NREL Comparison Between Absolute Cavity Pyrgeometers and Pyrgeometers Traceable to World Infrared Standard Group and the InfraRed Integrating Sphere

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1 Introduction

The comparison of the absolute cavity pyrgeometers (ACPs) with a precision infrared radiometer (PIR) pyrgeometer traceable to the World Infrared Standard Group (WISG) and a Kipp & Zonen (KZ) pyrgeometer traceable to the InfraRed Integrating Sphere Radiometer (IRIS) was held during the National Renewable Energy Laboratory (NREL) Pyrheliometer Comparison (NPC-2018) from September 24 to October 5, 2018. Data from all instruments was collected during nighttime clear sky conditions only. The irradiance measured by the ACPs and the PIR pyrgeometer traceable to the WISG were collected every 10 seconds during the ACPs' self-calibration and every 30 seconds during the measurement runs. The measurement runs lasted for two hours, while the calibration runs lasted for 6 minutes. The KZ pyrgeometer collected irradiance measurements every 30 seconds. During the comparison, the average (av) irradiance difference measured by three ACPs varied from 0.2 W/m^2 to -0.5 W/m^2, with a standard deviation (sd) from 0.5 W/m^2 to 0.8 W/m^2. The average irradiance difference measured by the three ACPs minus the irradiance measured by the PIR was 4.3 W/m^2 and sd 4.2 W/m^2, and the average irradiance difference measured by the KZ was 2.3 W/m^2 and sd 3.5 W/m^2.

2 Instrument List

- Absolute Cavity Pyrgeometer (ACP): 57F3, 95F3, and 96F3.
- PIR pyrgeometer: 31197F3
- KZ pyrgeometer: CGR4 110390

3 Measurement Equations

ACP

$$W = \frac{K_1 * V_{tp} + (2-\epsilon) * K_2 * W_r - (1+\epsilon) * W_c}{\tau}$$

Where,

- W is the atmospheric longwave irradiance ($W.m^{-2}$).
- K_1 is the reciprocal of the ACP's responsivity ($W.m^{-2}.uV^{-1}$).
- V_{tp} is the thermopile output voltage (uV).
- ϵ is the gold emittance.
- K_2 is the emittance of the black receiver surface.
- W_r is the receiver irradiance ($W.m^{-2}$).
- W_c is the concentrator irradiance ($W.m^{-2}$).
- τ is the ACP's throughput.

PIR

$$W = K_0 + K_1 * V_{tp} + K_2 * W_r + K_3 * (W_d - W_r)$$

Where,

- K_0, K_1 , K_2 , and K_3 are the calibration coefficients.
- W_d is the dome irradiance, in W/m^2.

KZ

$$W = \frac{V_{tp}}{C} + K_2 * W_c$$

Where C and K_2 are the calibration coefficients and W_c is the case irradiance.

4 Results

Figure 1 shows the irradiance of ACPs 57F3, 95F3, and 96F3; and Figure 2 shows the difference between the three ACPs' average irradiance and the irradiance measured by each ACP. Table 1 shows that the difference varied from 1.0 W/m^2 to 1.7 W/m^2, with a 95% confidence level.

Figure 3 shows the ACPs' average irradiance vs that of the PIR and KZ, as well as the PIR output thermopile voltage (V_{tp}). The V_{tp} is correlated to the net longwave irradiance, i.e., V_{tp} approaches zero when the sky gets cloudier. As is illustrated in the figure, the average irradiance of the ACPs is larger than that of the pyrgeometers when V_{tp} is less than -300 µV (i.e., during clear sky conditions), and smaller than irradiance measured by the pyrgeometers when V_{tp} is more than -300 µV (i.e. thin clouds). This behavior might be correlated to the spectral response of the pyrgeometers and the estimated precipitable water vapor (PWV), yet more comparisons and data might help in resolving this issue.

Figure 4 shows the estimated PWV vs the difference between the ACPs' average irradiance and the irradiance measured by the PIR pyrgeometer with traceability to WISG and the KZ pyrgeometer with traceability to the IRIS. As is shown in Table 2, the difference is 9.3 W/m^2 for the PIR and 7.3 W/m^2 for the KZ, with a 95% confidence level.

