Calibration and Thermal Offset of Pyranometers

by

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Calibration of Pyranometers

Based on solar irradiance component summation

$$F_{glo} = F_{dif} + \mu F_{Dir} \quad (1)$$

- F_{glo}: Unshaded pyranometer
- F_{dif}: Shaded pyranometer
- F_{Dir}: Calibrated pyrheliometer or cavity radiometer

Forgan Calibration:

- Two pyranometers are calibrated simultaneously
- Responsivity of pyranometers obtained as a function of SZA

Broadband Outdoor Radiometer CALibration (BORCAL):

- Previously calibrated pyranometer used to get diffuse component
- Responsivity of pyranometer averaged over 45-55^{o} SZA range

Forgan Calibration

Component summation using pyranometers 1 & 2 (am/pm):

$$F_{1g} = F_{2d} + \mu F_{Dir}$$
$$F_{2g} = F_{1d} + \mu F_{Dir} \quad (2)$$

Irradiance = Voltage/Responsivity [R]=V/Wm^{-2} :

$$\frac{V_{1g}}{R_1} = \frac{V_{2d}}{R_2} + \mu F_{Dir}$$
$$\frac{V_{2g}}{R_2} = \frac{V_{1d}}{R_1} + \mu F_{Dir} \quad (3)$$

Instrument voltage output contains SW and LW (thermal offset) components:

$$\frac{V_{1g}^{S} + V_{1g}^{L}}{R_1} = \frac{V_{2d}^{S} + V_{2d}^{L}}{R_2} + \mu F_{Dir}$$
$$\frac{V_{2g}^{S} + V_{2g}^{L}}{R_2} = \frac{V_{1d}^{S} + V_{1d}^{L}}{R_1} + \mu F_{Dir} \quad (4)$$

Responsivity of pyranometers 1 & 2, R(μ):

$$R_1 = \frac{(V_{1g}^S + V_{1g}^L) - (V_{2d}^S + V_{2d}^L)\left(\frac{V_{1g}^S + V_{1d}^S}{V_{2g}^S + V_{2d}^S}\right)}{\mu F_{Dir}}$$

$$R_2 = \frac{(V_{1g}^S + V_{1g}^L)\left(\frac{V_{2g}^S + V_{2d}^S}{V_{1g}^S + V_{1d}^S}\right) - (V_{2d}^S + V_{2d}^L)}{\mu F_{Dir}} \qquad (5)$$

If $V_g{}^L = V_d{}^L$, R is unaffected by offsets

True responsivity to solar radiation R' is found by removing the LW components from the output voltage of the pyranometer:

$$R' \approx R - \frac{V_g^L - V_d^L}{\mu F_{Dir}} \qquad (6)$$

Example: Thermal offset Global=+5Wm^{-2} Diffuse=-15Wm^{-2}
True responsivity R' 2% less than R (F' 2% larger than F)

BORCAL

Component summation using 1 pyranometer:

$$F_g = F_{dif} + \mu F_{Dir} \tag{7}$$

Irradiance = Voltage/Responsivity [R]=V/Wm^{-2} :

$$\frac{V_g}{R} = F_{dif} + \mu F_{Dir} \tag{8}$$

Instrument voltage output contains SW and LW (thermal offset) components:

$$\frac{V_g^S + V_g^L}{R} = F_{dif} + \mu F_{Dir} \tag{9}$$

Responsivity of pyranometer, R(45–55^{o}):

