigma * Td^4$ = dome irradiance (W/m²),
  - where, *Td* = dome temperature (K),
- $Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
  - where, σ = 5.6704e-8 W·m-2·K-4,
  - $Tr = Tc + Kr * V$ = receiver temperature (K),
  - *Tc* = case temperature (K),
  - *Kr* = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

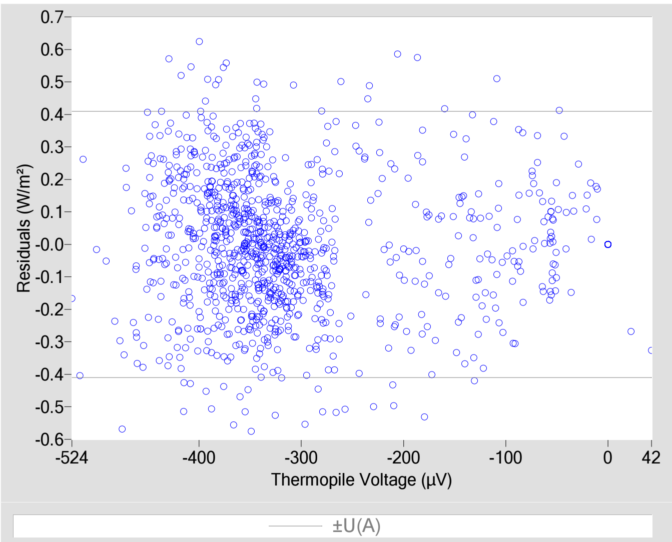


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

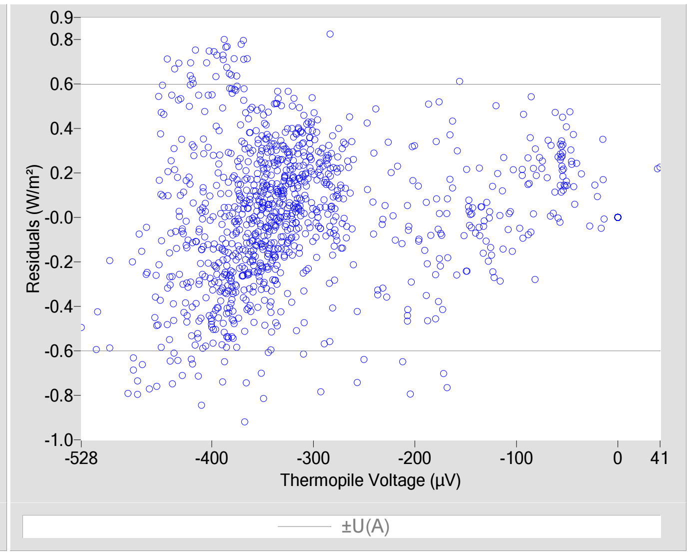


Table 2. Calibration Coefficients for K0<>0

K0	2.7
K1	0.22126
K2	0.9915
K3	-3.07
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.22076
K2	0.9988
K3	-3.01
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.21
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.31
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

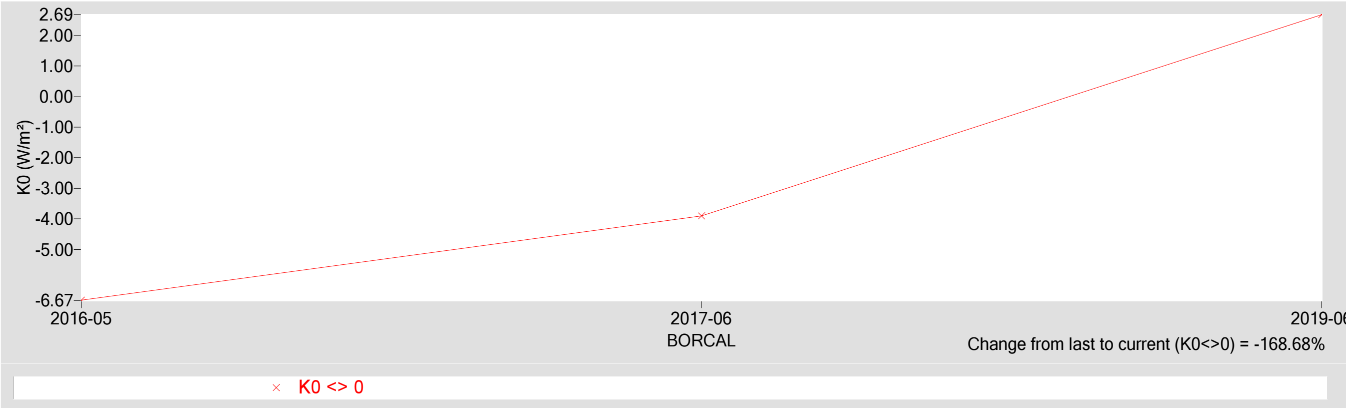


Figure 4. History of instrument (K1 Coefficient)

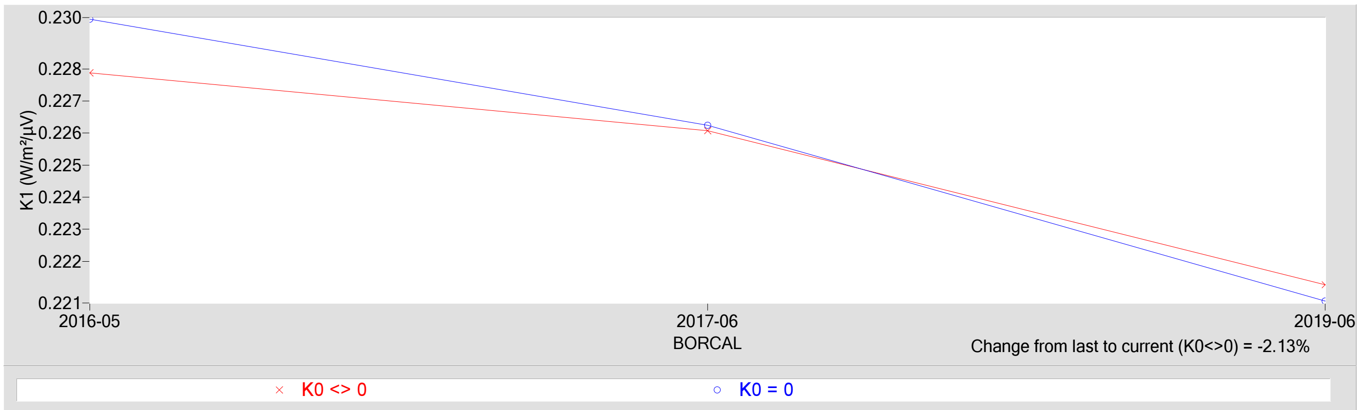


Figure 5. History of instrument (K2 Coefficient)

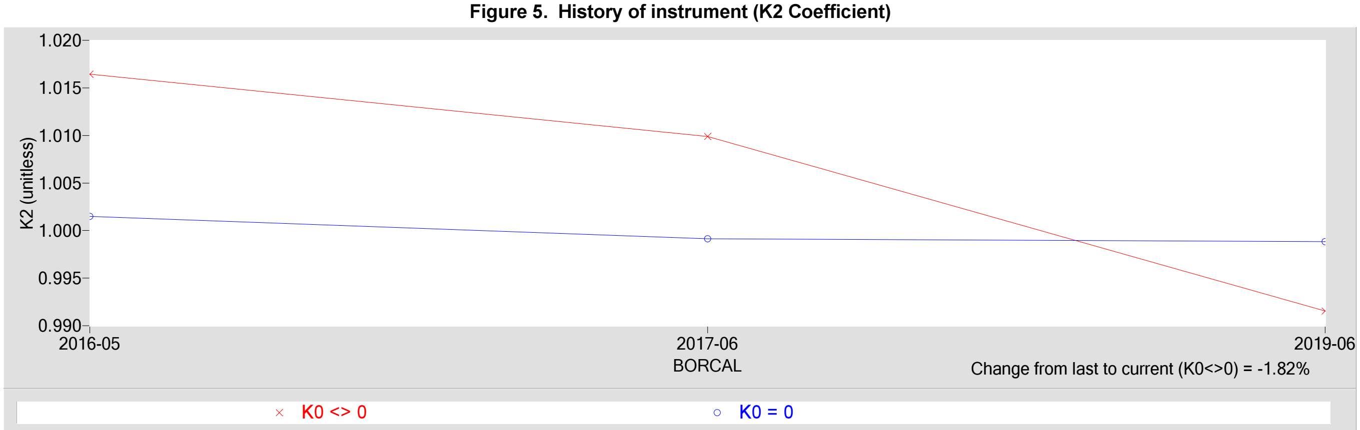
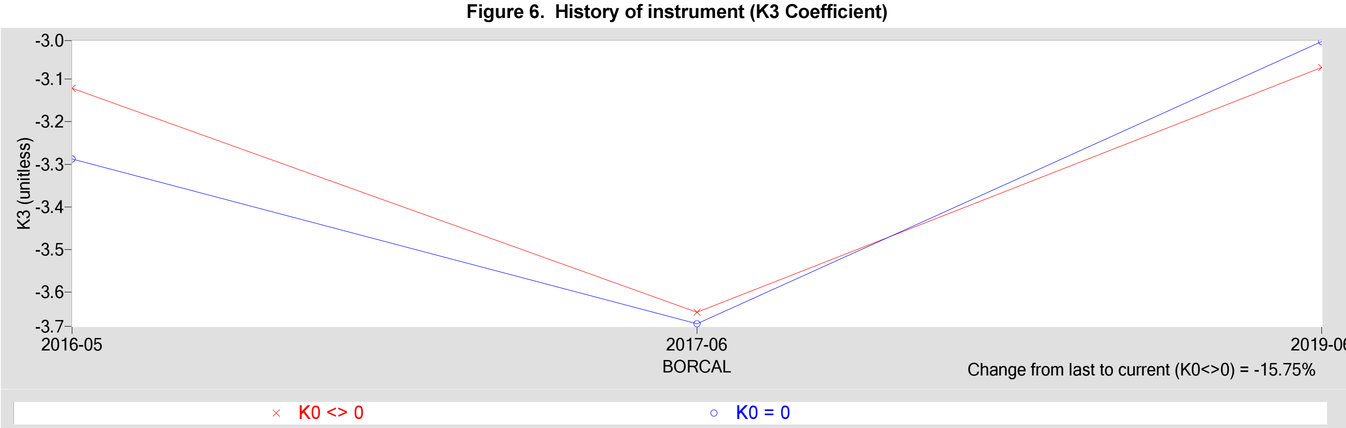


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	34304F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	AMF	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

34304F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1 * V + K2 * Wr + K3 * (Wd - Wr) \qquad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

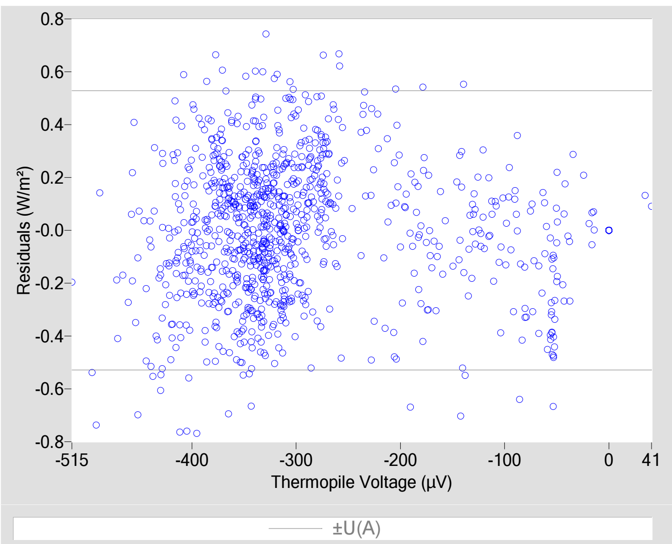


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

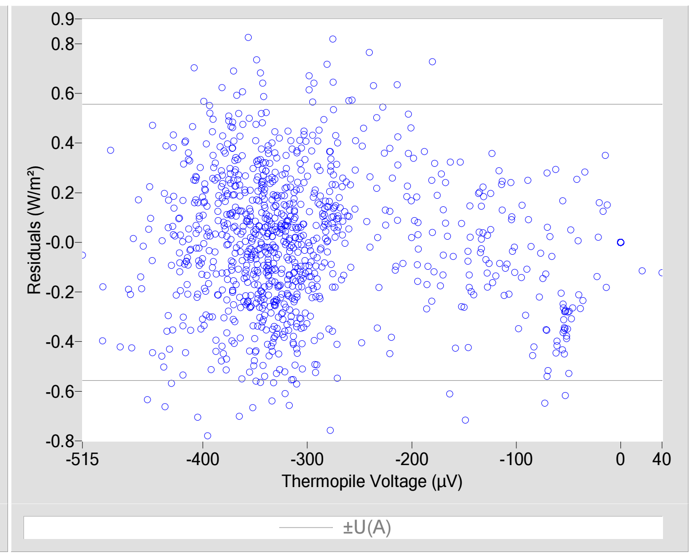


Table 2. Calibration Coefficients for K0<>0

K0	-1.2
K1	0.22784
K2	0.9967
K3	-4.25
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.22792
K2	0.9934
K3	-4.28
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.27
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.28
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

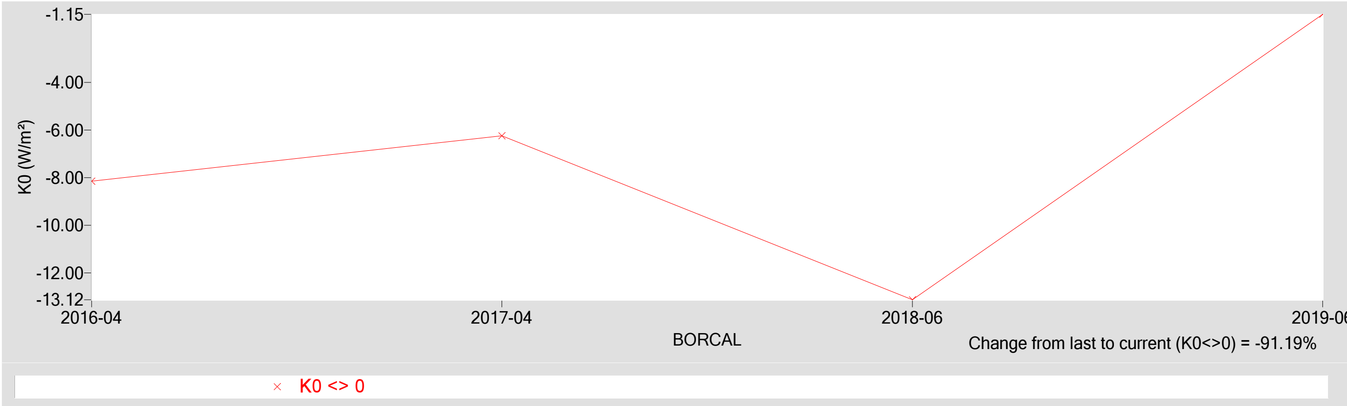


Figure 4. History of instrument (K1 Coefficient)

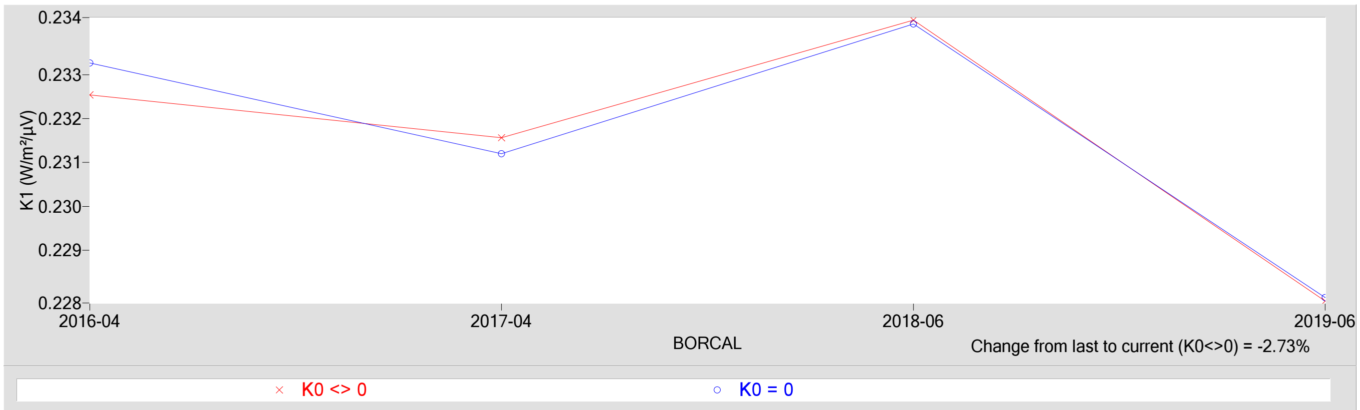


Figure 5. History of instrument (K2 Coefficient)

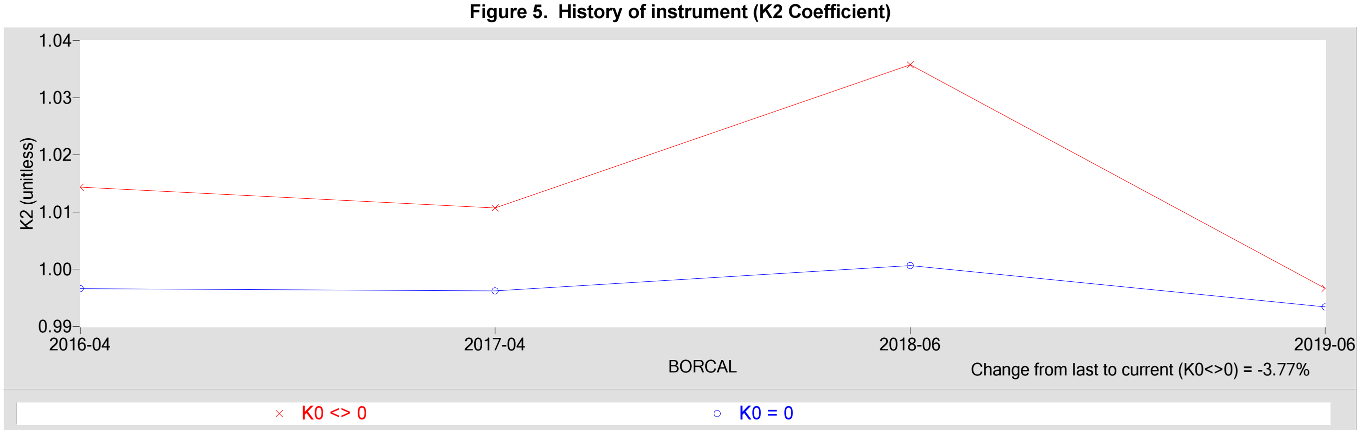
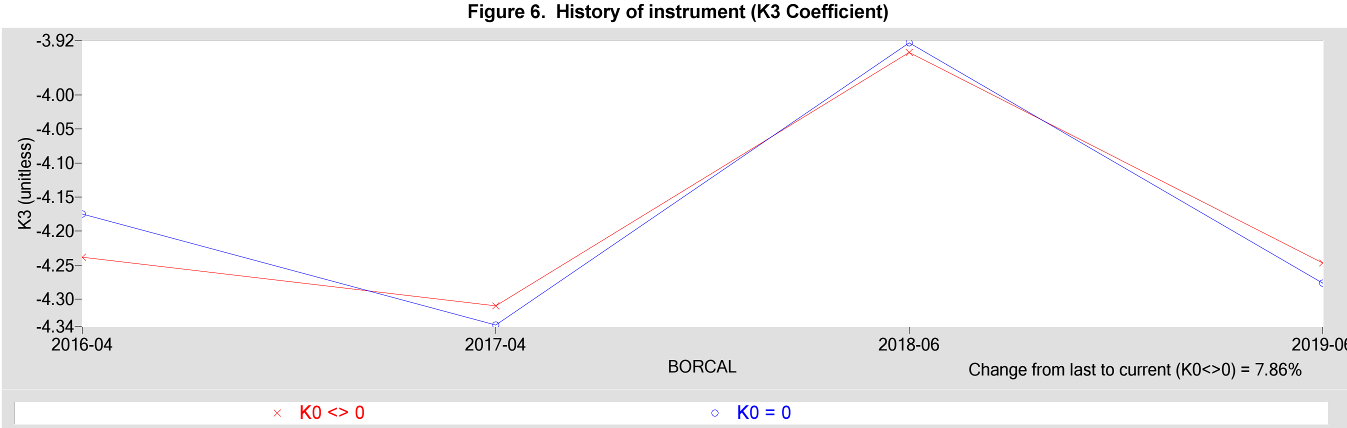


