Evaluation of Improved Pyrgeometer Calibration Method

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Abstract

Broadband longwave (atmospheric) irradiance measurements are important for determining the earth's total energy balance. The Atmospheric Radiation Measurement (ARM) Program has deployed more than 50 pyrgeometers for measuring the upwelling and downwelling longwave irradiance as part of Solar Infrared Station (SIRS), SKYRAD, and GNDRAD instrument platforms. The Eppley Laboratory, Inc. and the National Renewable Energy Laboratory (NREL) have developed a new Pyrgeometer Blackbody Calibration System for the ARM Program.

We compare the results of the new 4-coefficient calibration method with the traditional 2-coefficient approach, using measurements from 12 pyrgeometers calibrated with the new system and deployed at the Southern Great Plains (SGP) Radiometer Calibration Facility (RCF).

The results indicate a significant improvement to the measurement precision. The average difference of irradiance measurements between the 12 Model precision infrared radiometers (PIRs) from April 30 to June 8, 2002, was 3 Wm^{-2} (new method) versus 10 Wm^{-2} (traditional method).

Overview

Following are the steps performed during our evaluation:

- Calibrated 12 Model PIR pyrgeometers using New Pyrgeometer Blackbody Calibration System at the SGP/RCF to determine 2- and 4-coefficient calibration factors.
- Installed PIRs on sun trackers, under shading disks, and in ventilators.
- Collected data at the SGP/RCF, from April 30 to June 8, 2002.
- Used the 4-coefficients (NREL), and the 2-coefficients (Albrecht & Cox) equations to calculate the incoming longwave radiation:

$$* \text{ NREL: } W_{inc} = K_0 + K_1 * V + K_2 * \sigma * T^4_r + K_3 * \sigma * (T^4_d - T^4_r)$$

where $K_i = {}_{0\text{-}3}$ are the PIR calibration coefficients using the SGP Blackbody System.

$$* \text{ Albrecht\&Cox: } W_{inc} = K_1 * V + \sigma * T^4_c + K_2 * \sigma * (T^4_d - T^4_c)$$

where K_1 and K_2 are the PIR calibration coefficients provided by the manufacturer.

SGP Blackbody Calibration

We used the New Pyrgeometer Blackbody Calibration System at the SGP site to calculate the 2- and 4-coefficient calibration factors.

$$W_{bb} = K_0 + K_1 * V + K^2 * \sigma * T^4_r + K_3 * \sigma * (T^4_d - T^4_r)$$

where

W_{bb}	=	Blackbody radiation, in Watt/m^2
$K_{i = 0\text{-}3}$	=	PIR calibration coefficients
V	=	PIR thermopile output voltage, in uV
σ	=	5.6697 * 10-8 Watt/(m2.Kelvin4)
T_d	=	PIR dome temperature, in Kelvin
T_r	=	PIR receiver temperature, in Kelvin
	=	$T_c + \alpha * V$