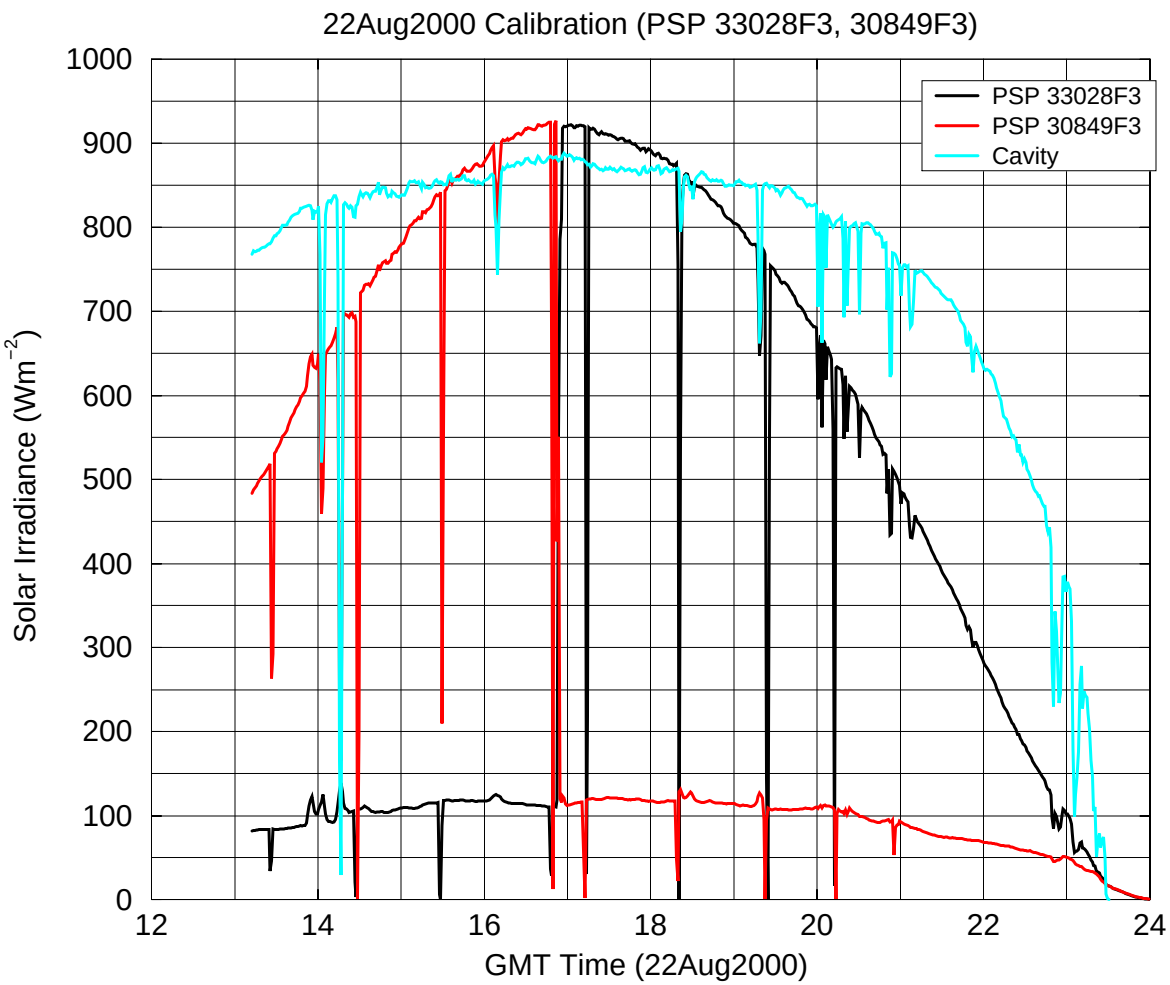
$$R = \frac{V_g^S + V_g^L}{F_{dif} + \mu F_{Dir}} \tag{10}$$

Uncertainty in $R_{dif} \approx 5\%$ + thermal offset $\approx -15\% \Rightarrow F_{dif} \approx$ underestimated 20%