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	36280F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	AMF	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

_______________________________ _______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

36280F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

*Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr)* [1]

where,

K0,K1,K2,K3 = calibration coeffceints,
V = thermopile output voltage (μV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

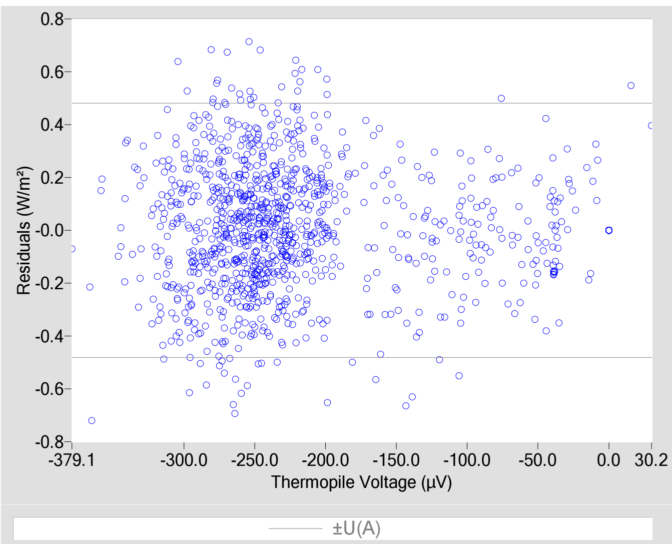


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

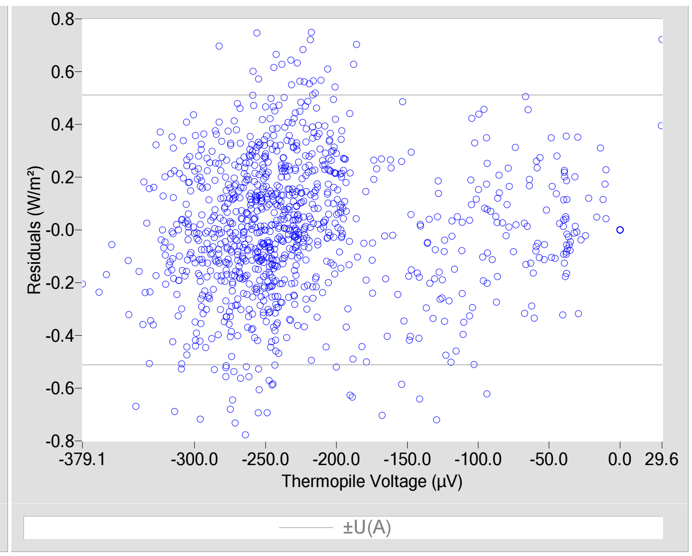


Table 2. Calibration Coefficients for K0<>0

K0	1.2
K1	0.31379
K2	1.0027
K3	-4.39
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.31344
K2	1.0058
K3	-4.28
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.25
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.26
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

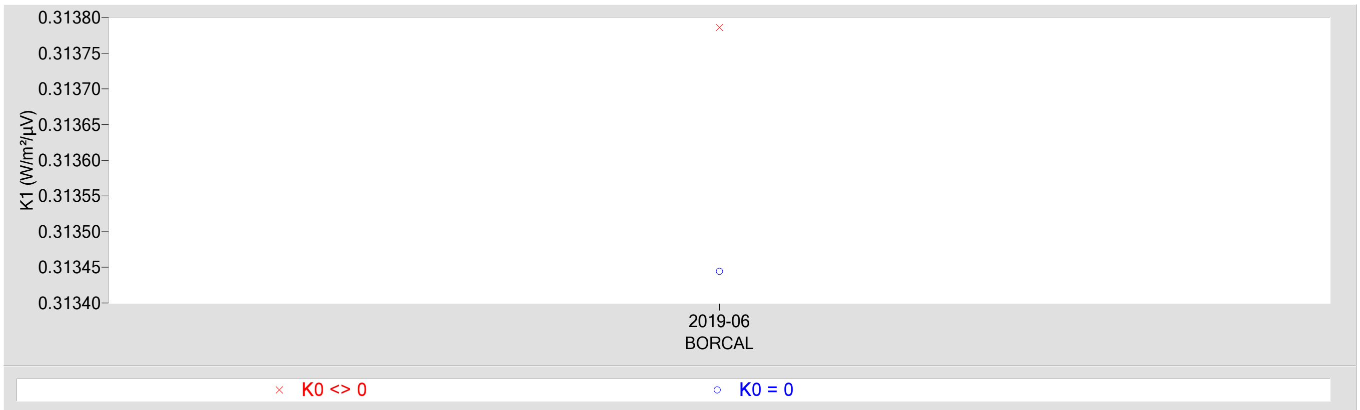


Figure 5. History of instrument (K2 Coefficient)

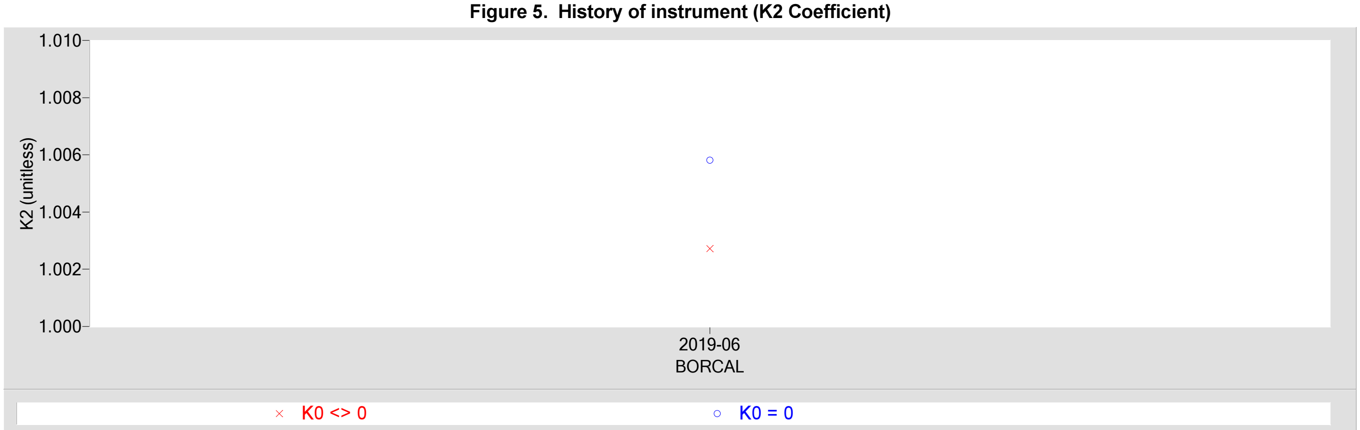
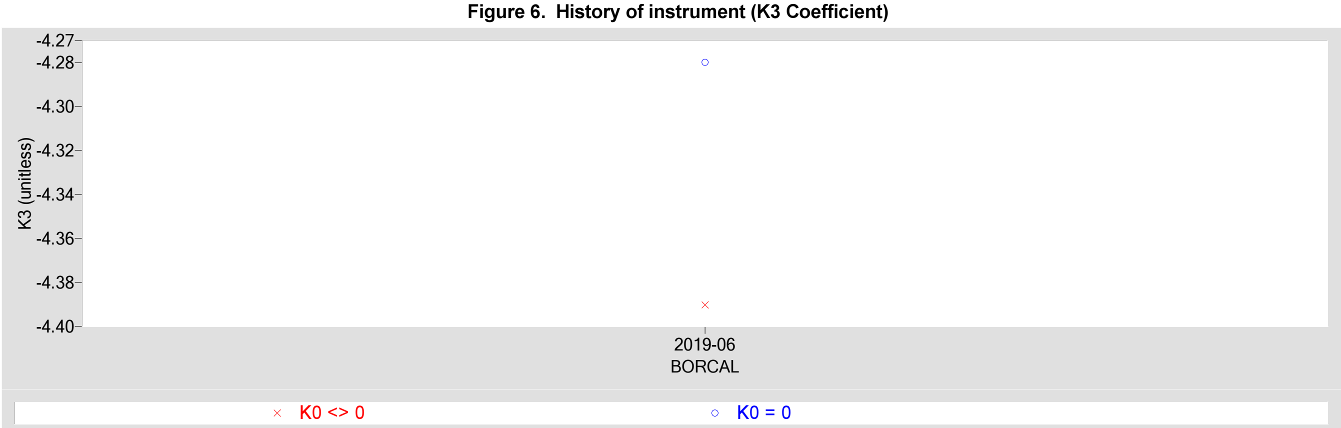


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	36368F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

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Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ____________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

36368F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

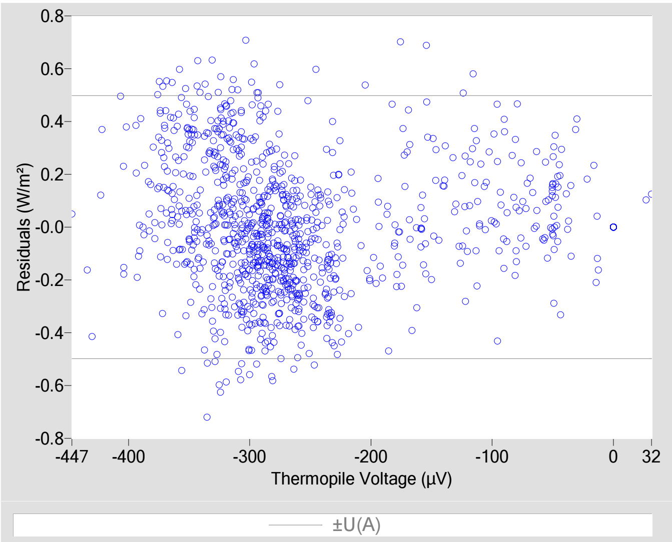


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

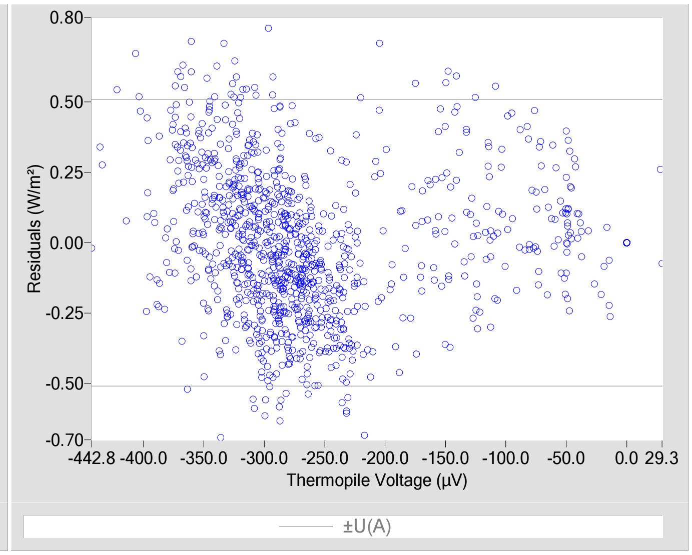


Table 2. Calibration Coefficients for K0<>0

K0	-0.8
K1	0.27217
K2	1.0099
K3	-4.56
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.27239
K2	1.0077
K3	-4.60
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.25
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.26
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

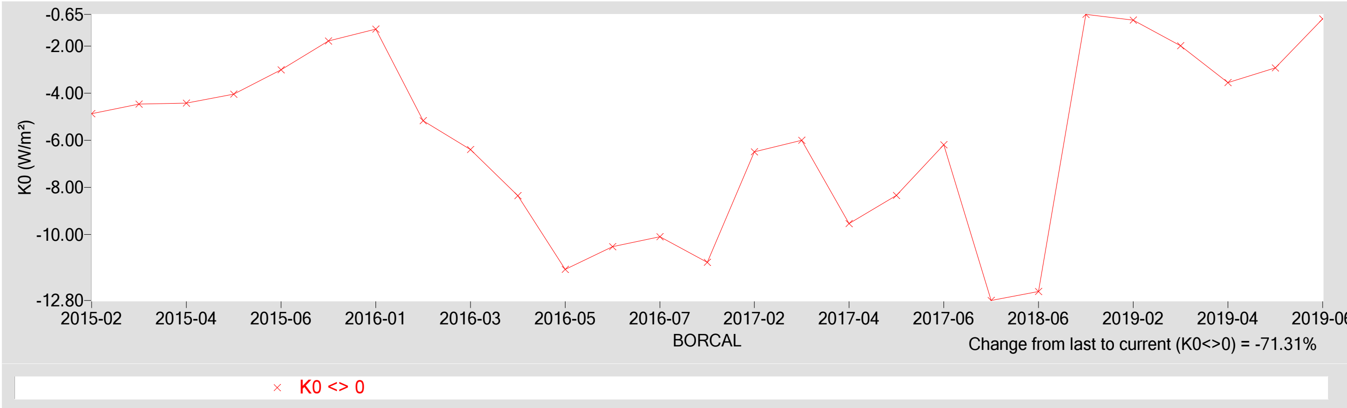


Figure 4. History of instrument (K1 Coefficient)

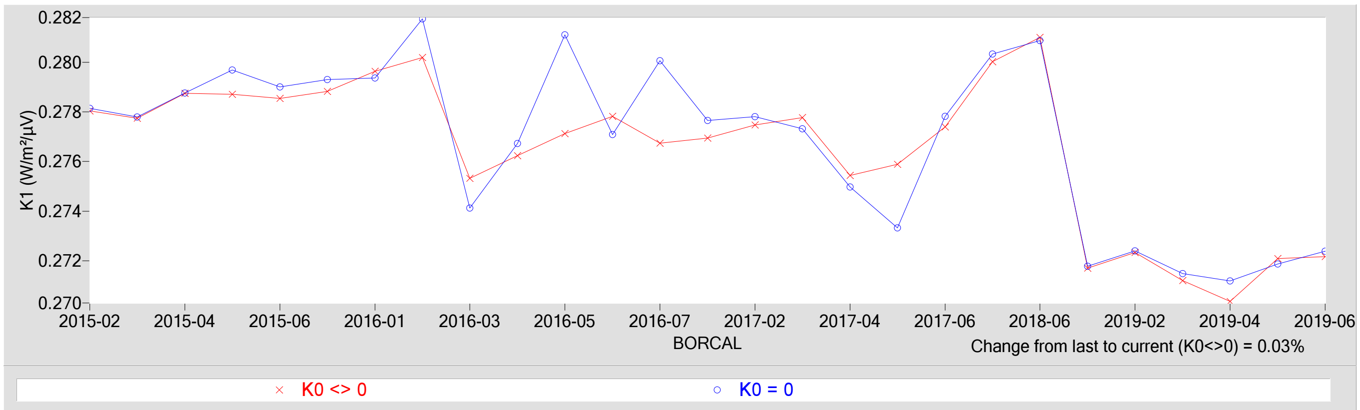


Figure 5. History of instrument (K2 Coefficient)

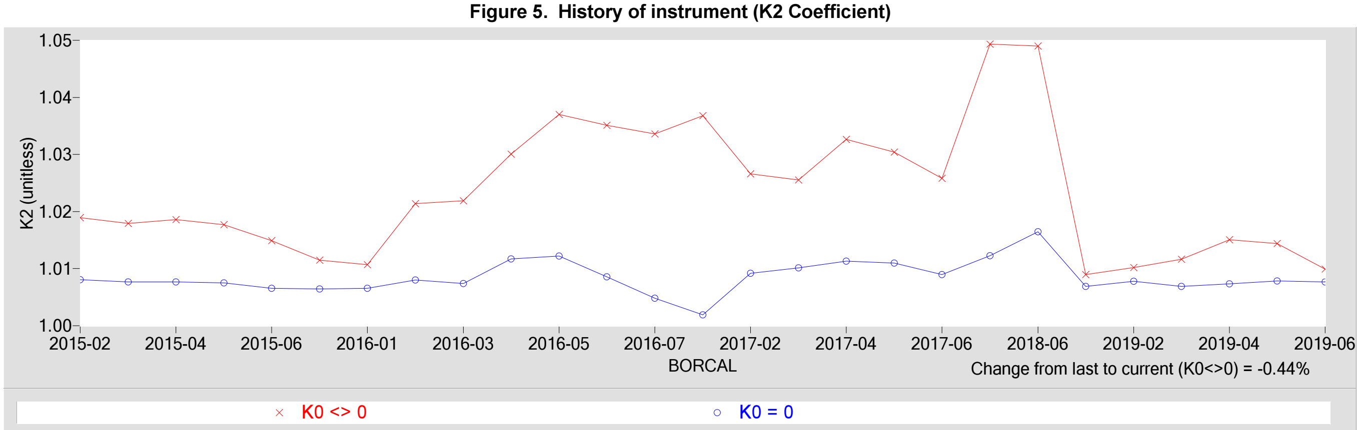
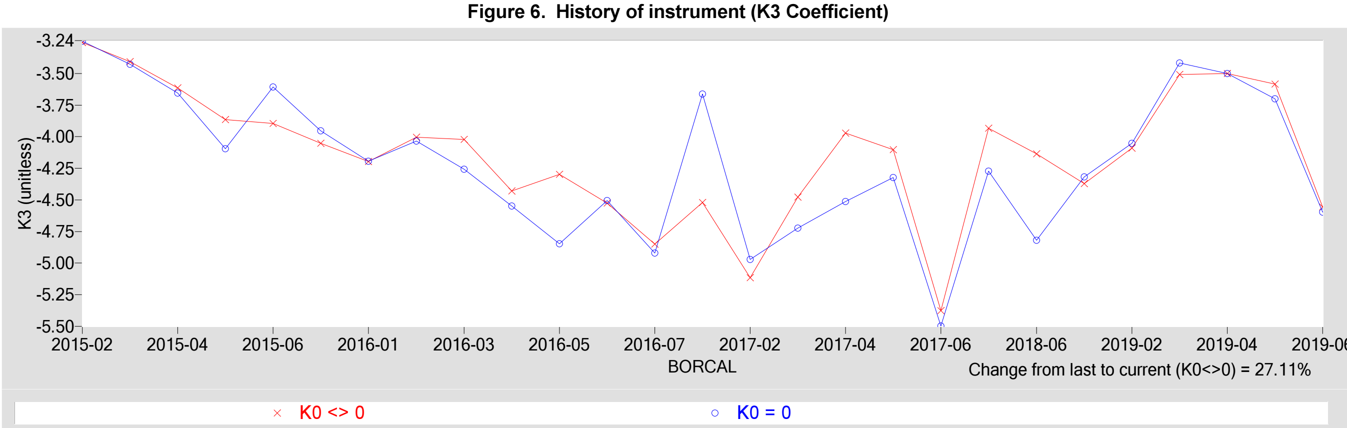


