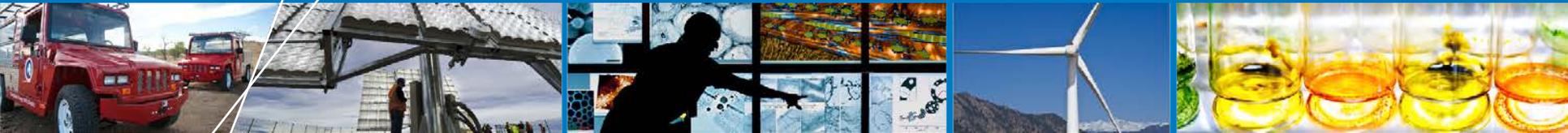# Uncertainty Estimates for SIRS, SKYRAD, & GNDRAD Data and Reprocessing the Pyrgeometer Data

ASR Science Team Meeting 2012

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The Guide to the Expression of Uncertainty in Measurement (GUM)*

Basic Steps:

1. ***Determine the measurement equation.***

2. ***Estimate the standard uncertainty*** (u_i) associated with <u>each variable</u> in the measurement equation and for each component that might introduce uncertainty to the measurement process (e.g. interpolation, environmental conditions).

3. ***Calculate the combined standard uncertainty*** (u_c) by <u>summing in quadrature</u> the standard uncertainties in step 2.

4. ***Calculate the expanded uncertainty*** (U) by multiplying the combined standard uncertainty by the <u>coverage factor, k</u> (typically known as Student's "t"), or prescribed coverage factors for known distributions of measurements representing the single value of the quantity to be measured (e.g. Gaussian, triangular, rectangular).

Uncertainty Estimates for SIRS, SKYRAD, & GNDRAD

Simple Expression:

1. ***Determine the measurement equation:***

    Pyrheliometers: Pyranometers:

    W = V / Rs   W = (V − Rnet * Wnet) / Rs

    $W \quad = \text{Flux (Wm}^{-2})$
    $V \quad = \text{Thermopile Voltage (μV)}$
    $Rs \quad = \text{Shortwave Responsivity (μV/Wm}^{-2})$
    $Rnet = \text{Longwave Responsity}$
    $Wnet = \text{Longwave Irradiance (Pyrgeometer)}$

2. ***Estimate the standard uncertainty*** (u_i) based on <u>Type A</u> and <u>Type B</u> error sources

    Calibration; Responses: Temperature, Spectral, Angular; Linearity, Stability, etc.

3. ***Calculate the combined standard uncertainty*** (u_c):

    $$u_c = \sqrt{u_A^2 + u_B^2}$$

4. ***Calculate the expanded uncertainty*** (U)

    $U = k * u_c$ (k = 1.96 for large degrees of freedom)

http://www.nrel.gov/docs/fy11osti/52194.pdf

Calibration Uncertainty Estimates

Traceable to SI Units

Radiometer	Expanded Uncertainty $U95 = U_c * 1.96$
Pyranometer	±3%
Pyrheliometer	±2%
Pyrgeometer	± (1% + 4 Wm^{-2})*

*Due to interim World Infrared Standard Group (WISG)

http://www.nrel.gov/docs/fy11osti/52194.pdf

Uncertainty Estimates for SIRS, SKYRAD & GNDRAD

Measurement	Abbreviation	Eppley Radiometer Model	Typical Responsivity ($\mu V/Wm^{-2}$)	Estimated Measurement Uncertainty	Value Added (correction for zenith, thermal offset, etc.)
Direct Normal (Beam)	DNI	NIP	8	$\pm 3.0\%$ $(>700\ Wm^{-2})$	$\pm 2.0\%$ $(>700\ Wm^{-2})$
Diffuse Horizontal (Sky)	DD	PSP	9	$+4.0\%$ to $-(4\%+20\ Wm^{-2})$	$+2.0\%$ to $-(2\%+4\ Wm^{-2})$
Diffuse Horizontal (Sky)	DD	8-48	8	$+4.0\%$ to $-(4\%+2 Wm^{-2})$	$+4.0\%$ to $-(4\%+2 Wm^{-2})$
Downwelling Shortwave (Global)	DS	PSP	9	$+4.0\%$ to $-(4\%+20\ Wm^{-2})$ zenith $< 80°$	$+2.0\%$ to $-(2\%+4\ Wm^{-2})$ zenith $< 80°$
Downwelling Longwave (Atmospheric)	DIR	PIR	4	$\pm(5\%+4^{*}\ Wm^{-2})$	$\pm(1\%+4^{*}\ Wm^{-2})$
Upwelling Shortwave (Reflected SW)	US	PSP	9	$\pm 3.0\%$	$\pm 2.0\%$
Upwelling Longwave (Reflected/Emitted LW)	UIR	PIR	4	$\pm 2\ Wm^{-2}$	$\pm 2\ Wm^{-2}$