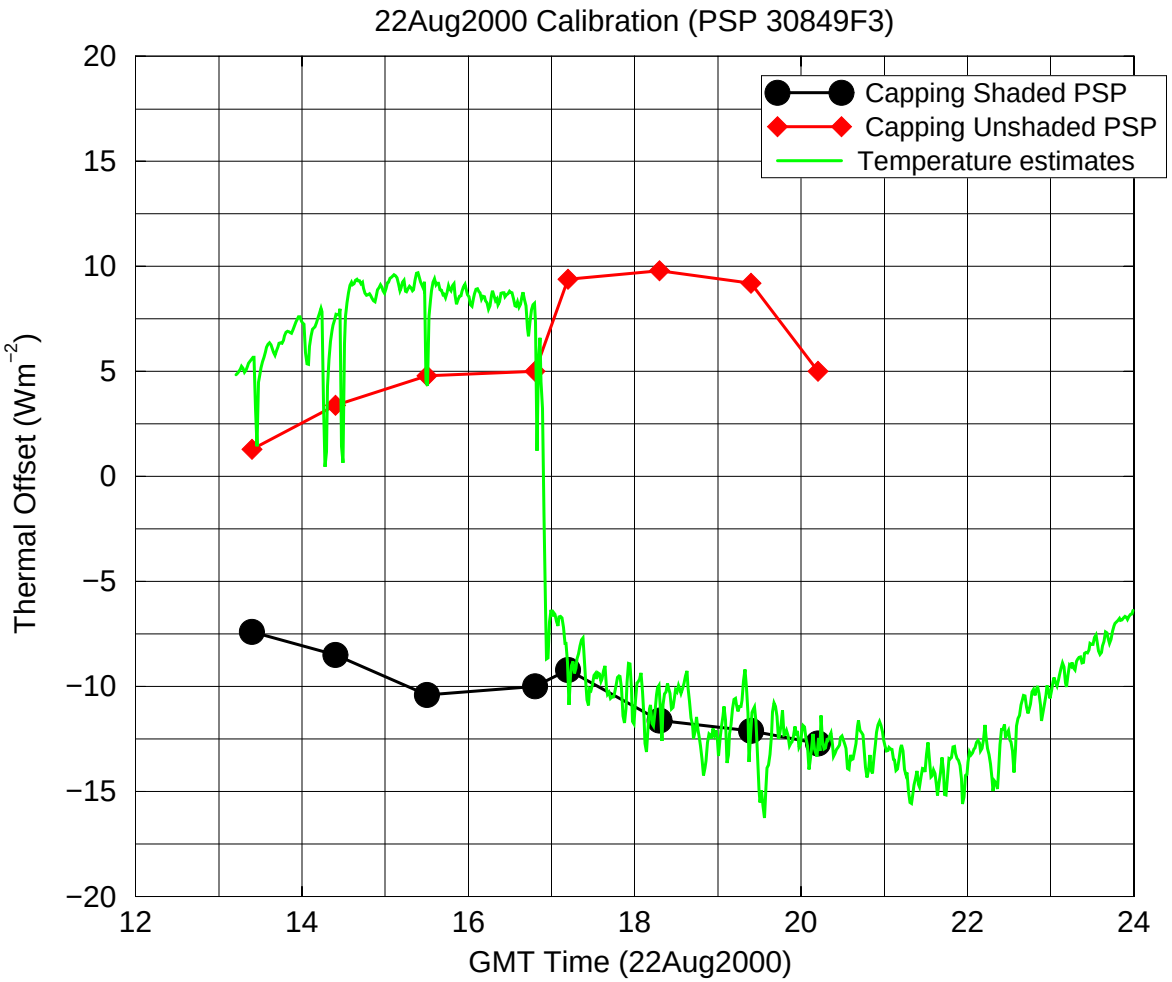
Thermal offset $V_g^L \approx +0.5\%$

$\Rightarrow$ uncertainty in $R \approx 2\%$

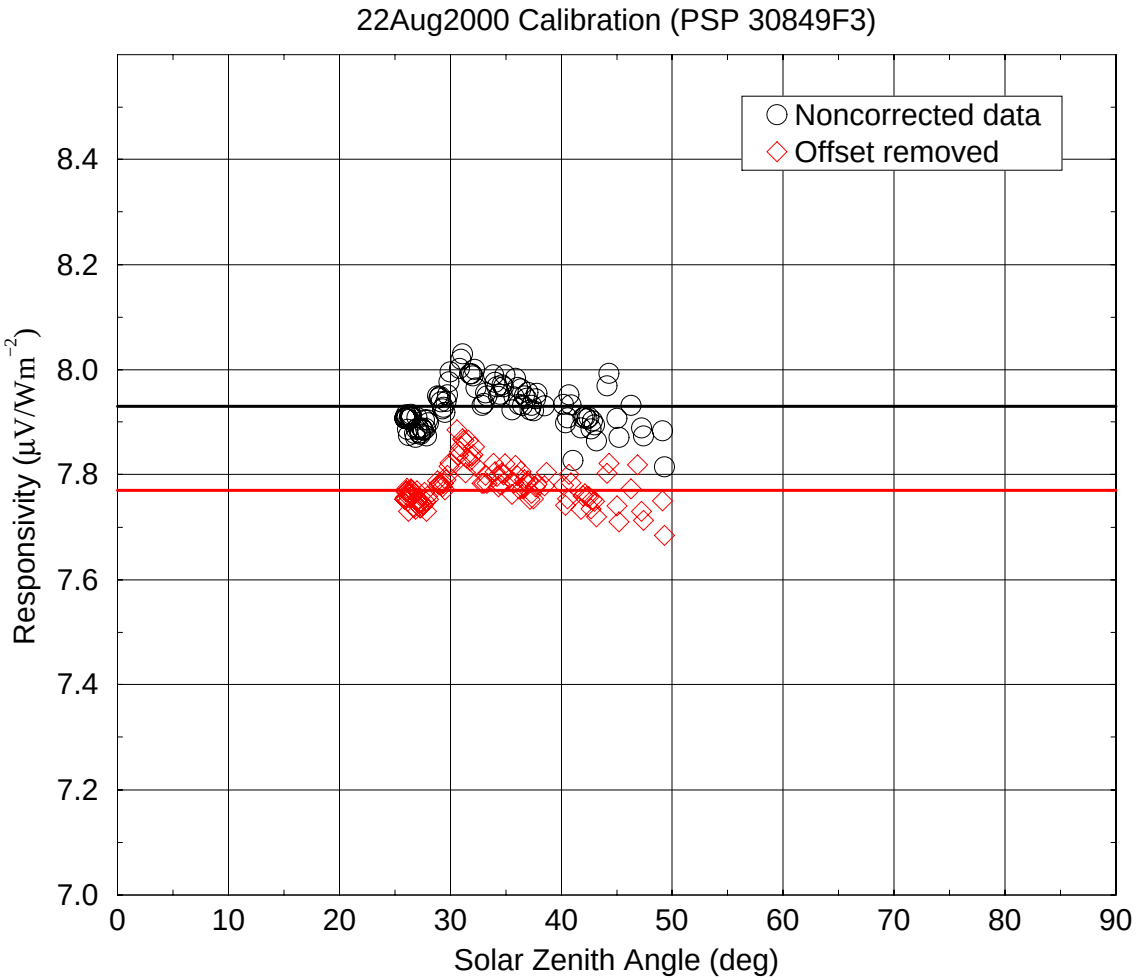
Global, Diffuse & Direct Solar Irradiance Measurements



Thermal Offset of Shaded and Unshaded PSP



Responsivity With and Without Thermal Offset



Summary of Results

- Thermal offsets affect output voltage of shaded and unshaded PSP
- Thermal offsets are not corrected by calibration
- Offset of unshaded PSP ≈ +0.5%
- Offset of shaded PSP ≈ –15%
- Thermal offsets modify calibration slope ⇒ overestimated responsivity (2%)
- Underestimated global irradiance (1.5%)
- Underestimated diffuse irradiance (17%)
- Problem can be solved by efficient ventilation and/or monitoring of offset