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	37325F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	AMF	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

_________________________________ _________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

37325F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \qquad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

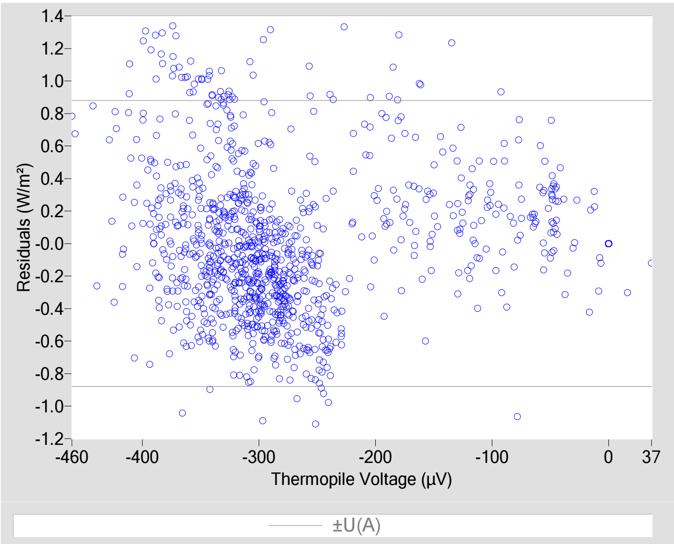


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

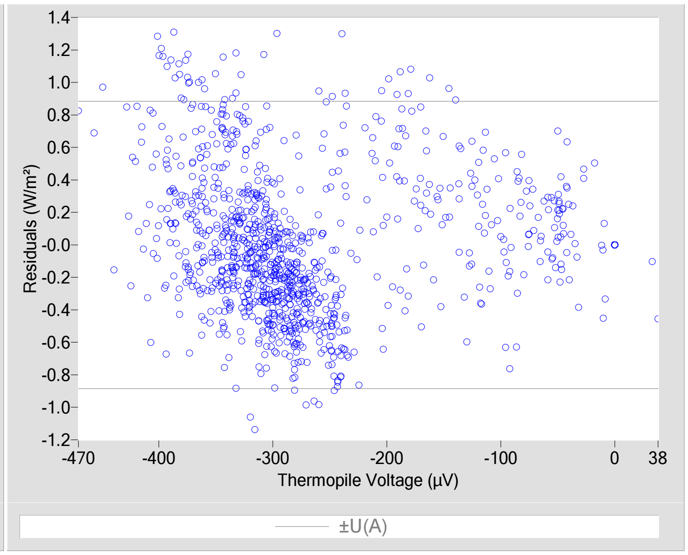


Table 2. Calibration Coefficients for K0<>0

K0	-0.6
K1	0.26269
K2	0.9985
K3	-7.32
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.26280
K2	0.9968
K3	-7.37
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.45
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.45
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

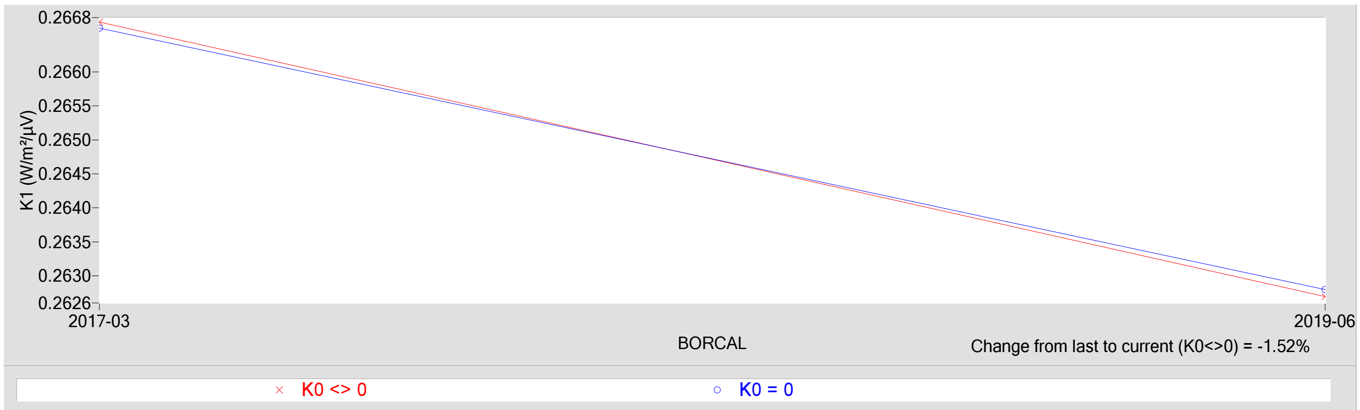


Figure 5. History of instrument (K2 Coefficient)

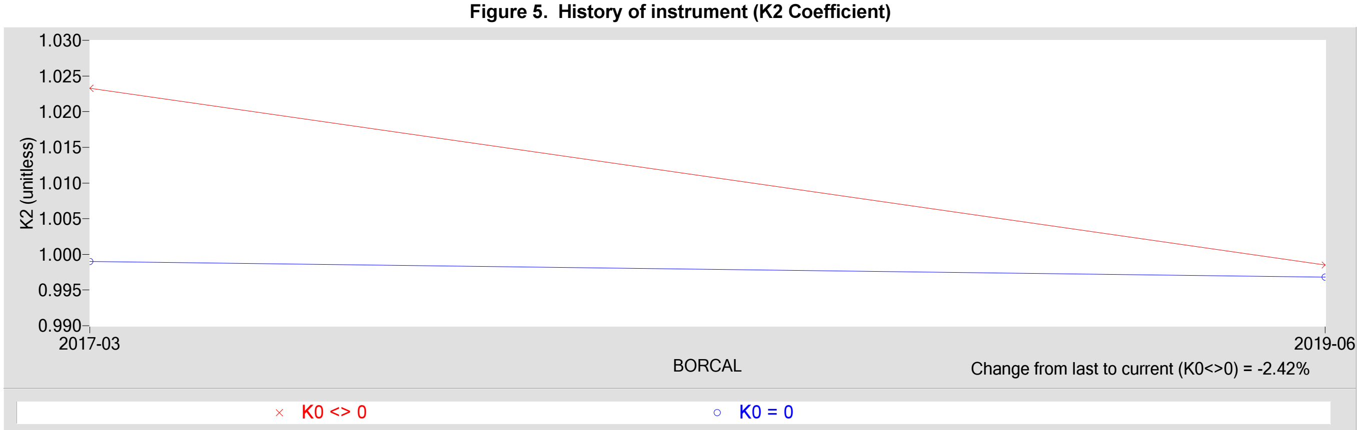
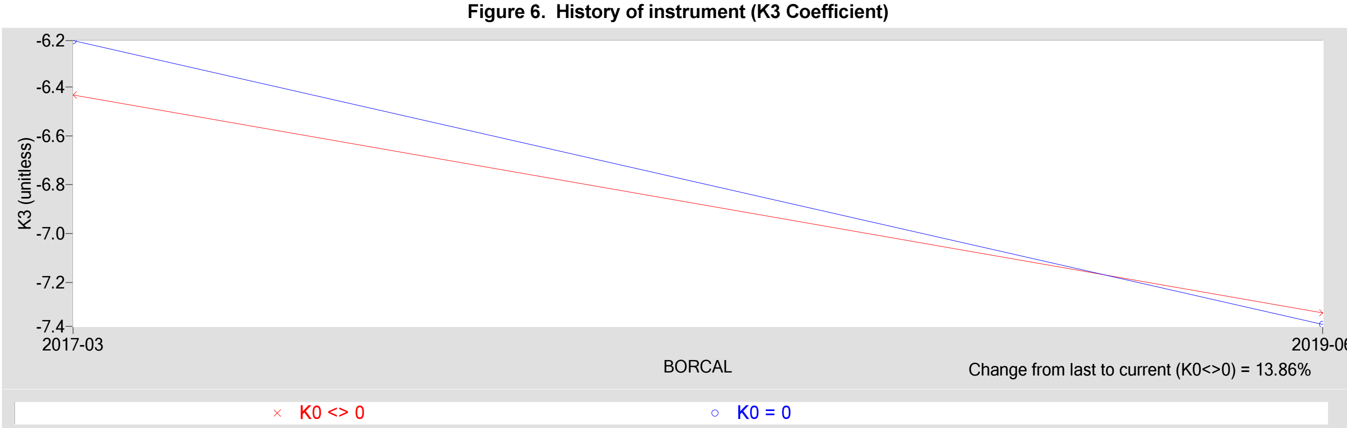


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	37327F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	AMF	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ _______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

37327F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

*Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr)* [1]

where,

K0,K1,K2,K3 = calibration coeffiECeints,
V = thermopile output voltage (µV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

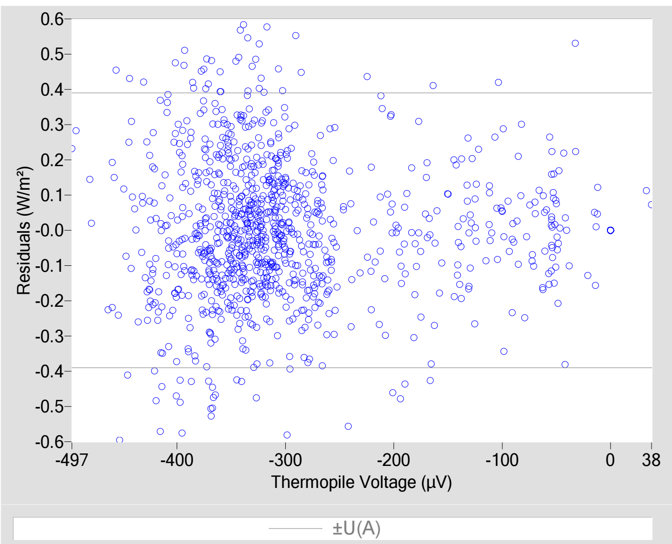


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

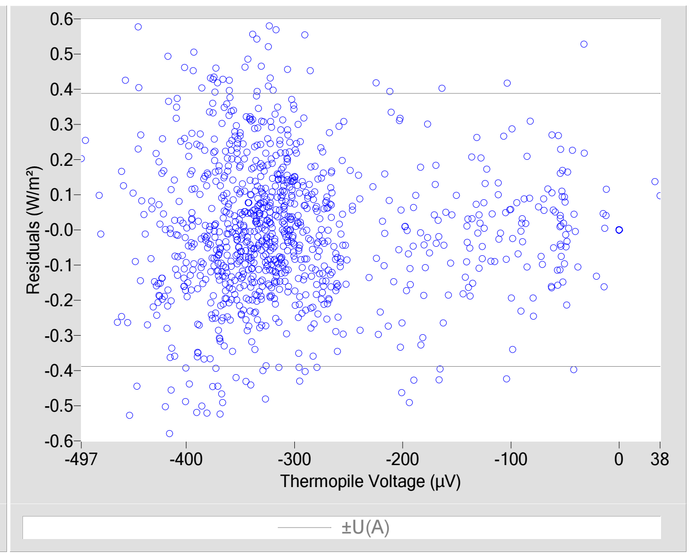


Table 2. Calibration Coefficients for K0<>0

K0	0.1
K1	0.23224
K2	0.9988
K3	-3.92
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.23221
K2	0.9992
K3	-3.94
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.20
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.20
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

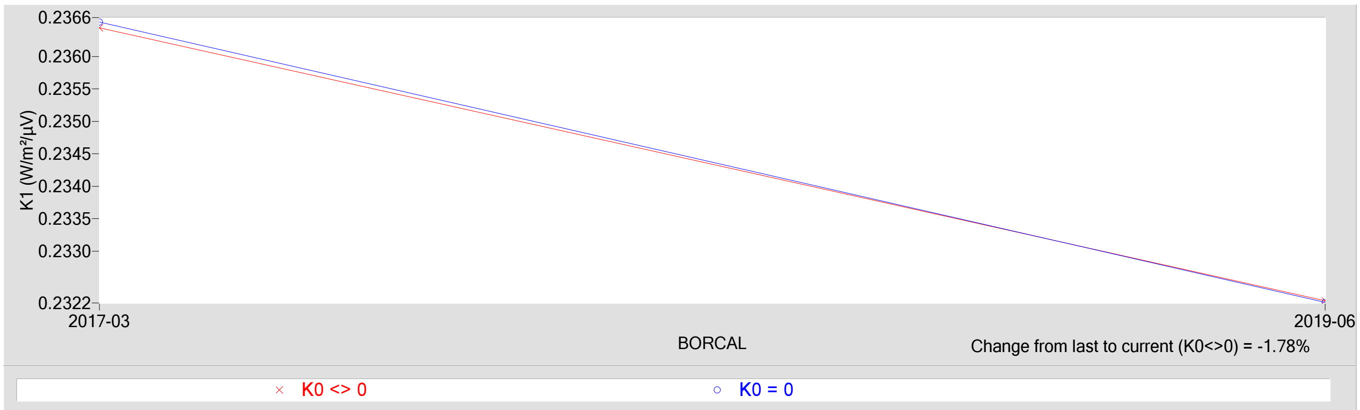


Figure 5. History of instrument (K2 Coefficient)

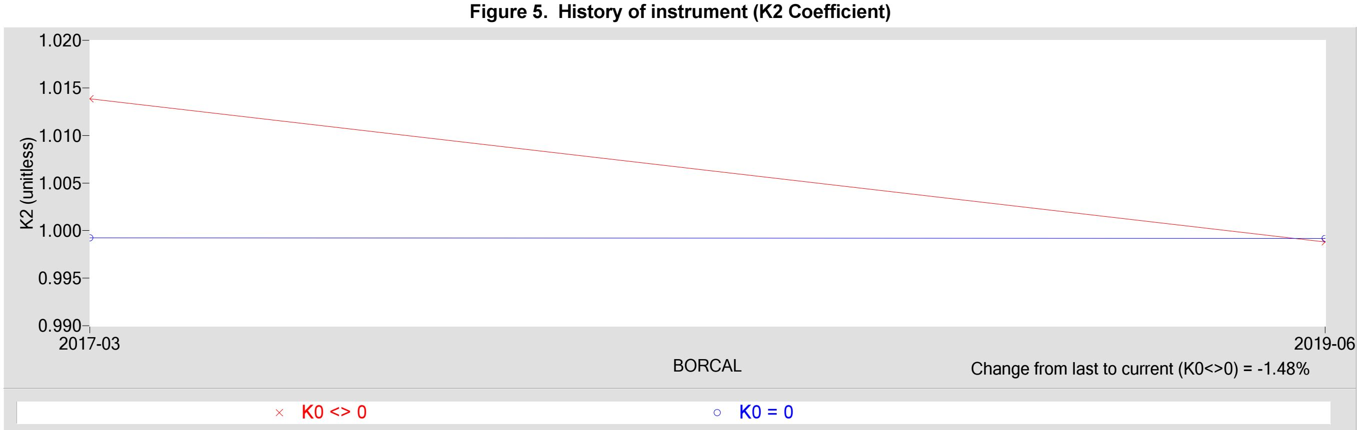
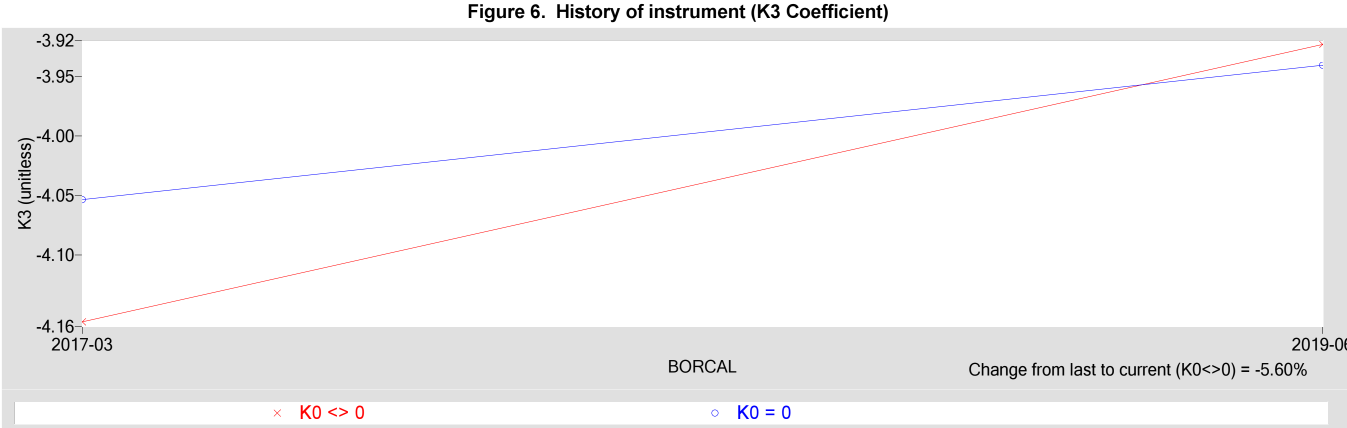


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	37332F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	AMF	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____________________________________ ________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

37332F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
Wd = σ * *Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr^4* = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

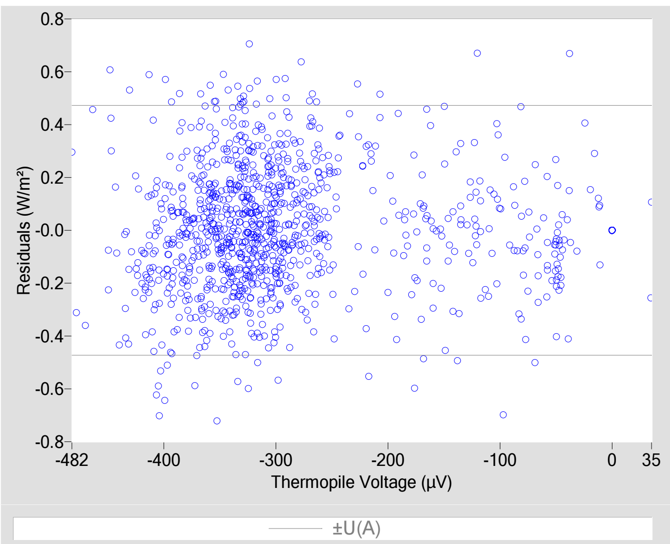


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

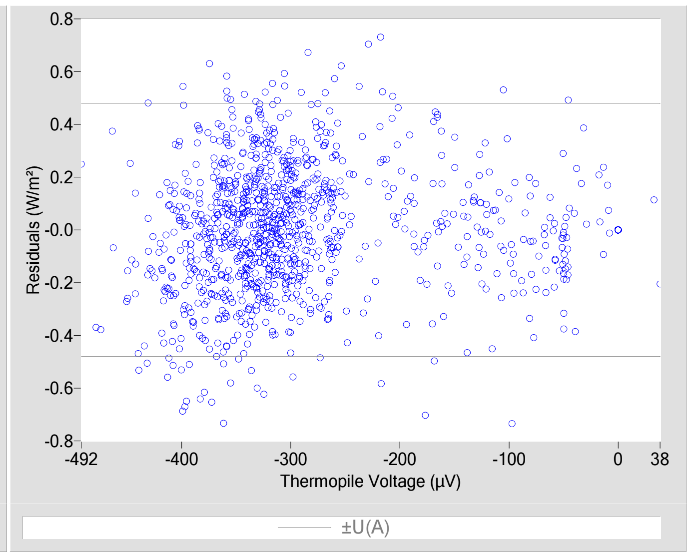


Table 2. Calibration Coefficients for K0<>0

K0	0.4
K1	0.24506
K2	1.0016
K3	-5.73
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.24493
K2	1.0027
K3	-5.70
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.24
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