# Pyrgeometer Calibrations: WISG vs. Blackbody Results

Dome coefficient = 3.5

Irradiance difference (Reference - Test) using the Manufacturer calibration coefficients for nine test pyrgeometers
Outdoors at SGP from December 15, 2006 to January 31, 2007
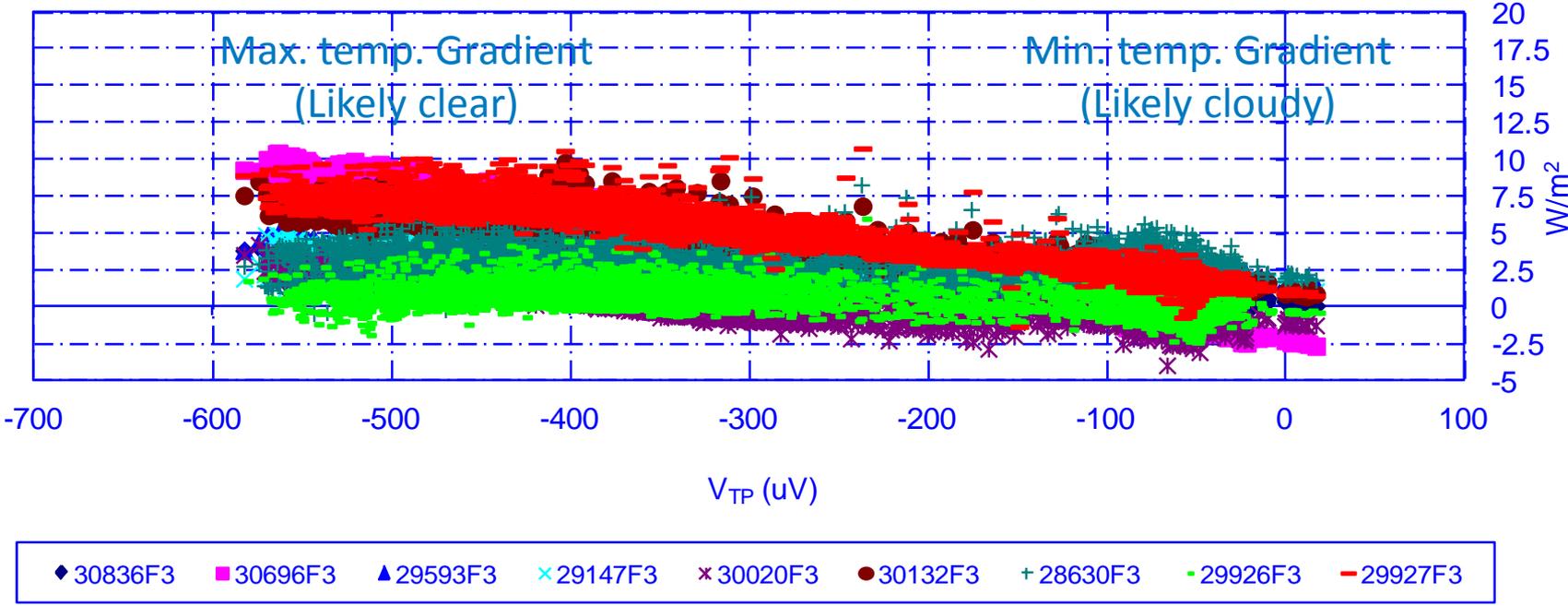
Reference: **Reda et al., 2007. "ARM/NREL Pyrgeometer Calibrations with Traceability to the World Infrared Standard Group (WISG)".** *ARM-CONF-2007, March 2007 Monterey, California*