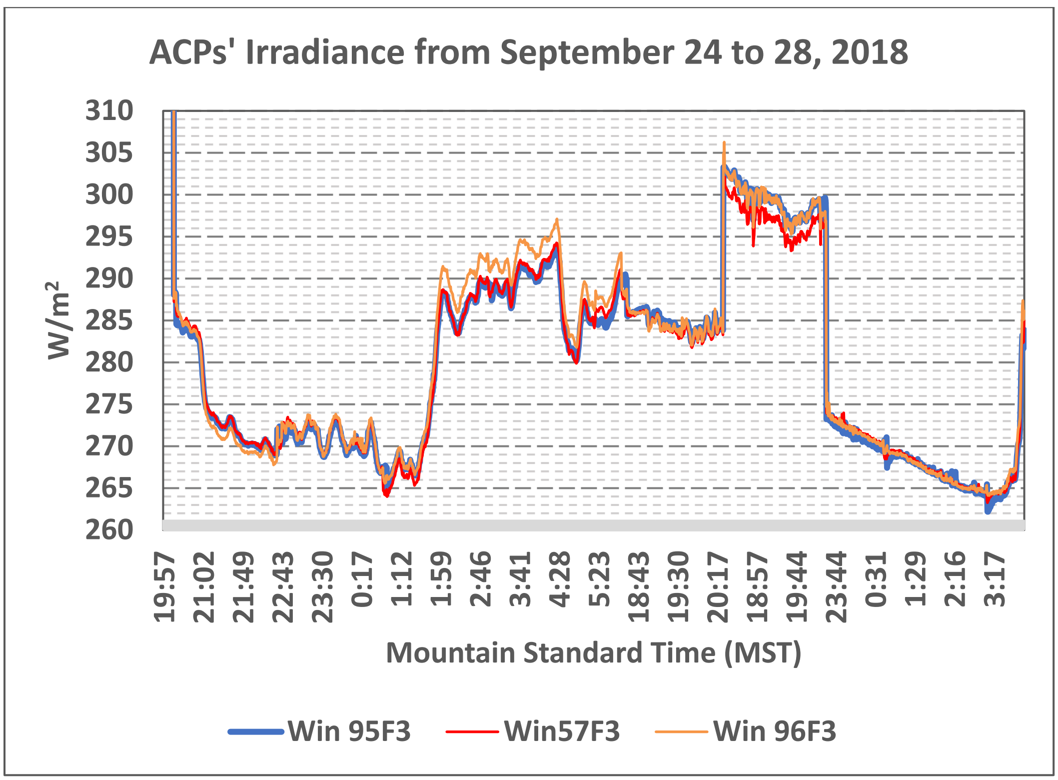

Figure 1. ACPs' irradiance

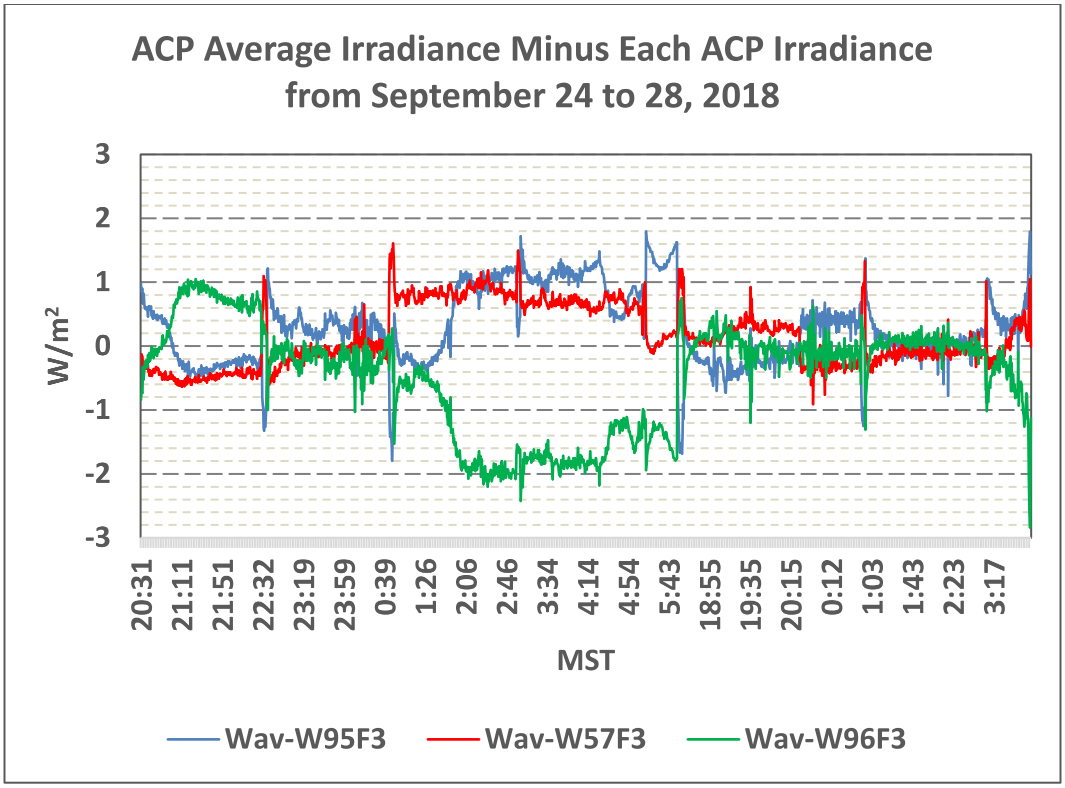

Figure 2. Average ACPs' irradiance minus the irradiance measured by each ACP

Table 1. Average ACPs' irradiance minus the irradiance measured by each ACP

	WavACPs - W(95F3)	WavACPs - W(57F3)	WavACPs - W(96F3)
av	0.3	0.2	-0.5
sd	0.6	0.5	0.8
U_{95}	1.2	1.0	1.7
nrdg	1754	1754	1754