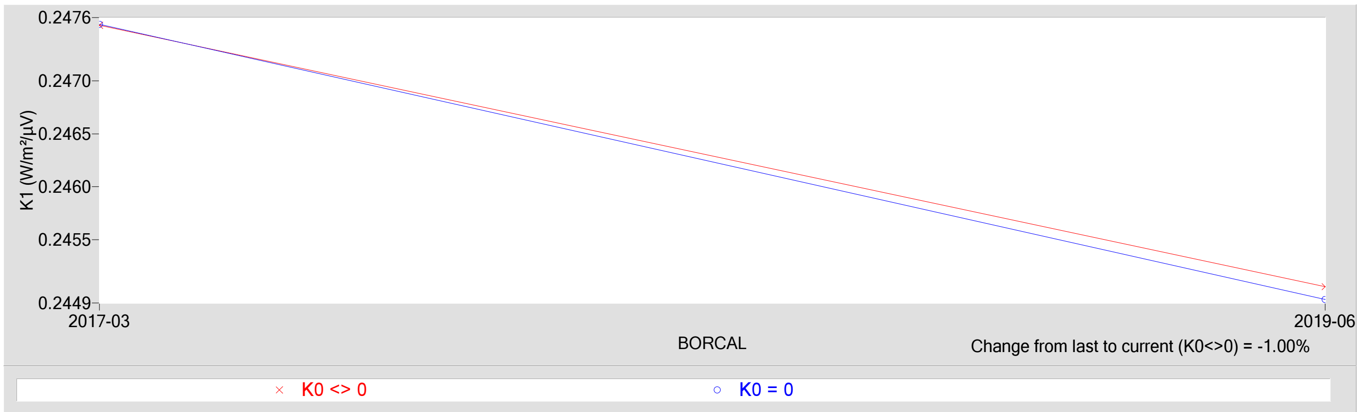


Figure 5. History of instrument (K2 Coefficient)

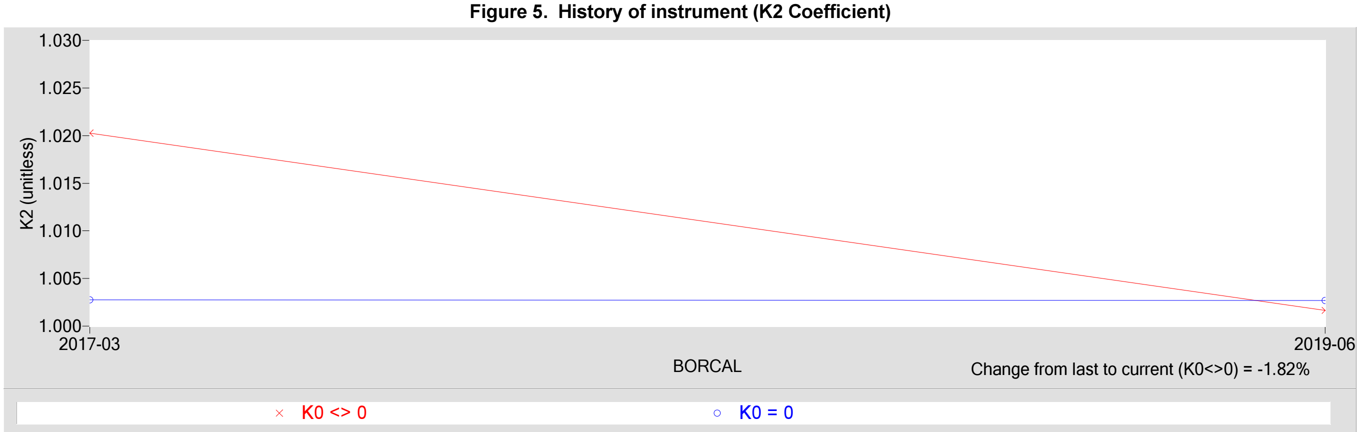
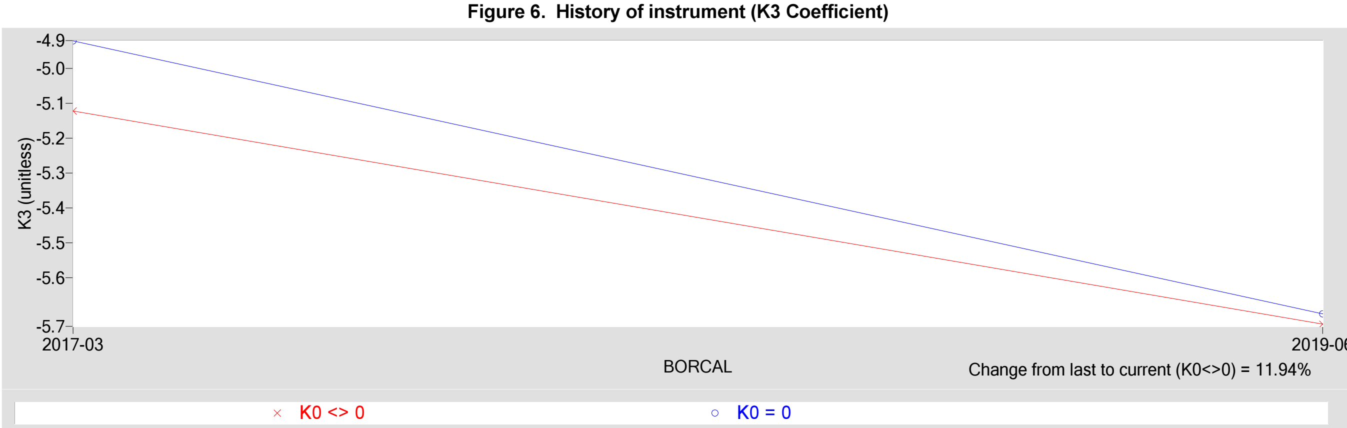


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	37334F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	NSA	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

__________________________________ ________________

Peter Gotseff, Technical Manager — Date

For questions or comments, please contact the technical manager at:

Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

37334F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
Wd = σ * *Td*^4 = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr*^4 = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

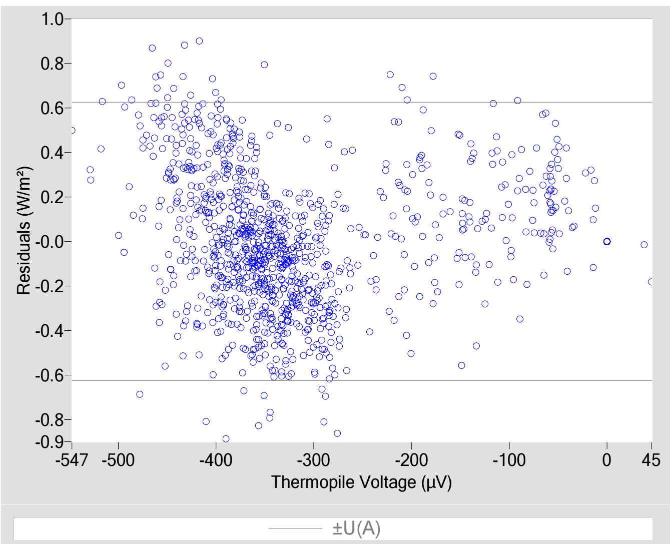


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

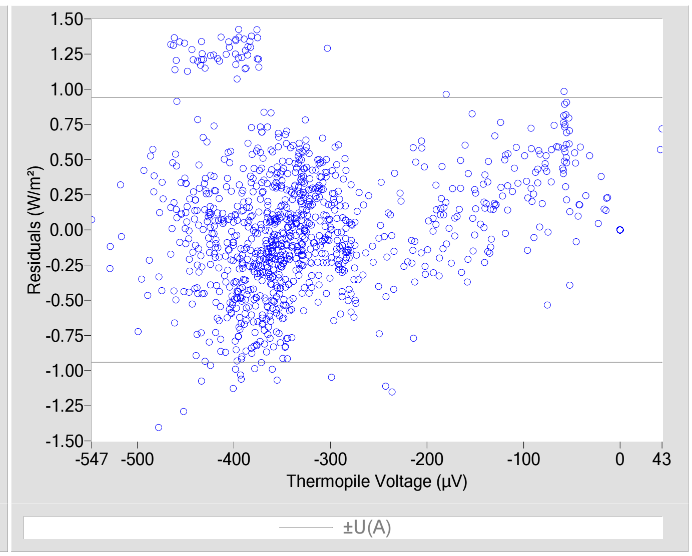


Table 2. Calibration Coefficients for K0<>0

K0	4.9
K1	0.22056
K2	0.9903
K3	-6.04
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.21899
K2	1.0029
K3	-5.15
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.32
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.48
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

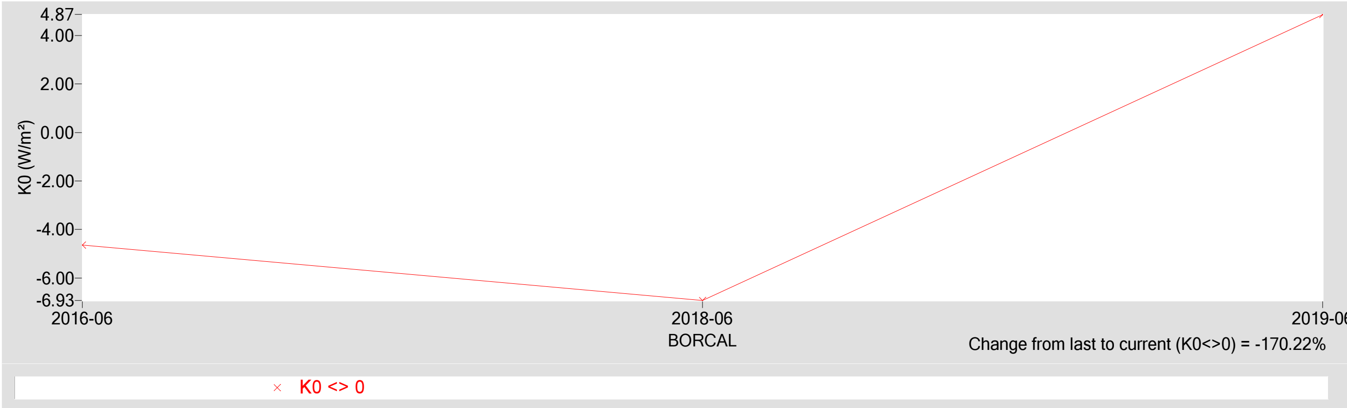


Figure 4. History of instrument (K1 Coefficient)

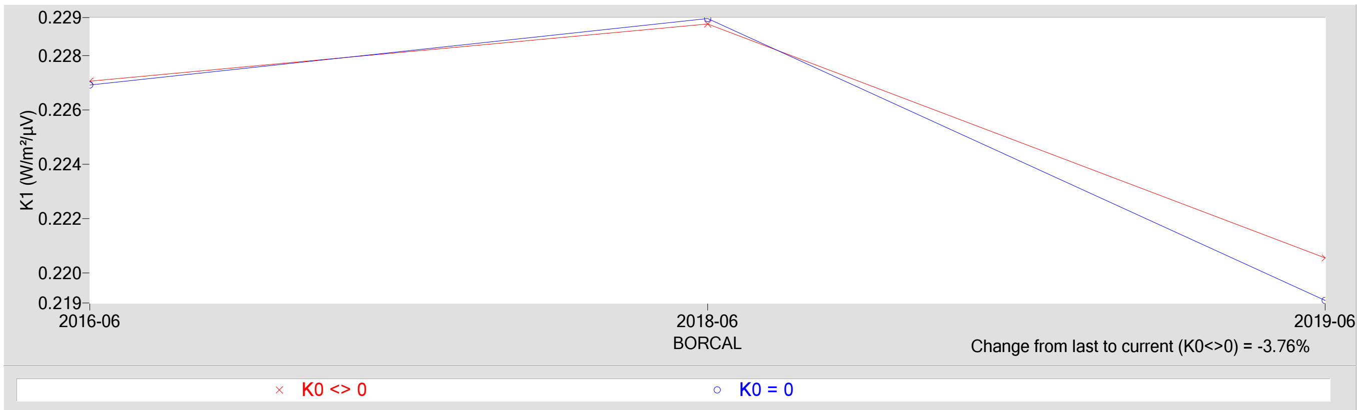


Figure 5. History of instrument (K2 Coefficient)

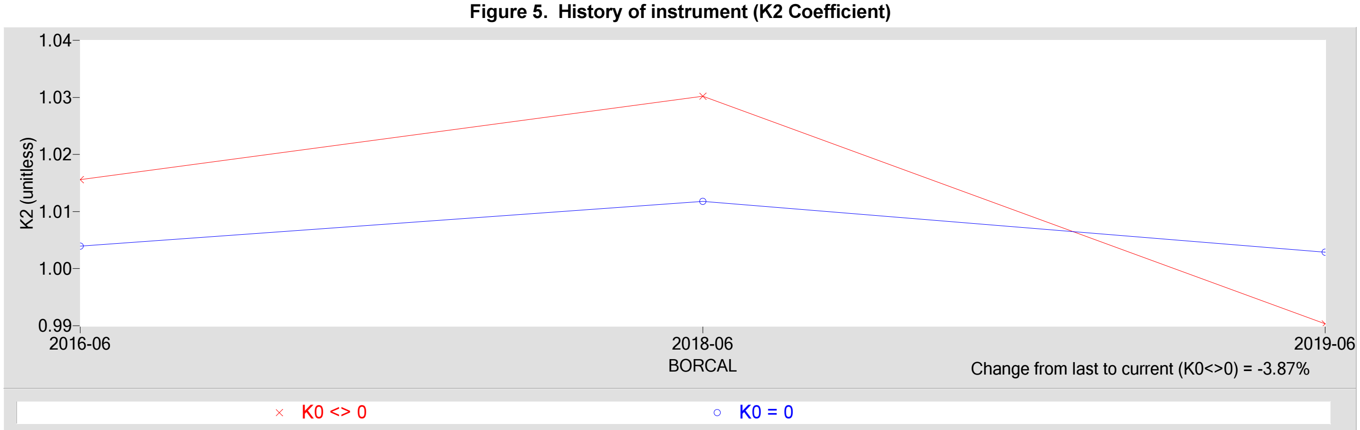
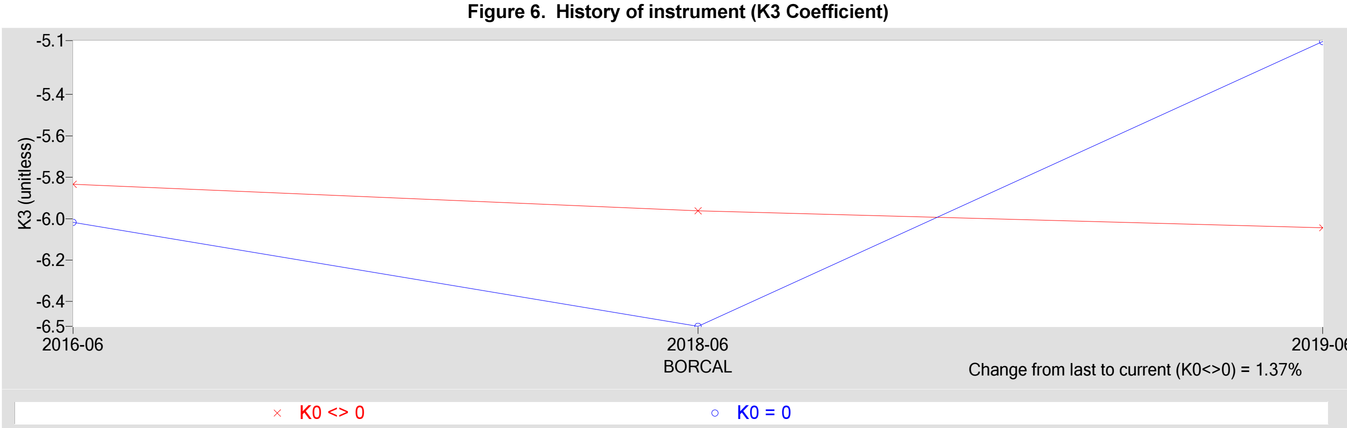


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	38865F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

________________________________ ________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

38865F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

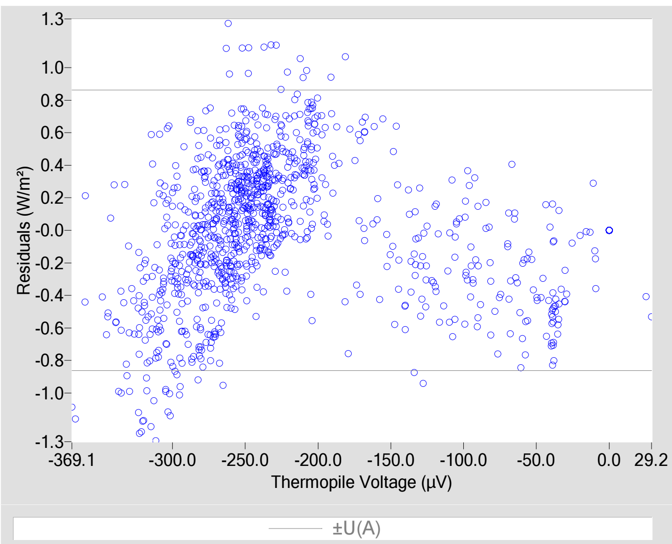


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

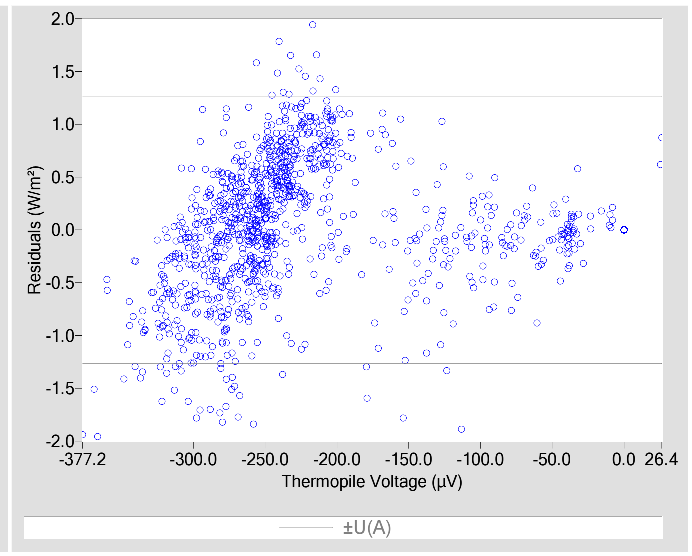


Table 2. Calibration Coefficients for K0<>0

K0	7.1
K1	0.30701
K2	0.9875
K3	-5.82
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.30562
K2	1.0052
K3	-4.19
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.44
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.65
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.2