Pyrgeometer Outdoor Calibration vs. Manufacturer Blackbody Calibration Histograms
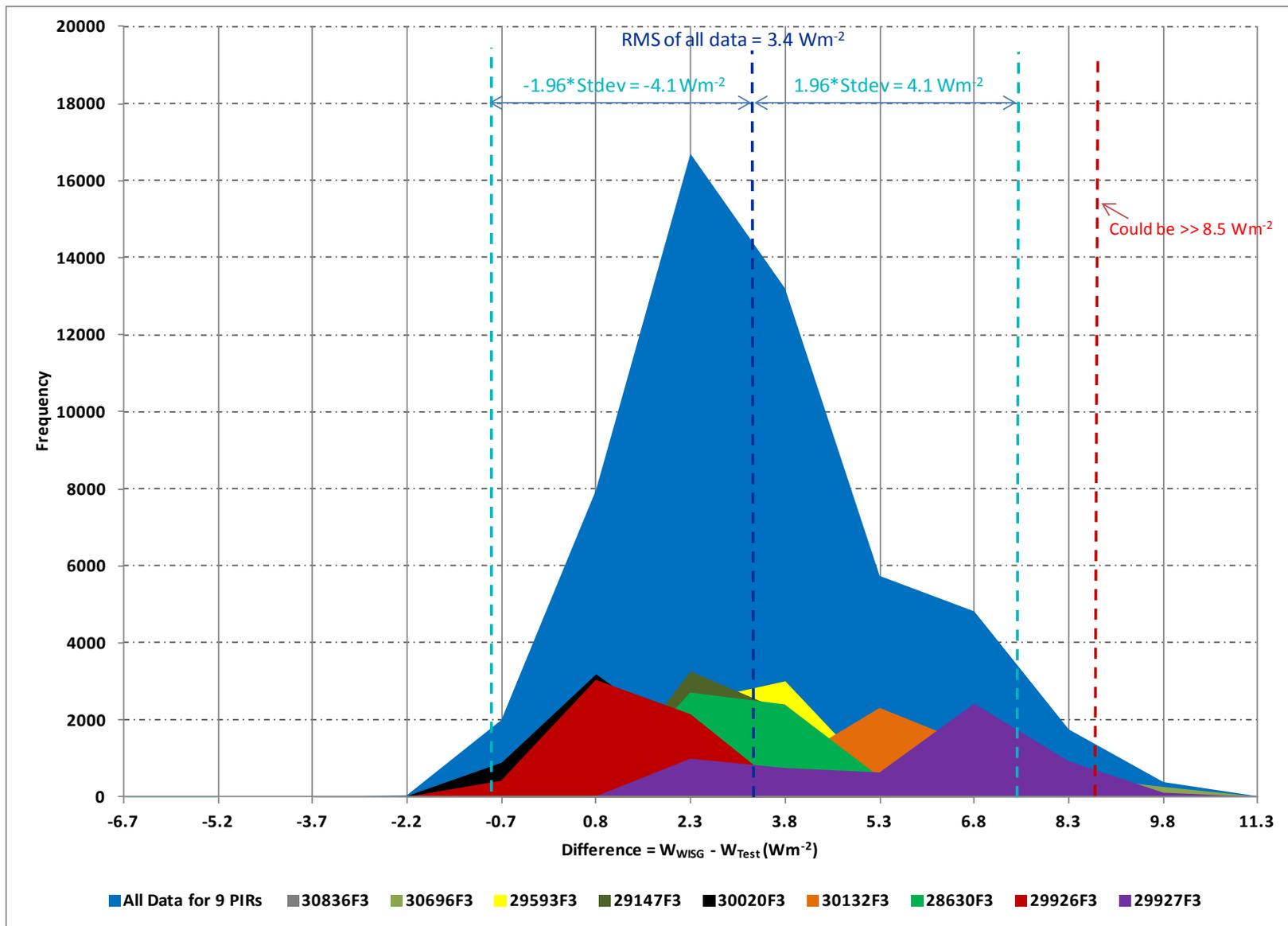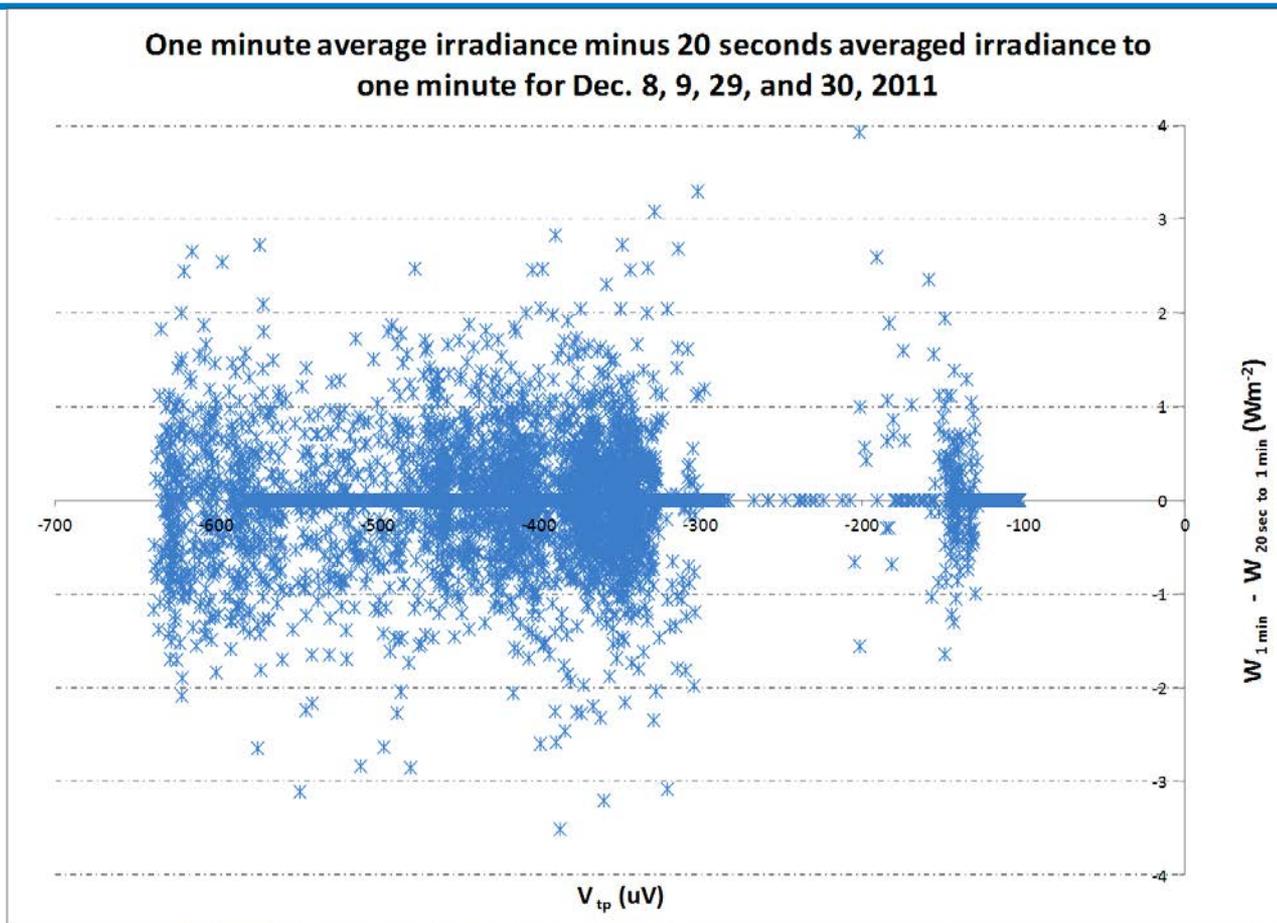
Pyrgeometer Aging Study