where

T_c	=	PIR case temperature, in Kelvin
$1/\alpha$	=	S * n * E

where

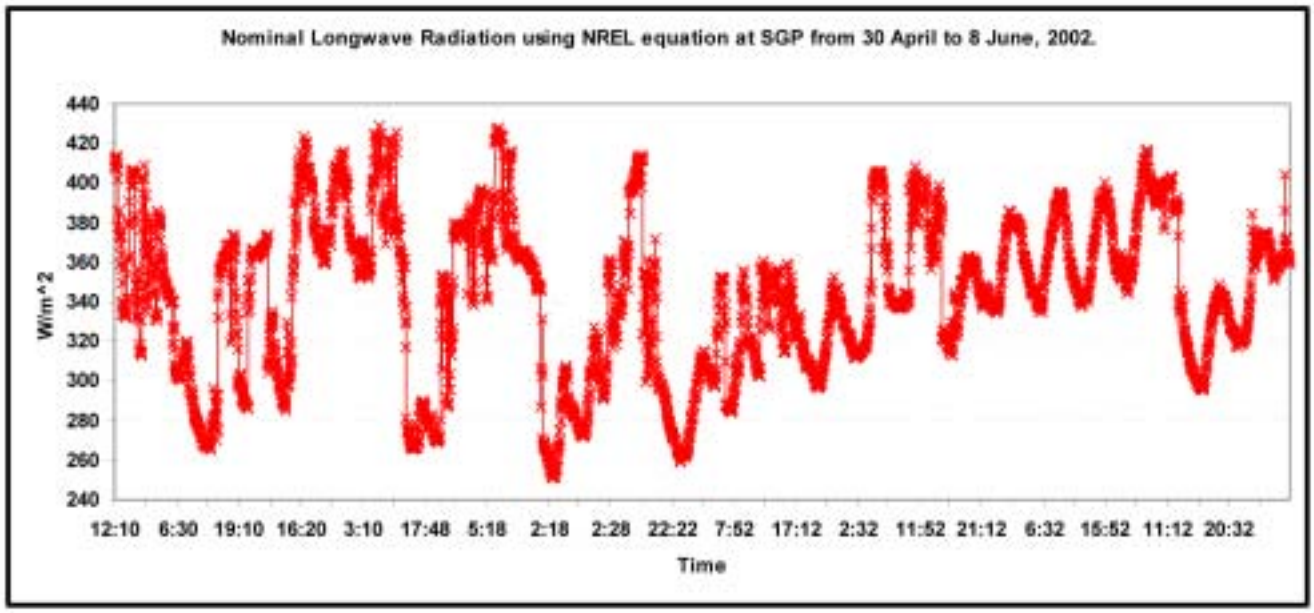
S	=	Seebeck coefficient = 39, in μV/K
N	=	number of junctions = 56
E	=	thermopile efficiency factor = 0.65

then $T_r = T_c + 0.0007044 * V$

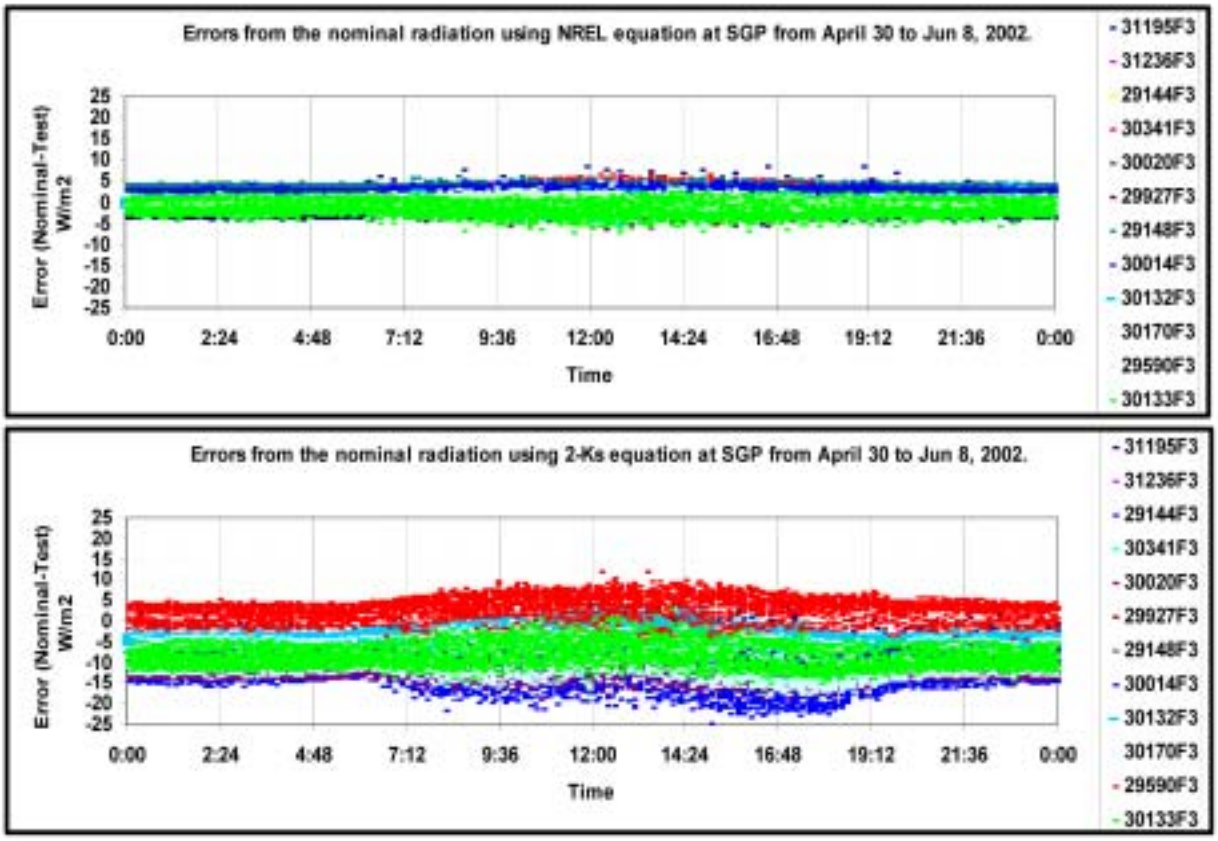
The calibration is performed at 7 *pyrgeometer case* and *blackbody* temperature plateaus then a linear regression is used to calculate the calibration coefficients.