Figure 3. History of instrument (K0 Coefficient)

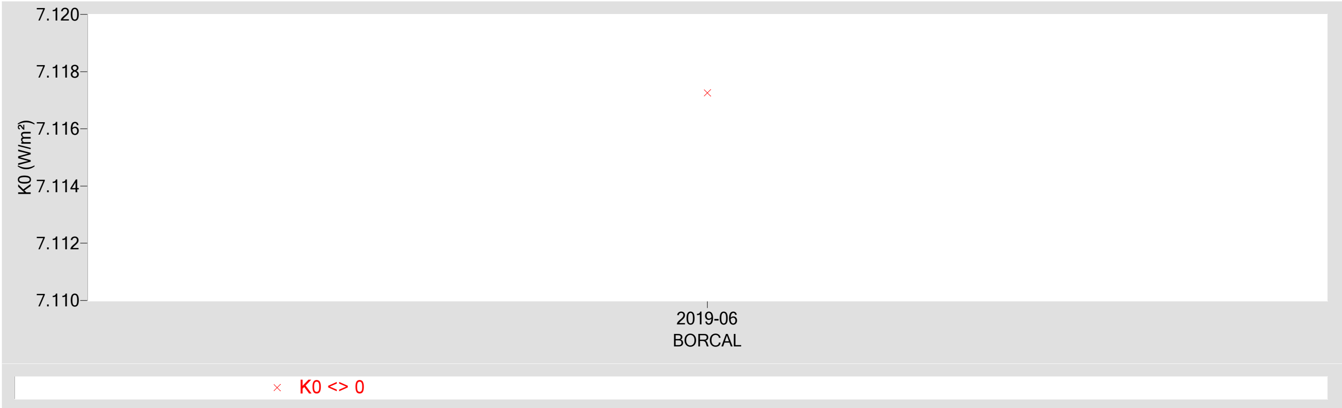


Figure 4. History of instrument (K1 Coefficient)

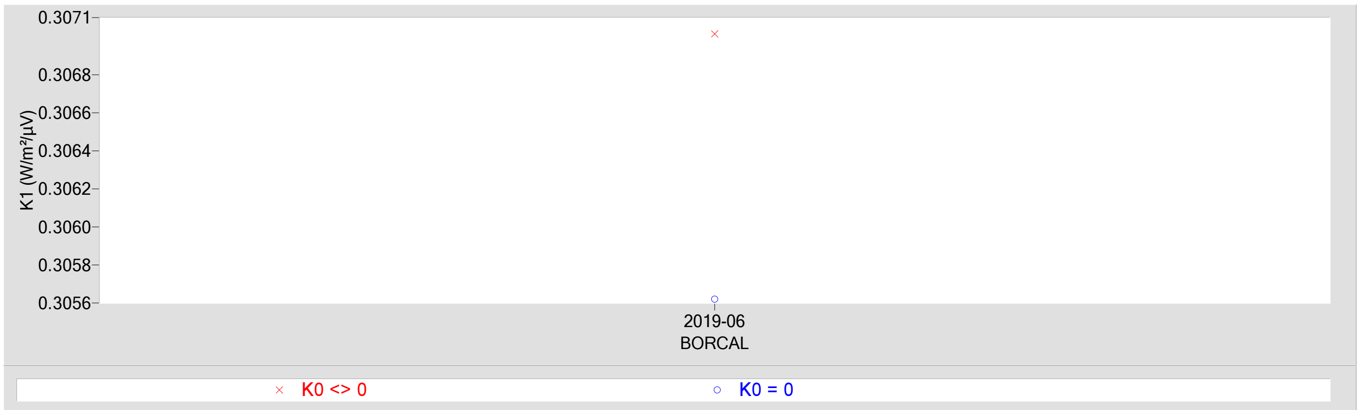


Figure 5. History of instrument (K2 Coefficient)

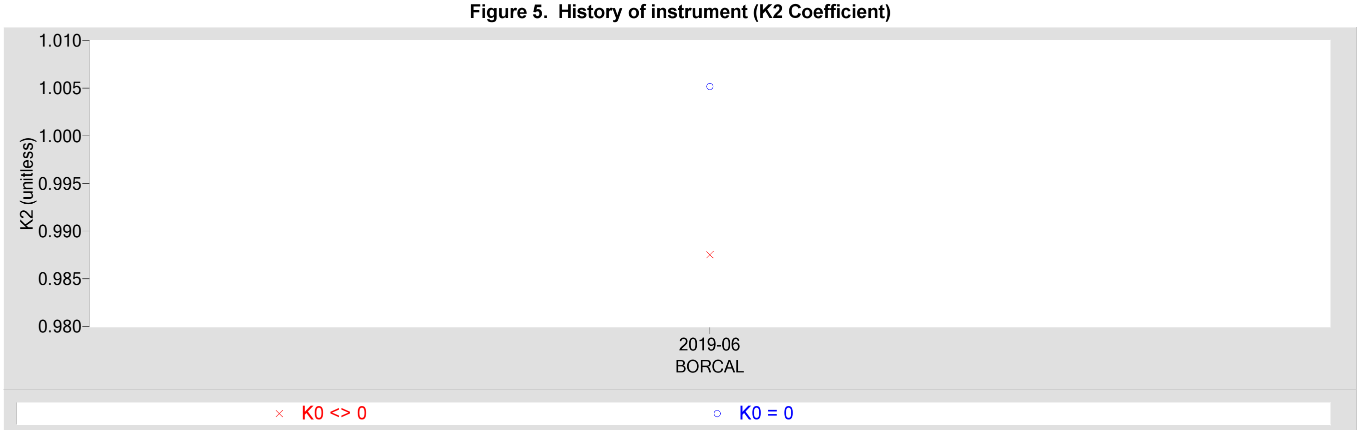
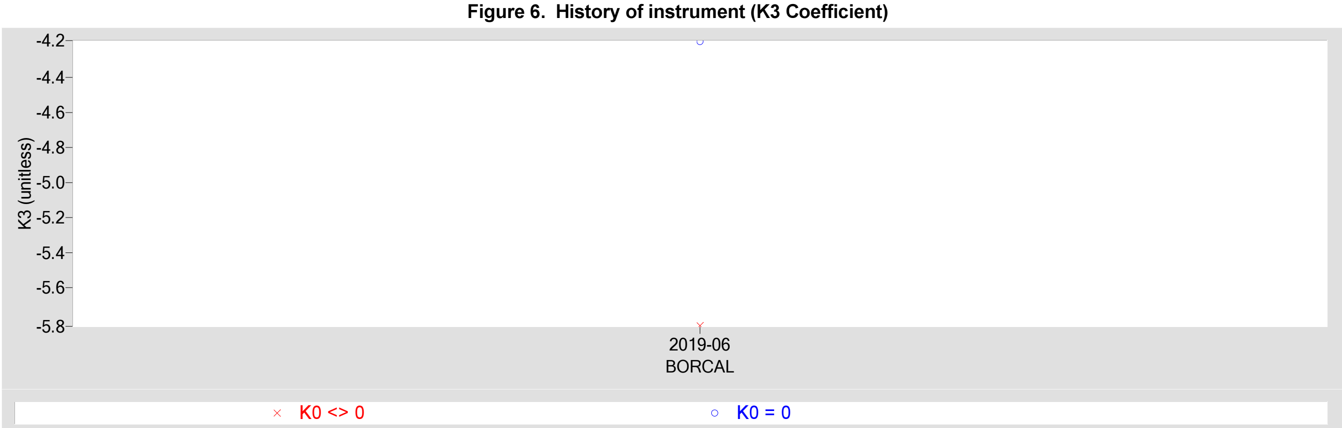


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	38866F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ______________

Peter Gotseff, Technical Manager — Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

38866F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
Wd = σ * *Td*^4 = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr*^4 = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

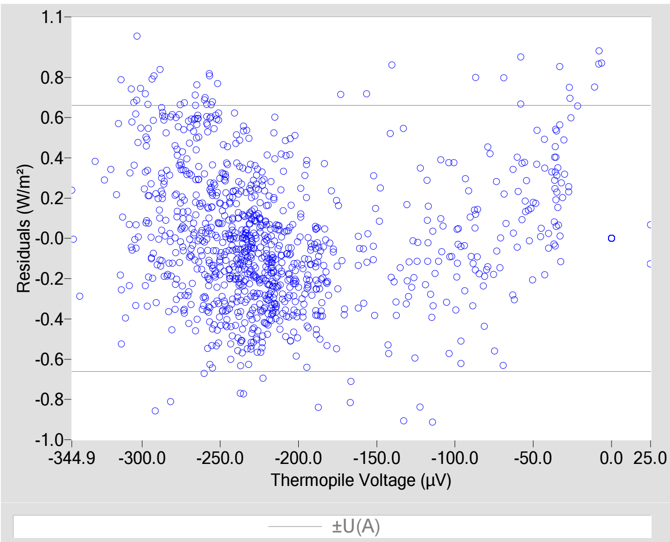


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

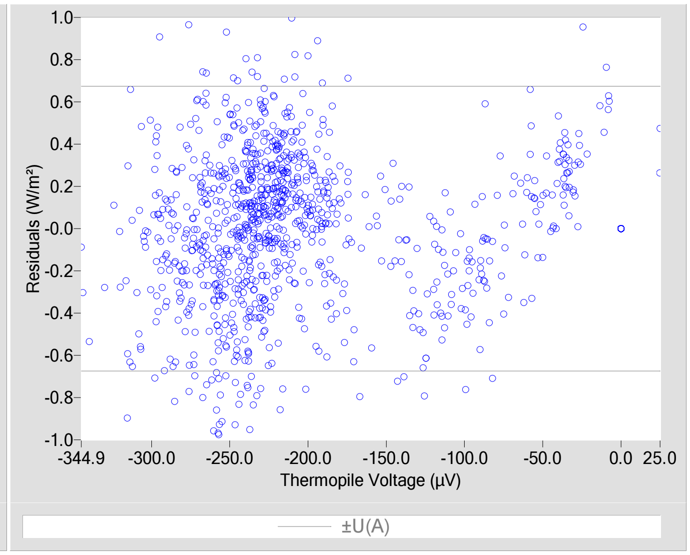


Table 2. Calibration Coefficients for K0<>0

K0	3.7
K1	0.32907
K2	0.9827
K3	-6.40
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.32960
K2	0.9935
K3	-6.40
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.34
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.34
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

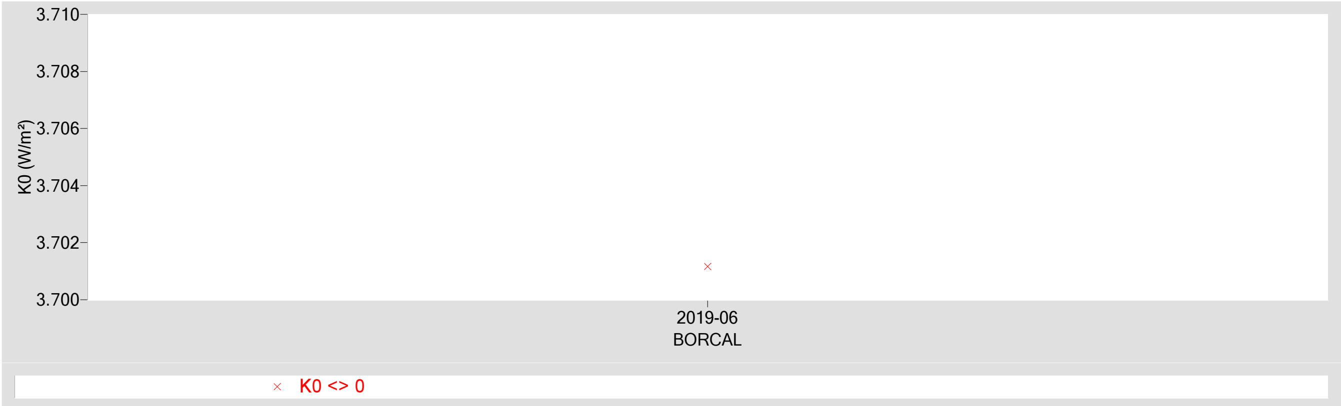


Figure 4. History of instrument (K1 Coefficient)

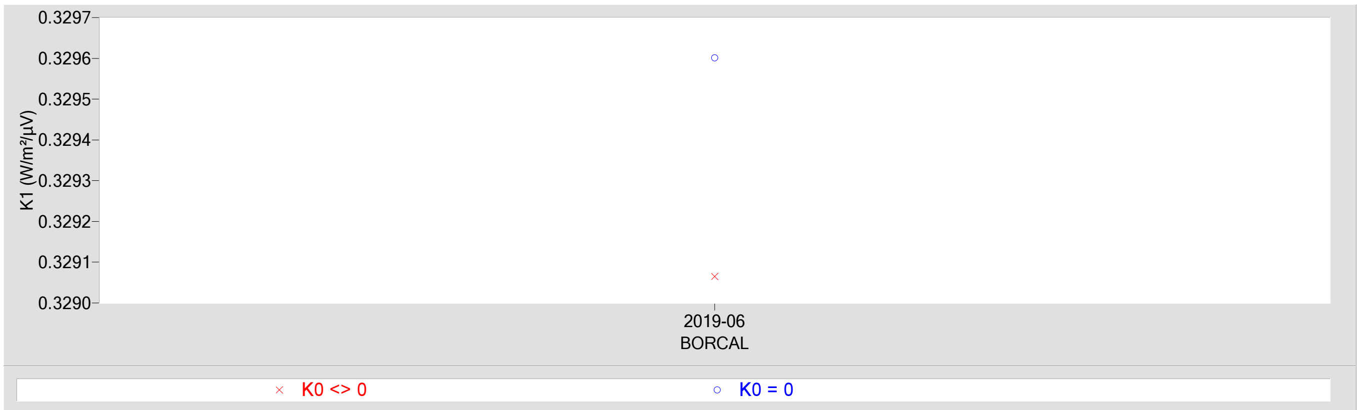


Figure 5. History of instrument (K2 Coefficient)

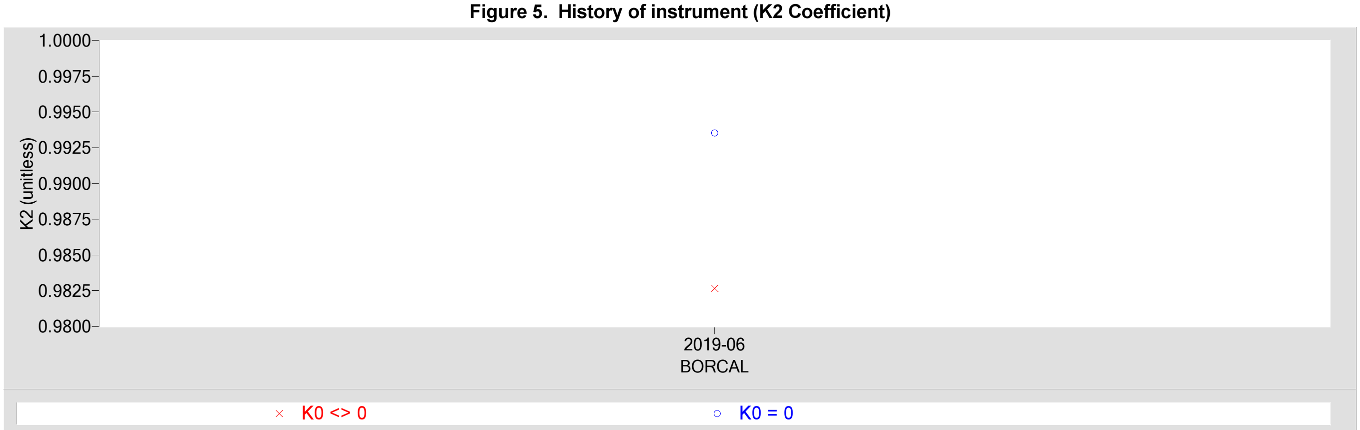
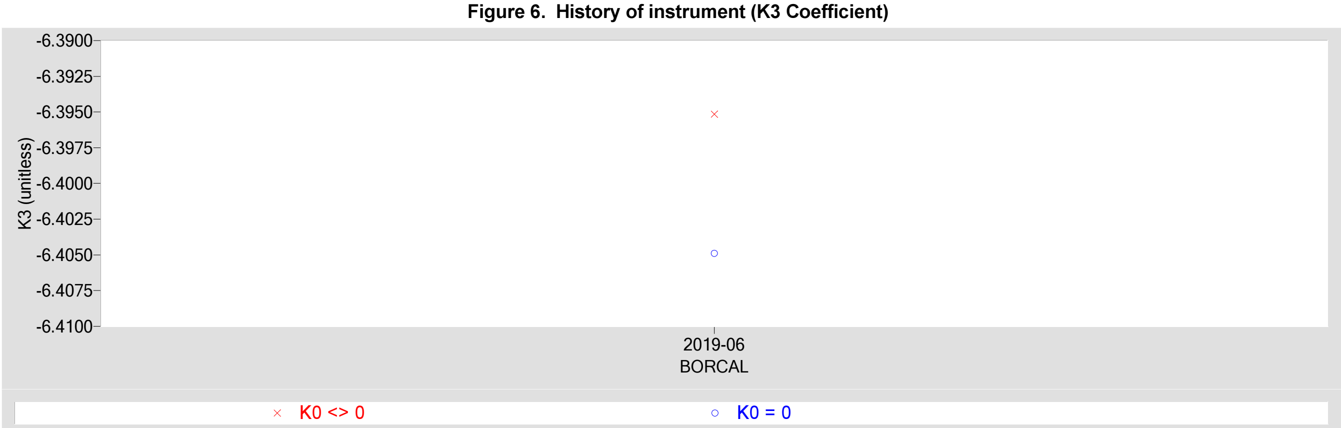


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	38867F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ _______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

38867F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

*Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr)* [1]

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
*Wd = σ * Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

*Wr = σ * Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
*Tr = Tc + Kr * V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