Manufacturer BB re-calibration after seven years of field deployment

S/N	Location	Date Deployed	Eppley Cal [uV/Wm^{-2}]	Date Returned from Eppley	New Eppley Cal [uV/(W/m^{-2})]	%difference between cals	%aging/year for a 7-year deployment	Cal interval (Year)	Error in $W_{incoming}$ (Wm^{-2})
30779F3	Ringwood, OK	8/17/2004	3.77	4/28/2011	3.79	0.53	0.08	1	0.15
30832F3	Vici, OK	8/18/2004	3.71	4/28/2011	3.67	-1.08	-0.15	1	-0.31
30688F3	Meeker, OK	8/19/2004	3.88	4/28/2011	3.9	0.52	0.07	1	0.15
30785F3	Ashton, KS	12/14/2004	4.14	4/28/2011	4.09	-1.21	-0.17	1	-0.35
30344F3	Pawhuska, OK	12/7/2004	3.95	4/28/2011	3.96	0.25	0.04	1	0.07
30010F3	Lamont, OK	8/27/2004	3.2	4/28/2011	3.24	1.25	0.18	1	0.35

From the inconsistency of the difference, no conclusion, yet a 2-year cal interval is reasonable

Sampling Rate Effect for Correcting Historical Data

One minute average irradiance minus 20 seconds averaged irradiance to one minute for Dec. 8, 9, 29, and 30, 2011

-Randomness of the data is a result of the nonlinearity of the basic variables in the pyrgeometer equation, i.e., resistance-to-temperature, (temperature)[4], etc.

-Correcting the 1-min average might introduce $> \pm 2$ W/m^2 randomness to the corrected data (site dependent)

-Correcting the present 20-sec irradiance data is more appropriate, yet it will introduce greater randomness than that corrected using the 2-second irradiance, site dependent … challenging for space/etc, yet it might not be an issue in the near future.

Implementing a New Calibration System

Broadband Outdoor Radiometer Calibration

System for Data Acquisition, Analyses, Reporting, Archival

BORCAL/SW

- Pyrheliometers

- Pyranometers

BORCAL/LW

- Pyrgeometers

Implementing a New BORCAL/LW System

SRRL – 5 PIRs

BORCAL/LW @ SRRL

Data Acquisition + Auto Analyses + Certs + Reports + Archive

SGP/RCF – 5 PIRs

BORCAL/LW @ SGP/RCF

Hardware & Software Installation

Data Acquisition + Auto Analyses + Certs + Reports + Archive

Validation
(5 PIRs)
Operational
31 March 2013

What Happened to the Schedule?

- **SRRL down for 8 months instead of 6 weeks!**
- **NPC-2011**
- **BORCAL-2012**