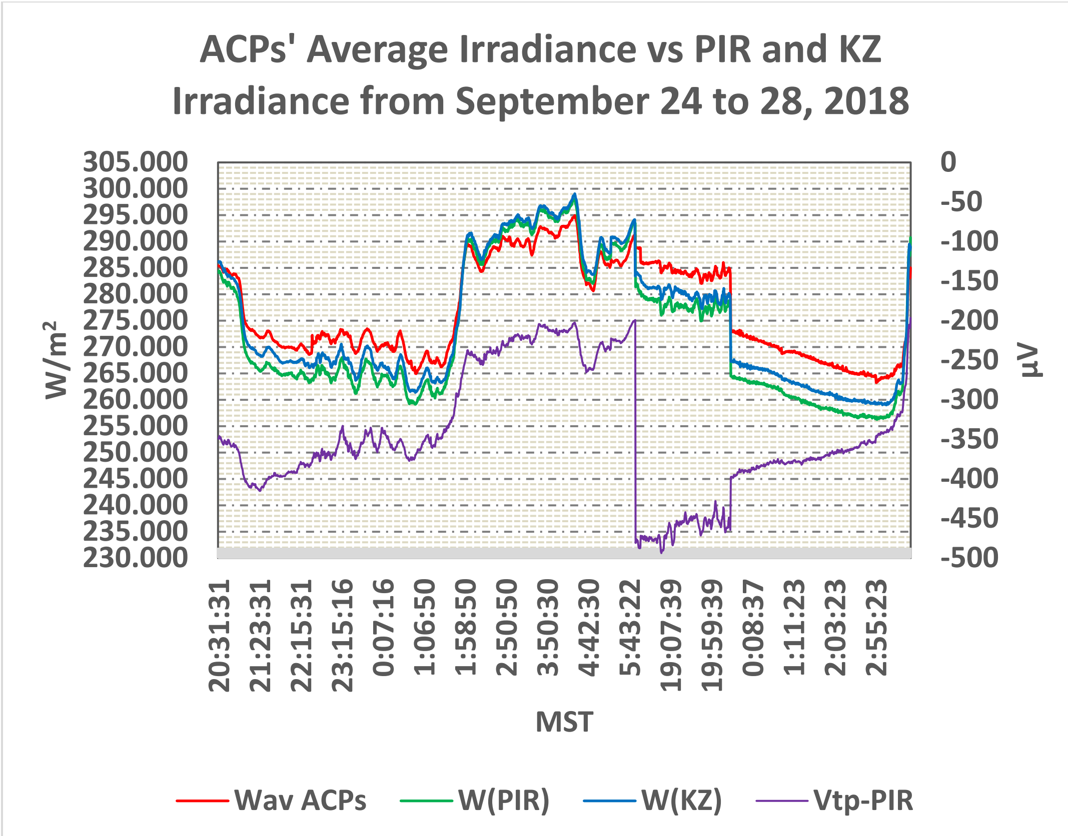

Figure 3. Average ACPs' irradiance vs irradiance measured by PIR and KZ

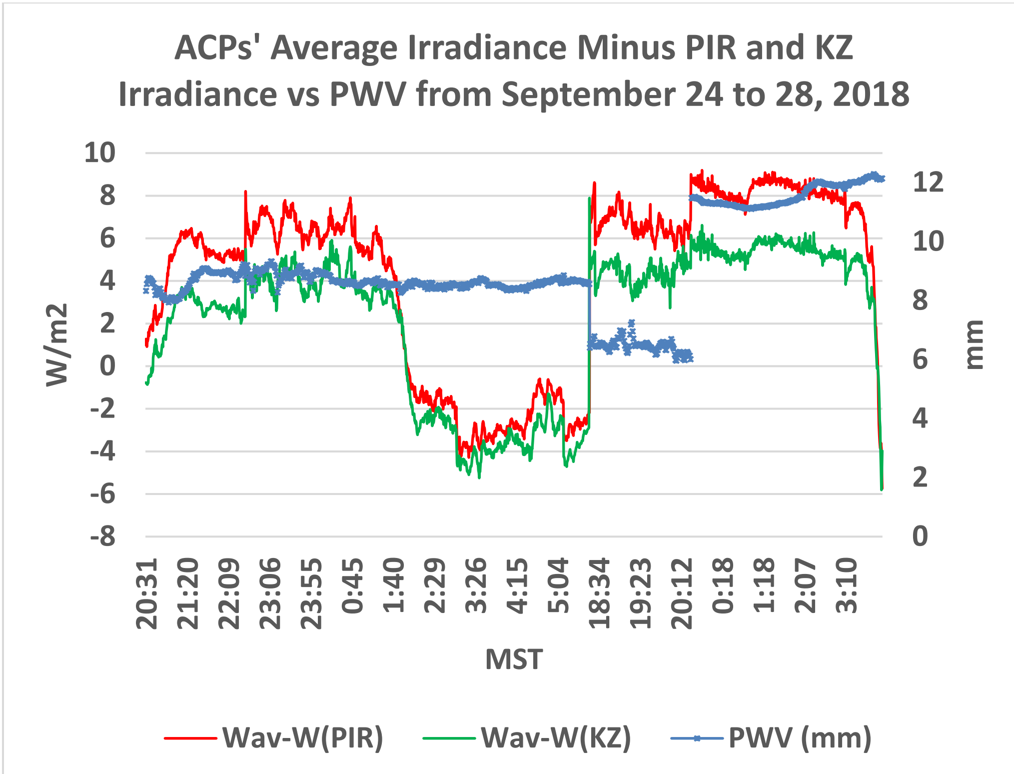

Figure 4. Average of ACPs' irradiance minus irradiance measured by PIR and KZ vs PWV

Table 2. Average ACPs' irradiance minus the irradiance measured by the PIR and KZ

	WavACPs - W(PIR)	WavACPs - W(KZ)
av	4.3	2.3
sd	4.2	3.5
U_{95}	9.3	7.3
nrdg	1754	1754