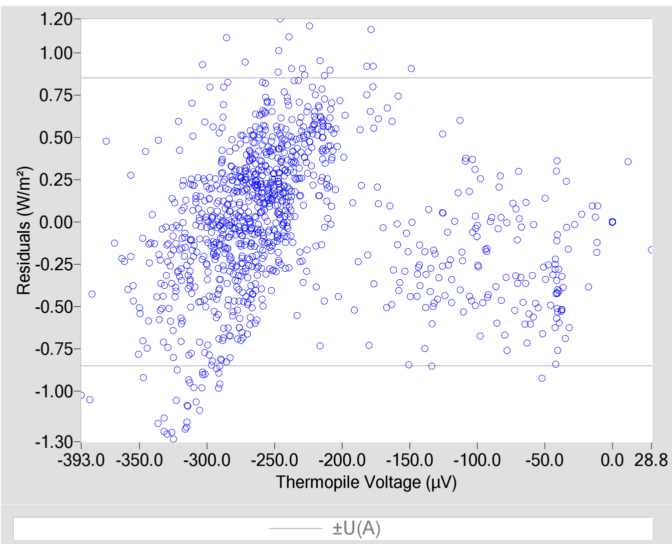


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

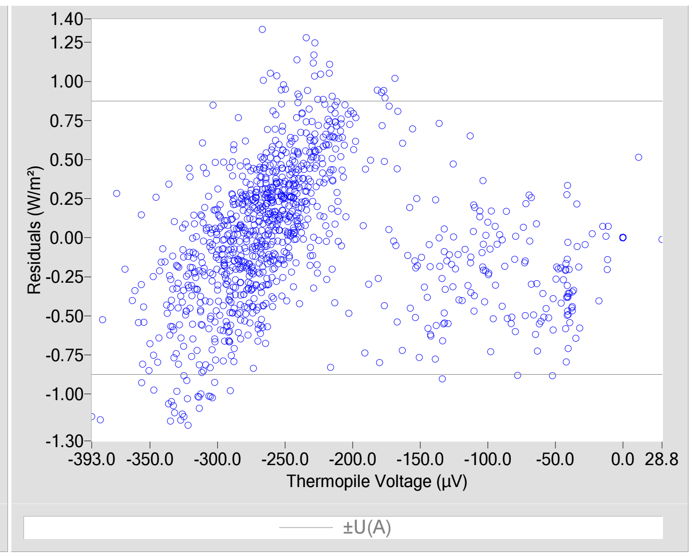


Table 2. Calibration Coefficients for K0<>0

K0	0.9
K1	0.29324
K2	0.9917
K3	-5.40
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.29311
K2	0.9943
K3	-5.37
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.43
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.45
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

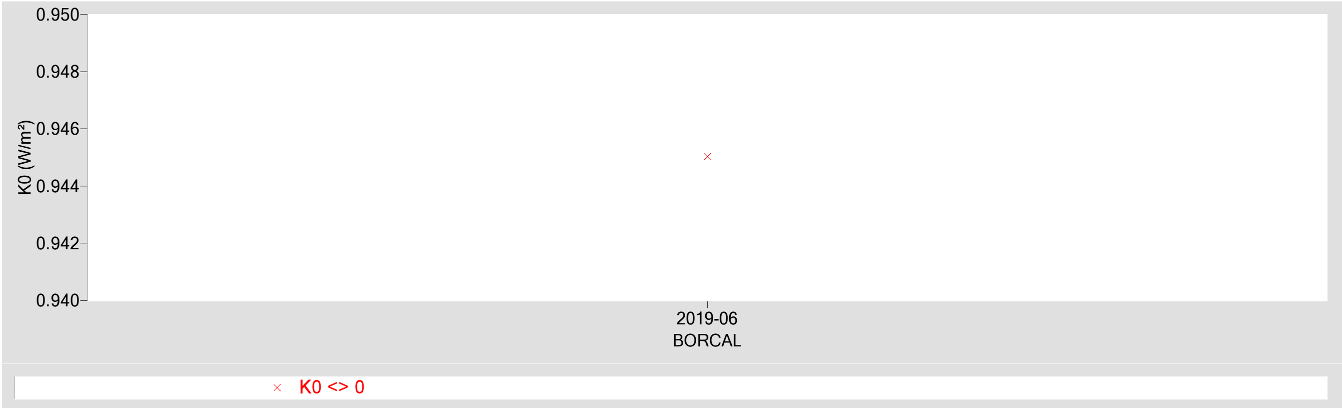


Figure 4. History of instrument (K1 Coefficient)

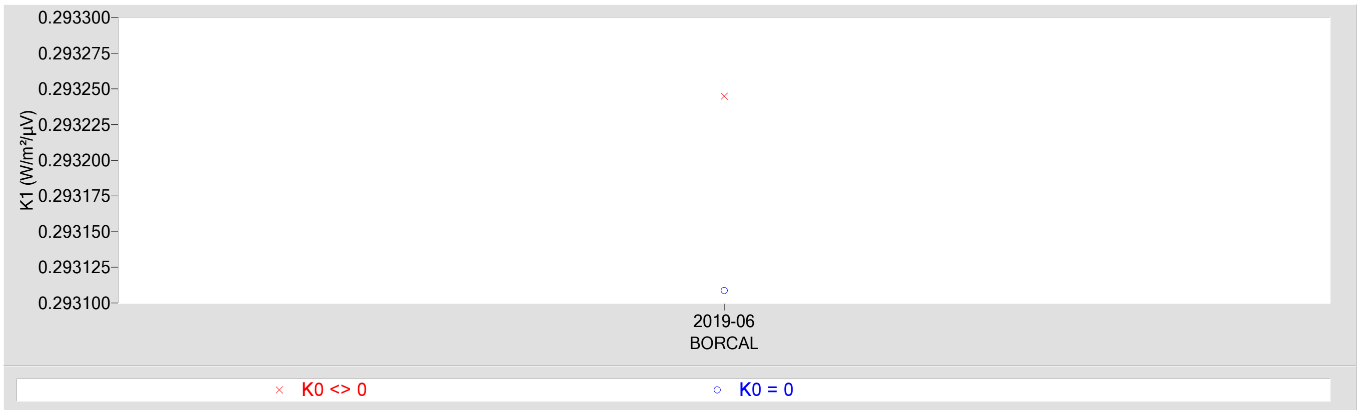


Figure 5. History of instrument (K2 Coefficient)

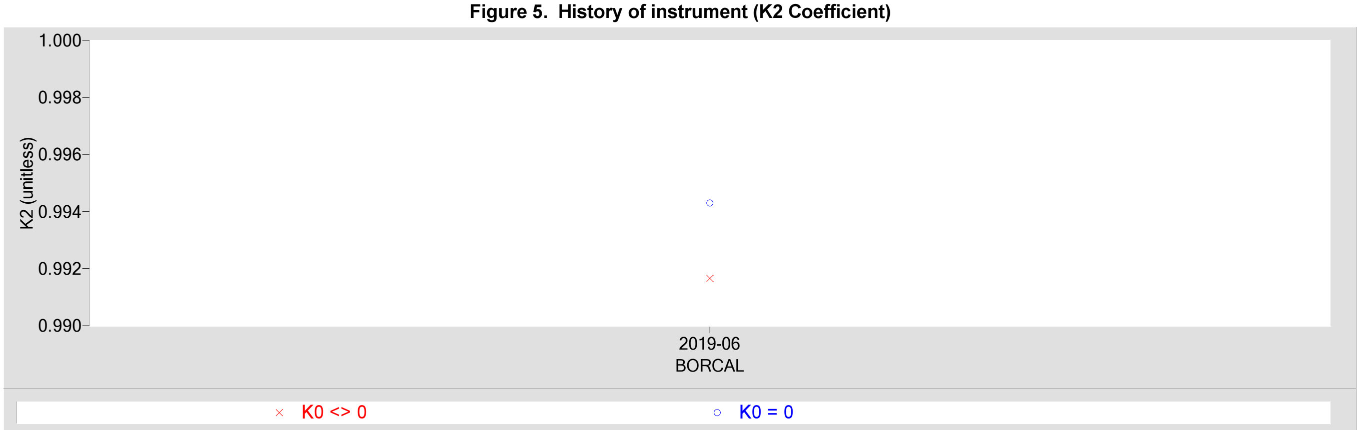
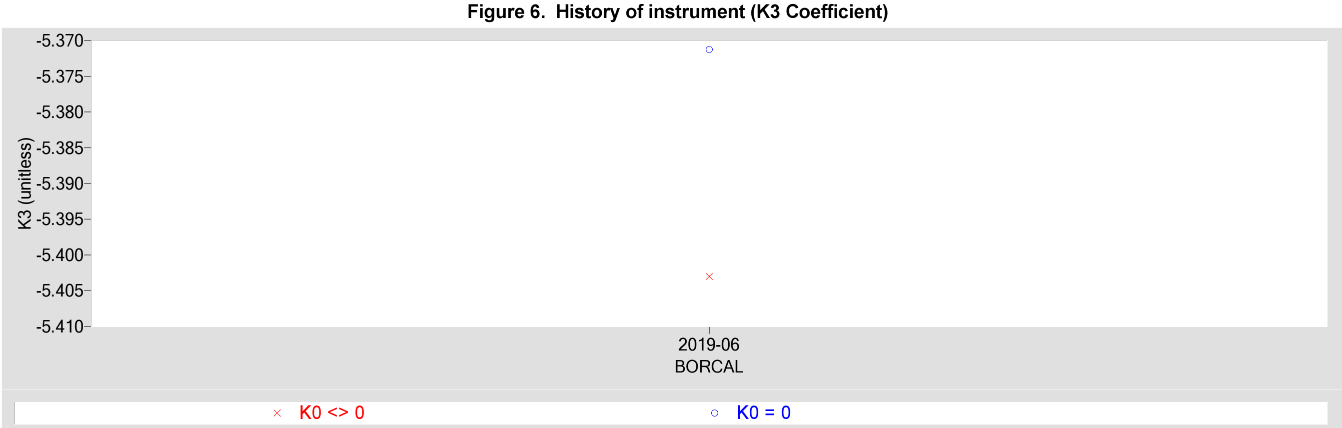


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	38868F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

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Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____ ____________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

38868F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (μV),
Wd = *σ* * *Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = *σ* * *Tr^4* = receiver irradiance (W/m²),
where, *σ* = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/μV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

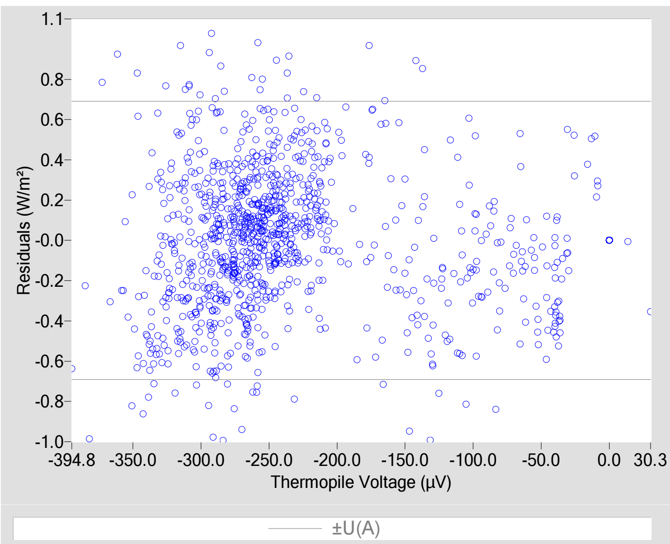


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

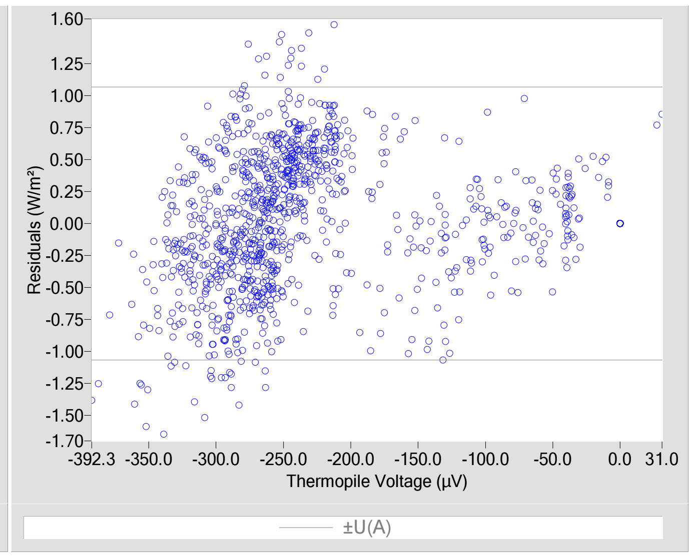


Table 2. Calibration Coefficients for K0<>0

K0	5.4
K1	0.29589
K2	0.9843
K3	-6.11
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.29418
K2	0.9992
K3	-5.04
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.35
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.54
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

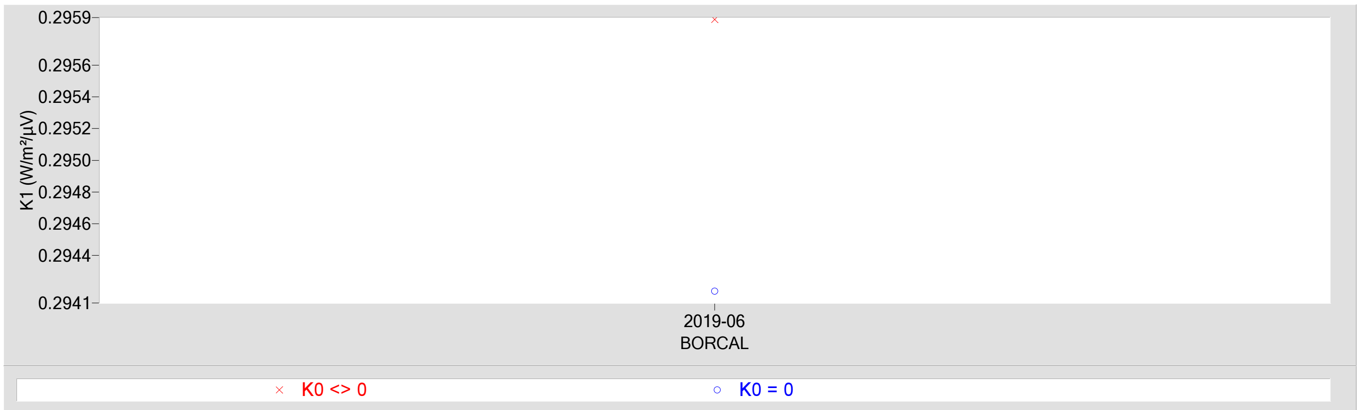


Figure 5. History of instrument (K2 Coefficient)

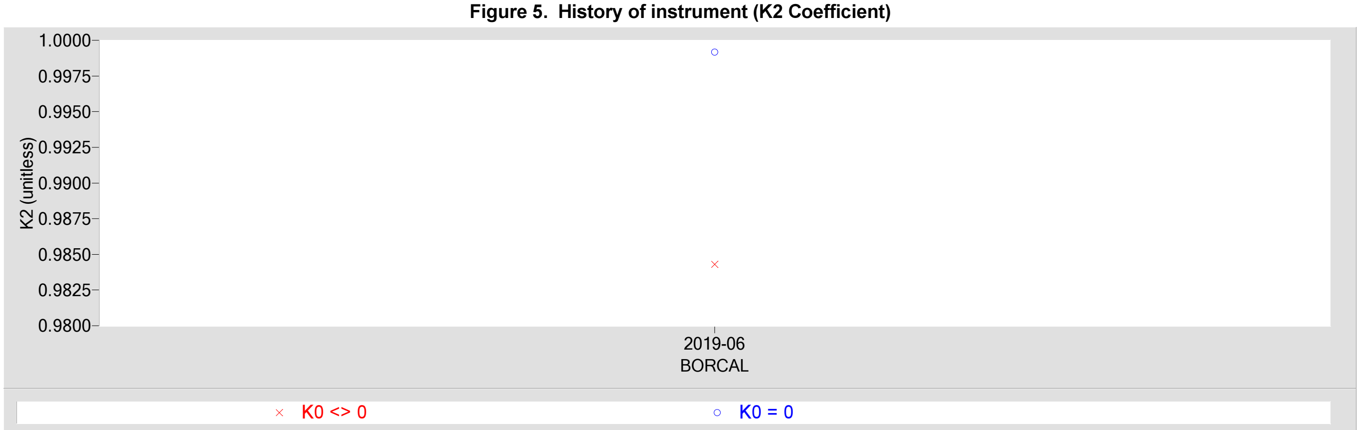
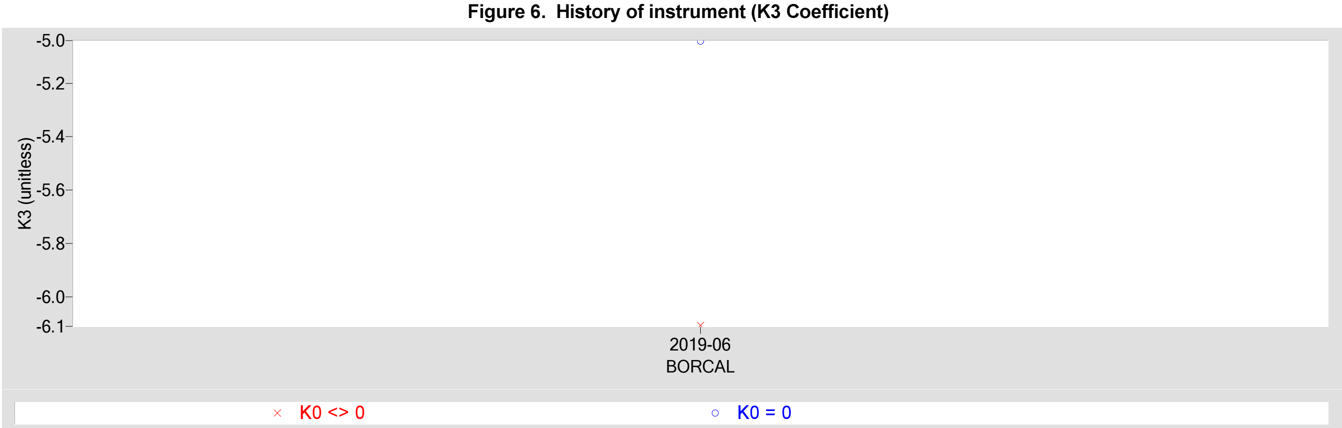


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	38869F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

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Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

____ ____________________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

38869F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

$K0, K1, K2, K3$ = calibration coefficeints,
V = thermopile output voltage (µV),
$Wd = \sigma * Td^4$ = dome irradiance (W/m²),
where, Td = dome temperature (K),

$Wr = \sigma * Tr^4$ = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
$Tr = Tc + Kr * V$ = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

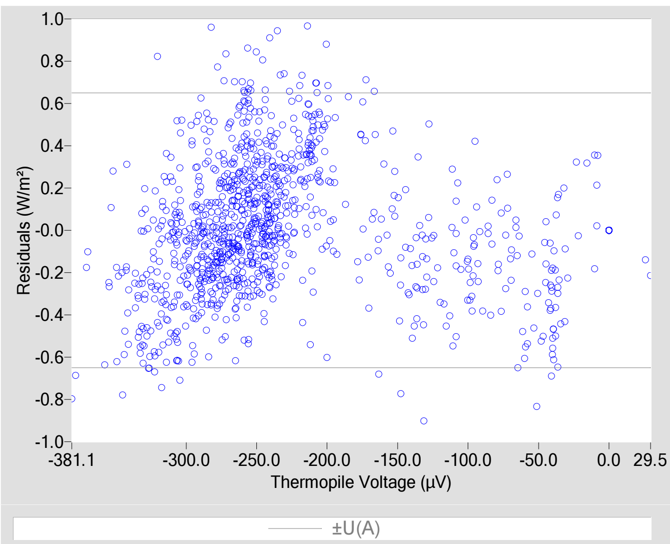


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

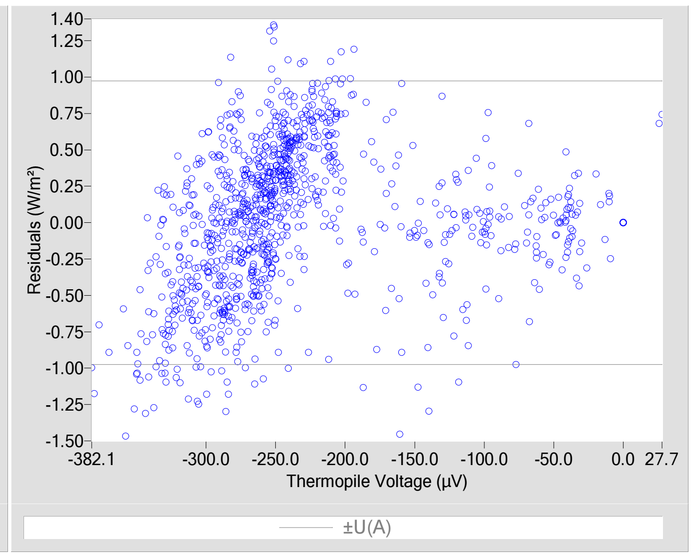


Table 2. Calibration Coefficients for K0<>0

K0	4.9
K1	0.29758
K2	0.9871
K3	-5.41
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.29656
K2	1.0002
K3	-4.79
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.33
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.50
Combined Standard Uncertainty, u(c) (W/m²)	±1.6
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.1