Nominal Outdoor Longwave Radiation

The nominal longwave radiation is calculated as the average of the incoming longwave radiation measured by 12 PIRs using the 4-coefficient NREL equation.

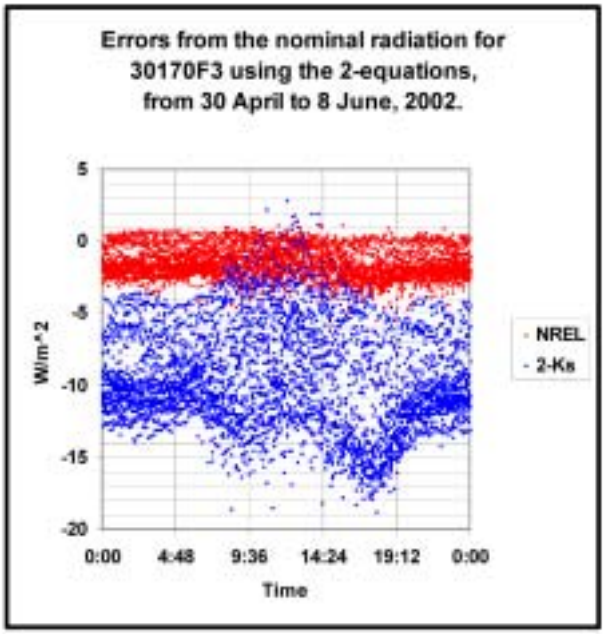


Comparing the Two Equation Results

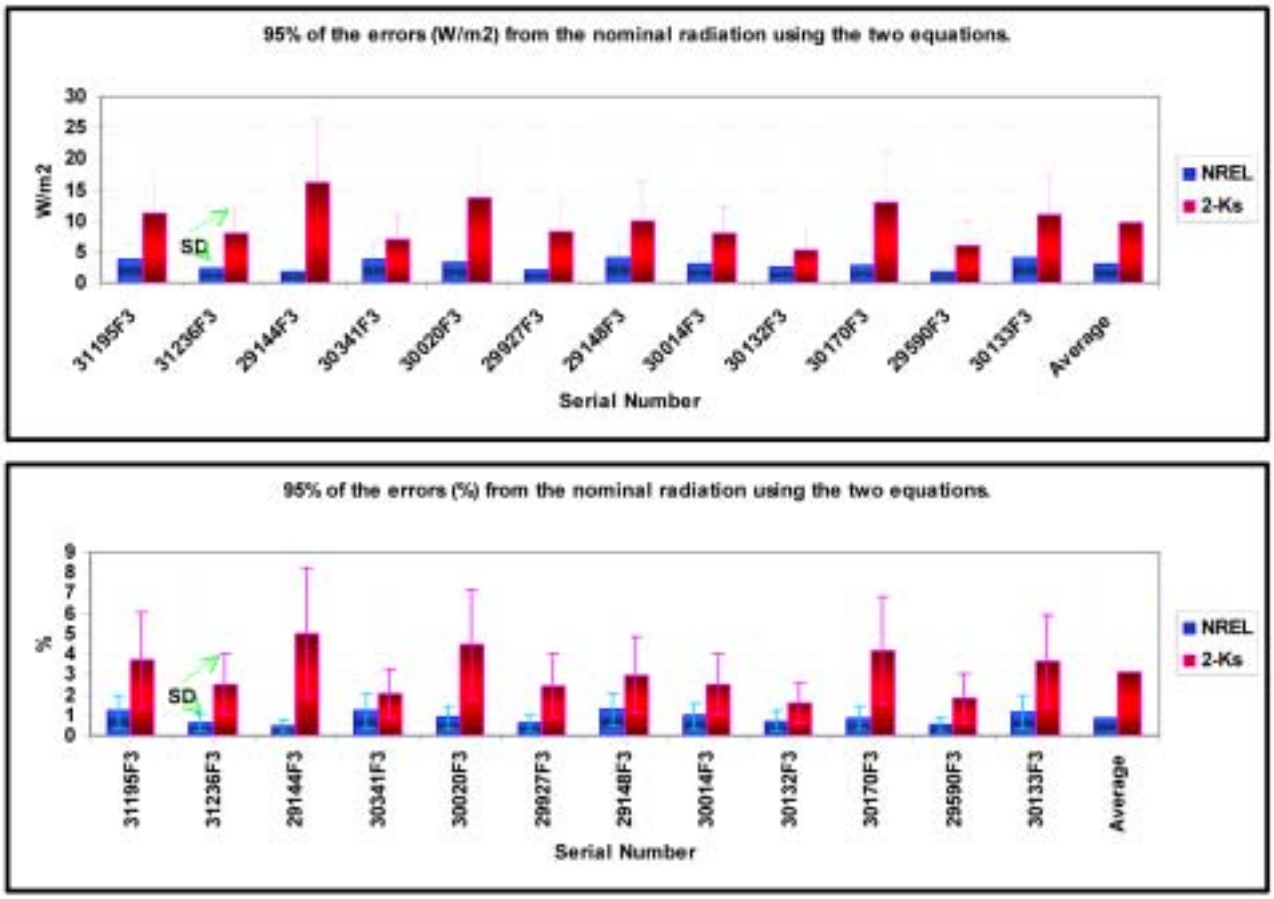


Outdoor Measurement Statistics Using the Two Equations

Serial Number	95% of the Errors (W/m^2)		95% of the Errors (%)	
	NREL	2-Ks	NREL	2-Ks
31195F3	3.8	11.1	1.2	3.7
31236F3	2.3	7.9	0.6	2.5
29144F3	1.6	16.2	0.5	5.0
30341F3	3.8	6.9	1.2	2.0
30020F3	3.2	13.7	0.9	4.4
29927F3	1.9	8.2	0.6	2.4
29148F3	3.9	10.0	1.3	3.0
30014F3	3.1	7.8	1.0	2.5
30132F3	2.4	5.3	0.7	1.6
30170F3	2.8	13.0	0.9	4.1
29590F3	1.7	5.9	0.5	1.8
30133F3	3.9	10.9	1.2	3.6
Average	2.9	9.7	0.9	3.1



How the PIRs Compare



Conclusions

- In the absence of a recognized measurement standard for longwave (infrared) irradiance, the ARM Program has acquired a unique Pyrgeometer Blackbody Calibration System.
- NREL has developed a 4-coefficient calibration method to account for zero-offset, dome correction factor, case emissivity, and other factors.
- Outdoor measurements from 12 pyrgeometers previously calibrated by the new system and installed at the RCF, suggests an improvement in pyrgeometer precision is now possible (10 Wm^{-2} using Albrecht & Cox versus 3 Wm^{-2} using the new NREL).

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