Figure 3. History of instrument (K0 Coefficient)

Figure 4. History of instrument (K1 Coefficient)

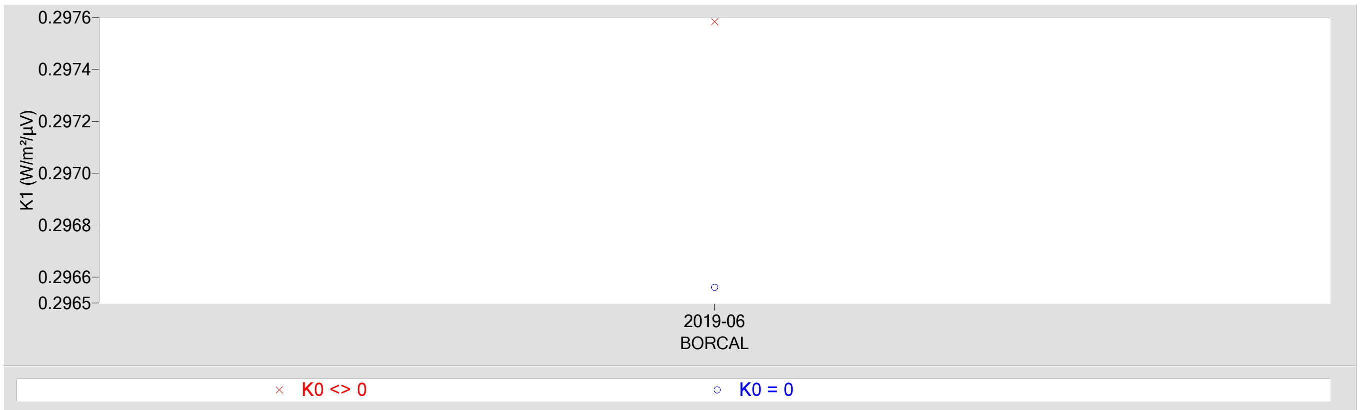


Figure 5. History of instrument (K2 Coefficient)

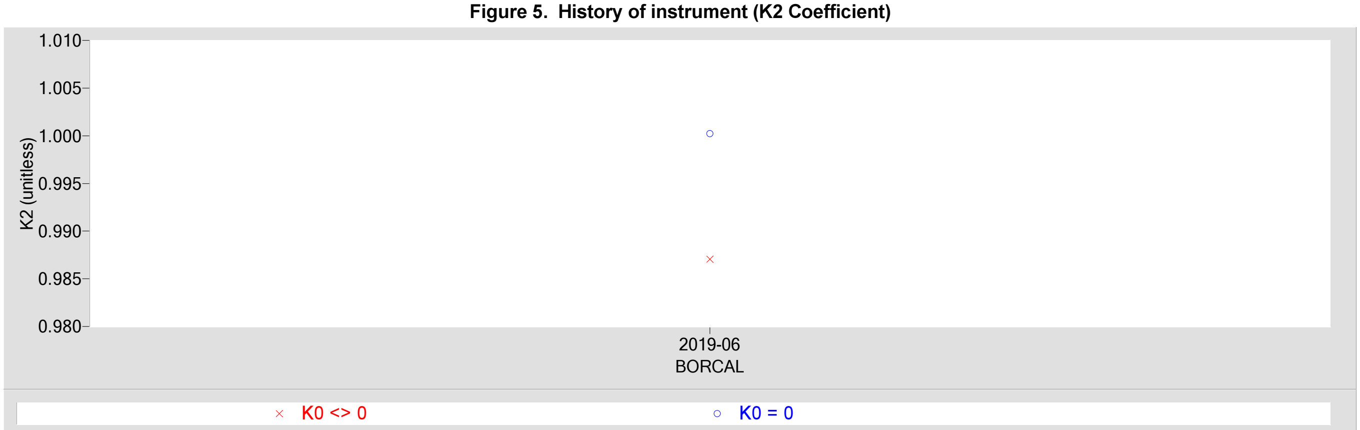
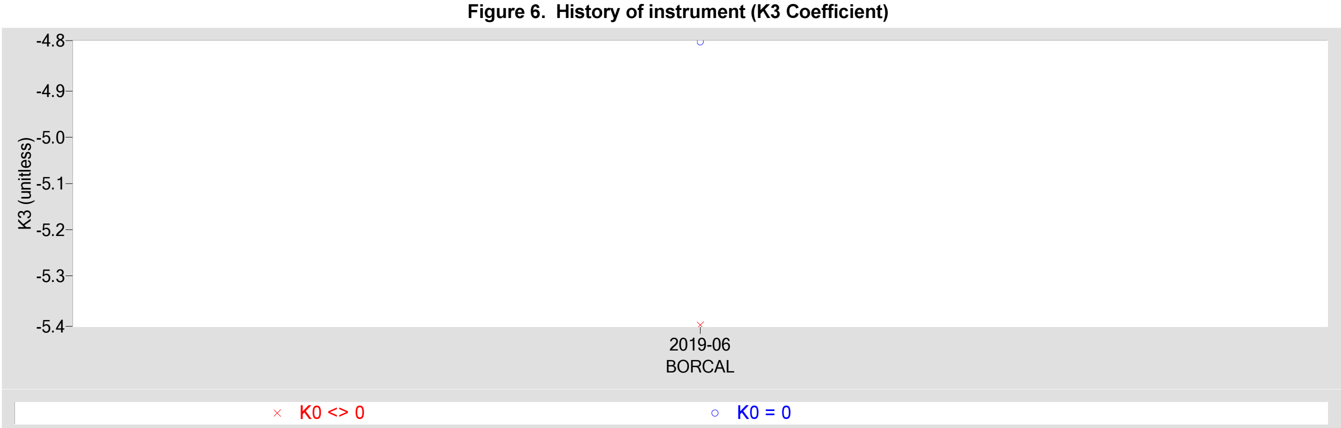


Figure 6. History of instrument (K3 Coefficient)



References:

[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Southern Great Plains Radiometer Calibration Facility

National Renewable Energy Laboratory

Metrology Laboratory

Calibration Certificate

Test Instrument:	Downwelling Pyrgeometer (Ventilated)	**Manufacturer:**	Eppley
Model:	PIR	**Serial Number:**	38870F3
Calibration Date:	11/18/2019	**Due Date:**	11/18/2020
Customer:	SGP	**Environmental Conditions:**	see page 4
Test Dates:	10/10-18, 10/20-24, 10/26-29, 11/1-3, 11/5-18		

This certifies that the above product was calibrated in compliance with procedure listed below. Measurement uncertainties at the time of calibration are consistent with the Guide to the Expression of Uncertainty in Measurement (GUM) using Reda et al., 2008. All nominal values are traceable to the World Infrared Standard Group (WISG).

No statement of compliance with specifications is made or implied on this certificate. However, the estimated uncertainties are the uncertainties of the calibration process; users must add other uncertainties that are relevant to their measuring system, environmental and sky conditions, outdoor set-up, and site location.

This certificate applies only to the item identified above and shall not be reproduced other that in full, without specific written approval from the calibration facility. Certificate without signature is not valid.

Table 1. Traceability

Measurement Type	Instrument	Calibration Date	Calibration Due Date
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1206	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1207	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2009-1208	01/10/2019	01/10/2020
Data Acquisition	NREL Data Acquisition System Model RAP-DAQ, S/N 2014-1302	01/10/2019	01/10/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31206F3	04/16/2018	04/16/2020
Infrared Irradiance ‡	Eppley Downwelling Pyrgeometer Model PIR, S/N 31237F3	04/16/2018	04/16/2020

‡ Through the World Infrared Standard Group (WISG)

Number of pages of certificate: 4

Calibration Procedure: SGP BORCAL-LW Calibration Procedure

Setup: Radiometers are calibrated outdoors, using the atmosphere as the source. Pyranometers and pyrgeometers are installed for horizontal measurements, with their signal connectors oriented north, if their design permits.

Calibrated by: Peter Gotseff and Craig Webb

______________________________ ______________

Peter Gotseff, Technical Manager Date

For questions or comments, please contact the technical manager at:
Peter.Gotseff@nrel.gov; 303-384-6327; 15013 Denver West Parkway, Golden, CO 80401, USA

Calibration Results

38870F3 Eppley PIR

The incoming irradiance (Win, W/m²) of the test instrument during calibration is calculated using this Measurement Equation:

$$Win = K0 + K1*V + K2*Wr + K3*(Wd - Wr) \quad [1]$$

where,

K0,K1,K2,K3 = calibration coefficeints,
V = thermopile output voltage (µV),
Wd = σ * *Td^4* = dome irradiance (W/m²),
where, *Td* = dome temperature (K),

Wr = σ * *Tr^4* = receiver irradiance (W/m²),
where, σ = 5.6704e-8 W·m-2·K-4,
Tr = *Tc* + *Kr* * *V* = receiver temperature (K),
Tc = case temperature (K),
Kr = efficiency coefficient (K/µV).

Figure 1. Residuals for calc. vs ref. irradiance using K0<>0 Coefficients

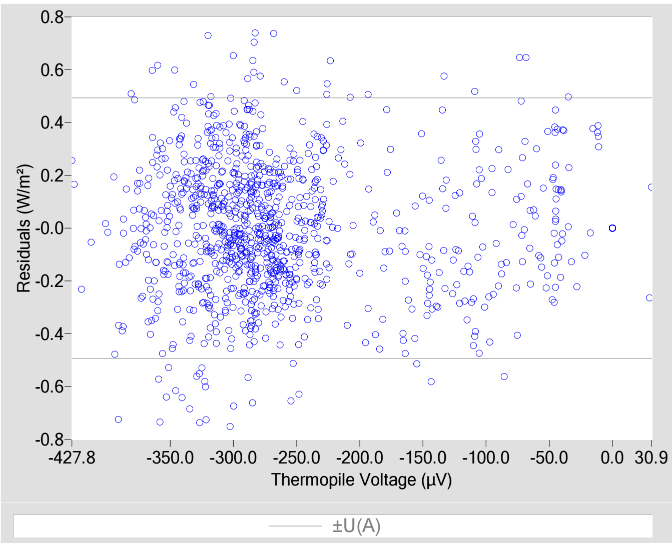


Figure 2. Residuals for calc. vs ref. irradiance using K0=0 Coefficients

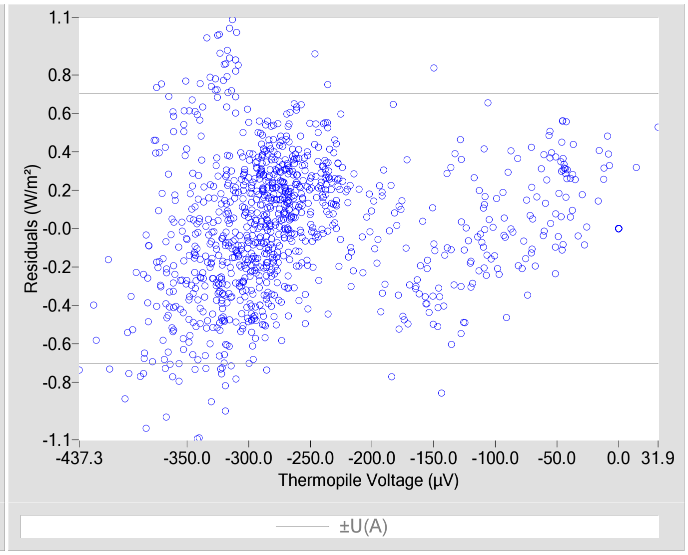


Table 2. Calibration Coefficients for K0<>0

K0	3.2
K1	0.26446
K2	0.9855
K3	-4.69
Kr used to derive coefficients	7.044e-4

Table 3. Calibration Coefficients for K0=0

K0	0.0
K1	0.26379
K2	0.9942
K3	-4.58
Kr used to derive coefficients	7.044e-4

Table 4. Uncertainty using K0<>0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.25
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Table 5. Uncertainty using K0=0 Coefficients

Type-B Standard Uncertainty, u(B) (W/m²)	±1.5
Type-A Standard Uncertainty, u(A) (W/m²)	±0.36
Combined Standard Uncertainty, u(c) (W/m²)	±1.5
Effective degrees of freedom, DF(c)	+Inf
Coverage factor, k	1.96
Expanded Uncertainty, U95 (W/m²)	±3.0

Figure 3. History of instrument (K0 Coefficient)

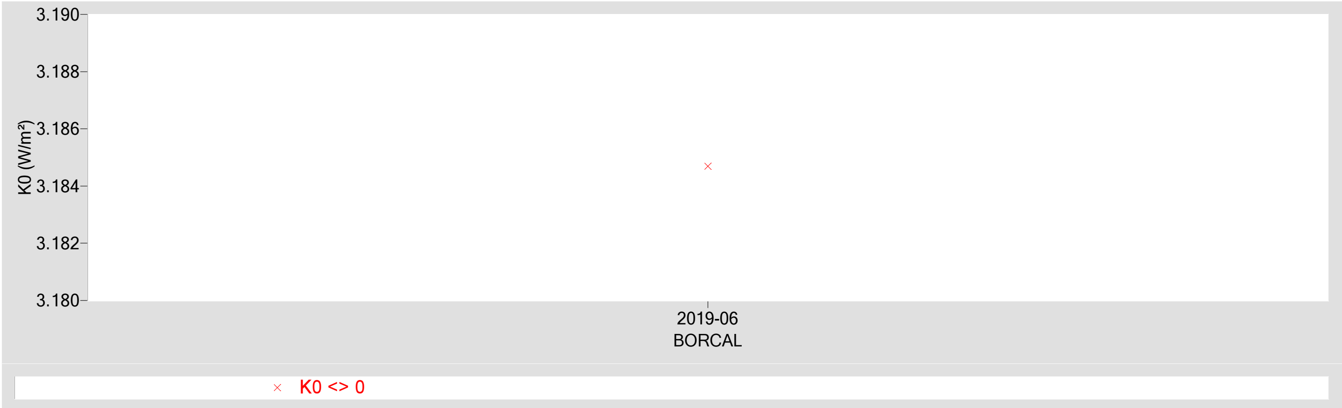


Figure 4. History of instrument (K1 Coefficient)

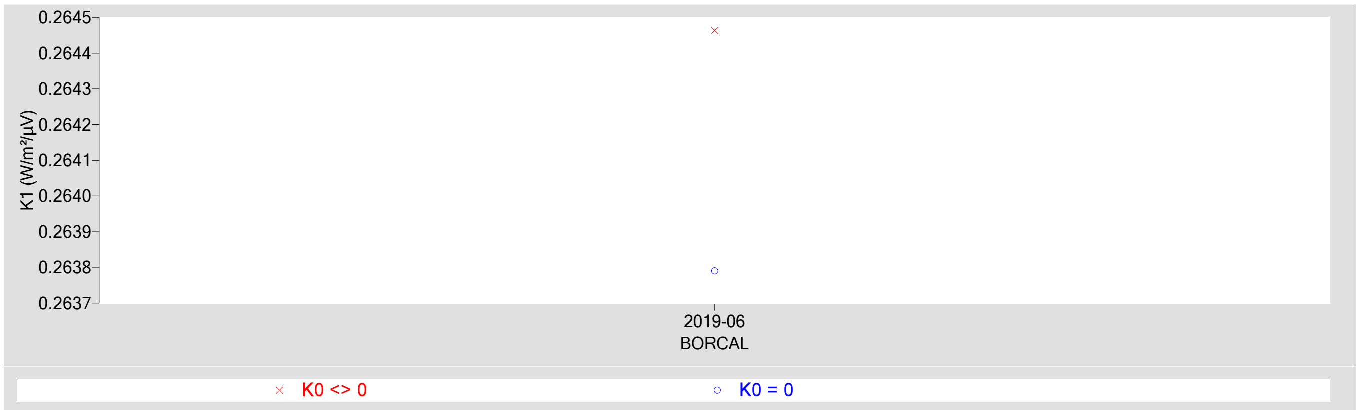


Figure 5. History of instrument (K2 Coefficient)

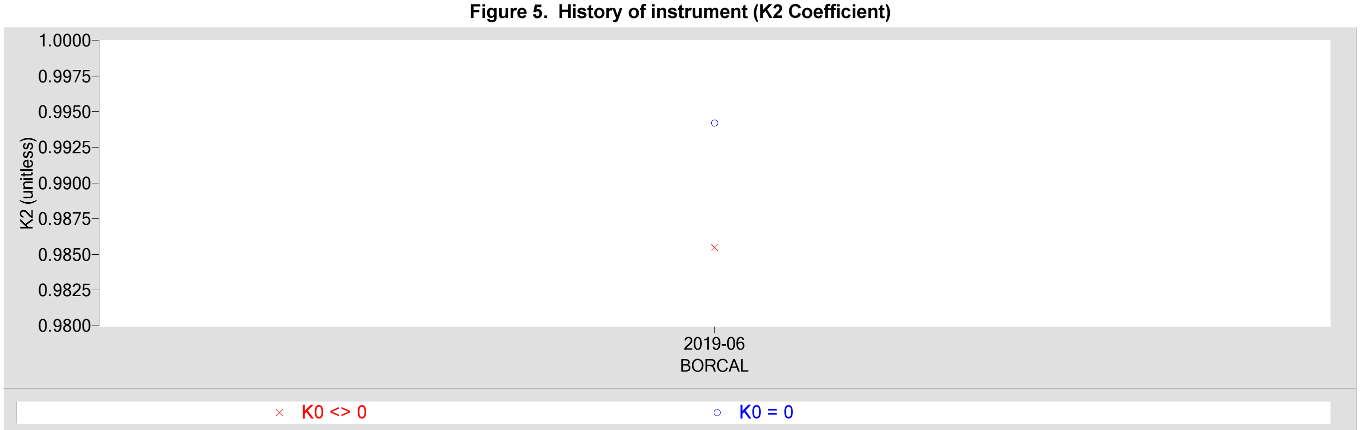
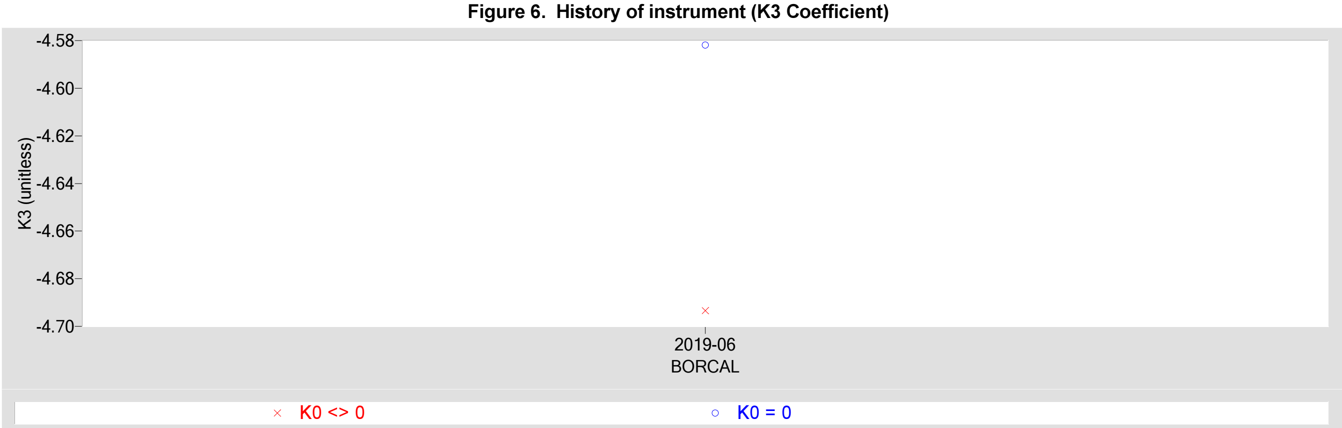


Figure 6. History of instrument (K3 Coefficient)



References:

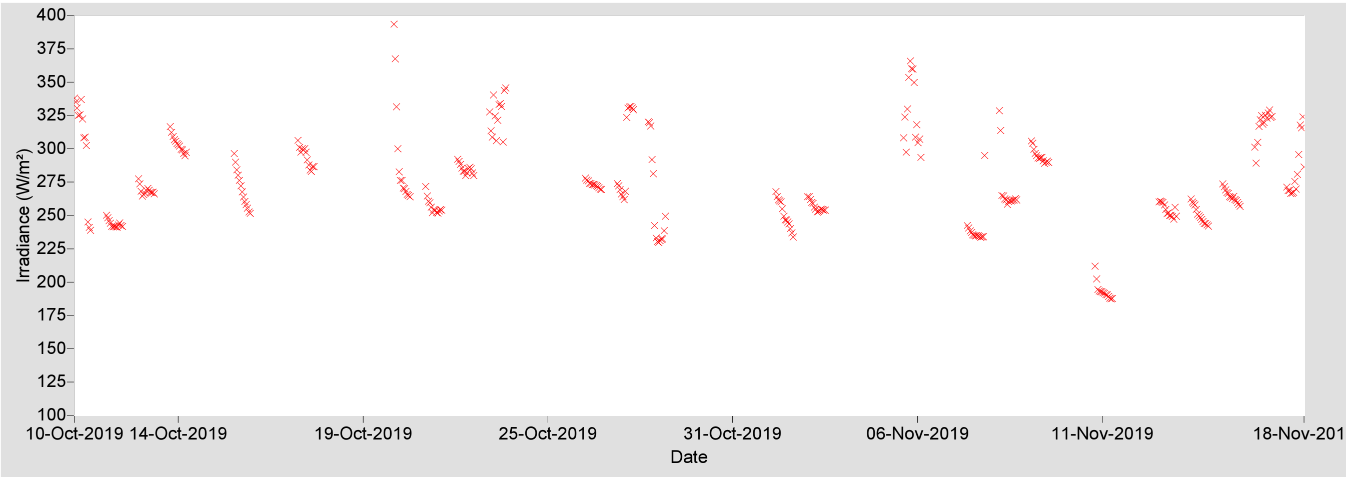
[1] Reda, I.; Stoffel, T. (2010). Pyrgeometer Calibration for DOE-Atmospheric System Research Program using NREL Method (Presentation). 9 pp.; NREL Report No. PR-3B0-47756; http://www.nrel.gov/docs/fy10osti/47756.pdf.

Environmental and Sky Conditions for BORCAL-LW 2019-06

Calibration Facility: Southern Great Plains

Latitude: 36.605°N Longitude: 97.488°W Elevation: 317.0 meters AMSL Time Zone: -6.0

Figure 6. Reference Irradiance



Meteorological Observations (hourly averages):

Figure 7. Temperature

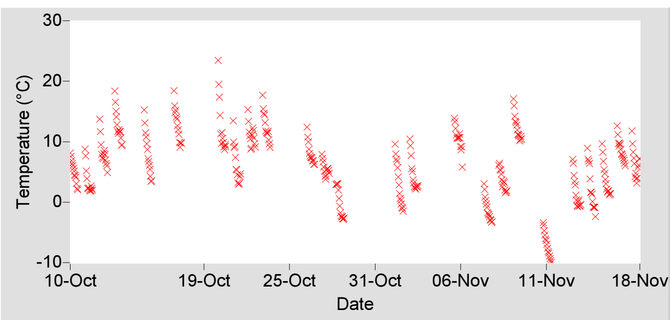


Figure 8. Humidity

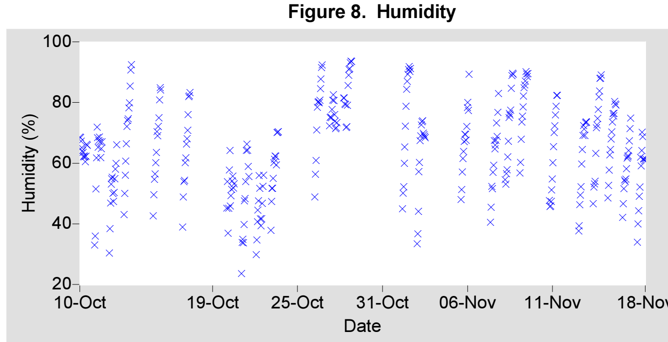


Figure 9. Pressure

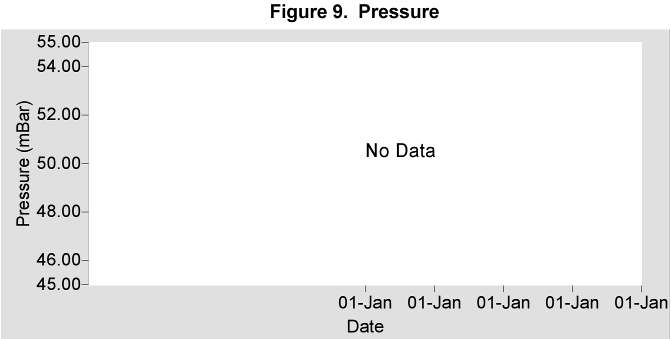


Figure 10. Estimated Precipitable Water Vapor (PWV)

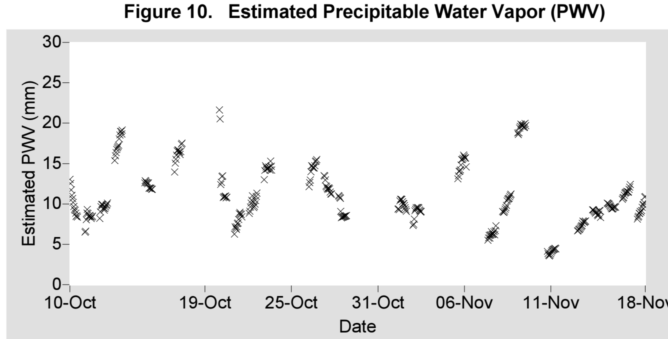


Table 6. Meteorological Observations

Observations	Mean	Min	Max
Temperature (°C)	6.04	-10.18	24.25
Humidity (%)	65.08	20.81	94.13
Pressure (mBar)	N/A	N/A	N/A
Est. Precipitable Water Vapor (mm)	11.0	3.5	23.0

For other information about the calibration facility visit: http://www.arm.gov/docs/sites/sgp/sgp.html

Appendix 2
BORCAL Notes

Instrument, Configuration, and Session Notes for the BORCAL

BORCAL Notes

Facility: Southern Great Plains
Comments:
Avg. Station Pressure and Temperature is for Tulsa, OK, which is used for the Solar Position Algorithm (SPA).

29596F3 Eppley PIR
Comments:
SGP address is 109596 Coal Road, Billings, OK 74630 tel 331-318-3354

Appendix 3
Session Configuration Audit Report

Latest Session Configuration Audit Report for the BORCAL

BORCAL/LW 2019-06 Session Configuration Audit Report

LOCATION

Facility	Facility Abbrev.	Contact	Latitude	Longitude	Elevation (m)	Avg press (mbr)	Avg temp (C)	Time zone	ISO
Southern Great Plains	SGP	Craig Webb	36.605	-97.488	317.0	992.0	15.0	-6.0	

SYSTEM

% Error Thresholds

TP(x) / TP(x-1): 25.0

Delta Thresholds

Ref Pyg Stability: 4.0
Temp(x) - Temp(x-1): 5.0
Hum(x) - Hum(x-1): 20.0
Bar(x) - Bar(x-1): 5.0
Thrm(x) - Temp(x): 10.0

Analysis Rejection

Threshold 1 (Blue): 3.000
Threshold 2 (Green): 4.000
Threshold 3 (Brown): 5.000
No. of Std. Dev.: 3

Clock

Reset Interval (m): 0
Warning Threshold (s): 0
Delta UT1: -0.100

Misc

Scan Rate (s): 300
Uncert. Significant Figures: 2

Auto Mode Zenith Angle

Afternoon Startup: 94
Morning Shutdown: 94

Solar Position Algorithm

Delta T (s): 69.284
Atmos. Refraction (deg): 0.5667

METEOROLOGICAL INSTRUMENTS

	Channel	Junction Box	Cable	Location	Scale	Offset
Temperature: E0710026T Vaisala HMP155 T	239			Temp	100	-40
Humidity: E0710026H Vaisala HMP155 H	255			Hum	100	0
Pressure: None					0	0

GPS TIME RECIEVER

GPS: None

Type	Port	Baud	Parity	Stop bits	Data bits
	0	0	0	0	0

DATALOGGER

	Logger/Relay	DMM
Unit 0	2009-1206 NREL RAP-DAQ	MY42002863 Agilent 34420A
Unit 1	2009-1207 NREL RAP-DAQ	MY42002864 Agilent 34420A
Unit 2	2009-1208 NREL RAP-DAQ	MY42002866 Agilent 34420A
Unit 3	2014-1302 NREL RAP-DAQ	SG42000596 Agilent 34420A

	Unit 0	Unit 1	Unit 2	Unit 3
Cal Date	01/10/2019	01/10/2019	01/10/2019	01/10/2019
Cal Due Date	01/10/2020	01/10/2020	01/10/2020	01/10/2020
System Offsets: Volts DC (µV)	1.41	1.41	1.41	1.41
2-Wire Res. (mOhms)	2571.00	2571.00	2571.00	2571.00
4-Wire Res. (mOhms)	0.00	0.00	0.00	0.00

Communications

	Unit	Type	Addr.	Board	Parity	Stop	Data
DMM	0	GPIB	21	0	0	0	0
Relay	0	GPIB	24	1	0	0	0
DMM	1	GPIB	22	0	0	0	0
Relay	1	GPIB	25	1	0	0	0
DMM	2	GPIB	23	0	0	0	0
Relay	2	GPIB	26	1	0	0	0
DMM	3	GPIB	1	0	0	0	0
Relay	3	GPIB	4	1	0	0	0

BORCAL/LW 2019-06 Session Configuration Audit Report

PYRGEOMETER REFERENCE INSTRUMENTS

Cal Date	Cal Due Date	K0	K1	K2	K3	Kr	Uncert. (W/m^2)	Max Out (mV)	Channel	Junction Box	Cable	Location	Active
Pyrgeometer 1: 31206F3 Eppley PIR (Ventilated)													
04/16/2018	04/16/2020	-0.20000	0.26400	0.99940	-3.26000	7.04400E-4	2.60	9	23		2	T5-2	✔
Pyrgeometer 1: Case 10K Temperature									19		2		
Pyrgeometer 1: Dome 10K Temperature									27		2		
Pyrgeometer 2: 31237F3 Eppley PIR (Ventilated)													
04/16/2018	04/16/2020	3.50000	0.22892	0.99110	-3.69000	7.04400E-4	2.60	9	71		2	T6-2	✔
Pyrgeometer 2: Case 10K Temperature									67		2		
Pyrgeometer 2: Dome 10K Temperature									75		2		

(K0–Kr: Calibration Coefficients)

BORCAL/LW 2019-06 Session Configuration Audit Report

INSTRUMENTS

Serial Number / Model	Customer	Mfg RS	Ch	Box	Cable	Act	ISO	AIM	Stickr	Vent	Use	Kr	Location	Due
29592F3	SGP	3.7800	161		84	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	84/85	12
PIR	(Case 10K Temperature)		169		84									
	(Dome 10K Temperature)		170		85									
29596F3	SGP	4.2400	114		56	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	56/62	12
PIR	(Case 10K Temperature)		122		56									
	(Dome 10K Temperature)		41		62									
30010F3	SGP	3.2400	232		83	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	83	12
PIR	(Case 10K Temperature)		240		83									
	(Dome 10K Temperature)		248		83									
30014F3	SGP	3.7000	128		57	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	57/58	12
PIR	(Case 10K Temperature)		136		57									
	(Dome 10K Temperature)		137		58									
30084F3	TWP	3.5900	151		1	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T8-1	12
PIR	(Case 10K Temperature)		147		1									
	(Dome 10K Temperature)		155		1									
30133F3 ‡	SGP	3.9000	215		2	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T9-2	12
PIR	(Case 10K Temperature)		211		2									
	(Dome 10K Temperature)		219		2									
30345F3	SGP	3.7100	65		13	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	13/14	12
PIR	(Case 10K Temperature)		73		13									
	(Dome 10K Temperature)		74		14									
30356F3	SGP	3.8500	80		19	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	19/9	12
PIR	(Case 10K Temperature)		88		19									
	(Dome 10K Temperature)		10		9									
30682F3	SGP	3.9300	113		55	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	55/61	12
PIR	(Case 10K Temperature)		121		55									
	(Dome 10K Temperature)		40		61									
30684F3	SGP	3.7000	48		1	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	1/8	12
PIR	(Case 10K Temperature)		56		1									
	(Dome 10K Temperature)		9		8									
30685F3	SGP	3.7500	50		11	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	11/12	12
PIR	(Case 10K Temperature)		58		11									
	(Dome 10K Temperature)		72		12									
30687F3	SGP	3.7600	49		10	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	10/16	12
PIR	(Case 10K Temperature)		57		10									
	(Dome 10K Temperature)		16		16									
30688F3	SGP	3.9000	145		73	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	73/53	12
PIR	(Case 10K Temperature)		153		73									
	(Dome 10K Temperature)		33		53									
30689F3	SGP	3.4200	61		3	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	3/5/7	12
PIR	(Case 10K Temperature)		1		5									
	(Dome 10K Temperature)		8		7									
30780F3	SGP	3.7500	82		29	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	29/18	12
PIR	(Case 10K Temperature)		90		29									
	(Dome 10K Temperature)		18		18									
30784F3	SGP	3.7400	60		2	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	2/4/6	12
PIR	(Case 10K Temperature)		0		4									
	(Dome 10K Temperature)		2		6									

‡ Control Instrument

BORCAL/LW 2019-06 Session Configuration Audit Report

INSTRUMENTS

Serial Number / Model	Customer	Mfg RS	Ch	Box	Cable	Act	ISO	AIM	Stickr	Vent	Use	Kr	Location	Due
30835F3	SGP	4.0700	135		3	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T7-3	12
PIR	(Case 10K Temperature)		131		3									
	(Dome 10K Temperature)		139		3									
30837F3	SGP	3.8700	146		74	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	74/54	12
PIR	(Case 10K Temperature)		154		74									
	(Dome 10K Temperature)		34		54									
31639F3	SGP	4.2200	160		82	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	82/63	12
PIR	(Case 10K Temperature)		168		82									
	(Dome 10K Temperature)		42		63									
32041F3	SGP	3.7500	98		37	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	37/43	12
PIR	(Case 10K Temperature)		106		37									
	(Dome 10K Temperature)		24		43									
32042F3	SGP	3.8200	130		64	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	64/44	12
PIR	(Case 10K Temperature)		138		64									
	(Dome 10K Temperature)		25		44									
32043F3	NSA	4.1600	144		65	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	65/45	12
PIR	(Case 10K Temperature)		152		65									
	(Dome 10K Temperature)		26		45									
32048F3	SGP	3.7900	112		46	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	46/52	12
PIR	(Case 10K Temperature)		120		46									
	(Dome 10K Temperature)		32		52									
34304F3	AMF	3.9500	96		31	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	31/32	12
PIR	(Case 10K Temperature)		104		31									
	(Dome 10K Temperature)		105		32									
36280F3	AMF	3.0800	208		30	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	30	12
PIR	(Case 10K Temperature)		216		30									
	(Dome 10K Temperature)		224		30									
36368F3 ‡	SGP	3.0200	167		2	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T8-2	12
PIR	(Case 10K Temperature)		163		2									
	(Dome 10K Temperature)		171		2									
37325F3	AMF	3.7800	183		3	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T8-3	12
PIR	(Case 10K Temperature)		179		3									
	(Dome 10K Temperature)		187		3									
37327F3	AMF	3.9300	199		1	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T9-1	12
PIR	(Case 10K Temperature)		195		1									
	(Dome 10K Temperature)		203		1									
37332F3	AMF	3.7700	231		3	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T9-3	12
PIR	(Case 10K Temperature)		227		3									
	(Dome 10K Temperature)		235		3									
37334F3	NSA	4.3100	81		28	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	28/17	12
PIR	(Case 10K Temperature)		89		28									
	(Dome 10K Temperature)		17		17									
38865F3	SGP	2.8600	7		1	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T5-1	12
PIR	(Case 10K Temperature)		3		1									
	(Dome 10K Temperature)		11		1									
38866F3	SGP	2.6600	39		3	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T5-3	12
PIR	(Case 10K Temperature)		35		3									
	(Dome 10K Temperature)		43		3									

‡ Control Instrument

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INSTRUMENTS

Serial Number / Model	Customer	Mfg RS	Ch	Box	Cable	Act	ISO	AIM	Stickr	Vent	Use	Kr	Location	Due
38867F3	SGP	2.9500	55		1	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T6-1	12
PIR	(Case 10K Temperature)		51		1									
	(Dome 10K Temperature)		59		1									
38868F3	SGP	2.9600	87		3	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T6-3	12
PIR	(Case 10K Temperature)		83		3									
	(Dome 10K Temperature)		91		3									
38869F3	SGP	2.9100	103		1	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T7-1	12
PIR	(Case 10K Temperature)		99		1									
	(Dome 10K Temperature)		107		1									
38870F3	SGP	3.3200	119		2	Yes	No	Yes	K0=0	Yes	PYG	7.044e-4	T7-2	12
PIR	(Case 10K Temperature)		115		2									
	(Dome 10K Temperature)		123		2									