NREL Comparison of Absolute Cavity Pyrgeometers and Pyrgeometers Traceable to the World Infrared Standard Group and the Infrared Integrating Sphere: September 23-October 4, 2019

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National Renewable Energy Laboratory

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Technical Report
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NOTICE

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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 WISG and the InfraRed Integrating Sphere Radiometer (IRIS) was held during the National Renewable Energy Laboratory (NREL) Pyrheliometer Comparison (NPC-2019) from September 23 to October 4, 2019. Data from all instruments was collected during nighttime clear sky conditions only. The irradiance measured by the ACPs, PIR, and CG4 pyrgeometers collected 30 seconds during the measurement runs. The measurement runs lasted for two hours, while the calibration runs lasted for 6 minutes. During the comparison, the average (av) irradiance difference measured by three ACPs varied from 0.2 W/m^2 to 0.8 W/m^2, with a standard deviation (sd) from 0.4 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 7.1 W/m^2 and sd 1.0 W/m^2, and the average irradiance difference measured by the KZ traceable to WISG was 8.1 W/m^2 and sd 0.9 W/m^2, and average irradiance difference measured by the KZ traceable to IRIS was 4.0 W/m2 and sd 0.9 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. Figure 3 shows the ACPs' average irradiance vs that of the PIR and KZ traceable to WISG and the KZ traceable to IRIS. Figure 4 shows the difference between the ACPs' average irradiance and the irradiance measured by the PIR and KZ with traceability to WISG and KZ with traceability to IRIS. Figure 5 is the water vapor content during the comparison. Table 1 shows that the difference between the ACPs average irradiance and ACP95F3, ACP57F3, and ACP96F3 varied from -0.2 W/m^2 to 0.8 W/m^2 , and uncertainty from 1 W/m^2 to 1.7 W/m^2 with 95% confidence level (U_{95}). As is shown in Table 1, the difference is 7.0 W/m^2, 8.1 W/m^2, and 4.0 W/m^2 for the PIR and KZ with traceability to WISG and KZ with traceability to IRIS, and U_{95} of 7.3 W/m^2, 8.3 W/m^2 , and 4.3 W/m^2.

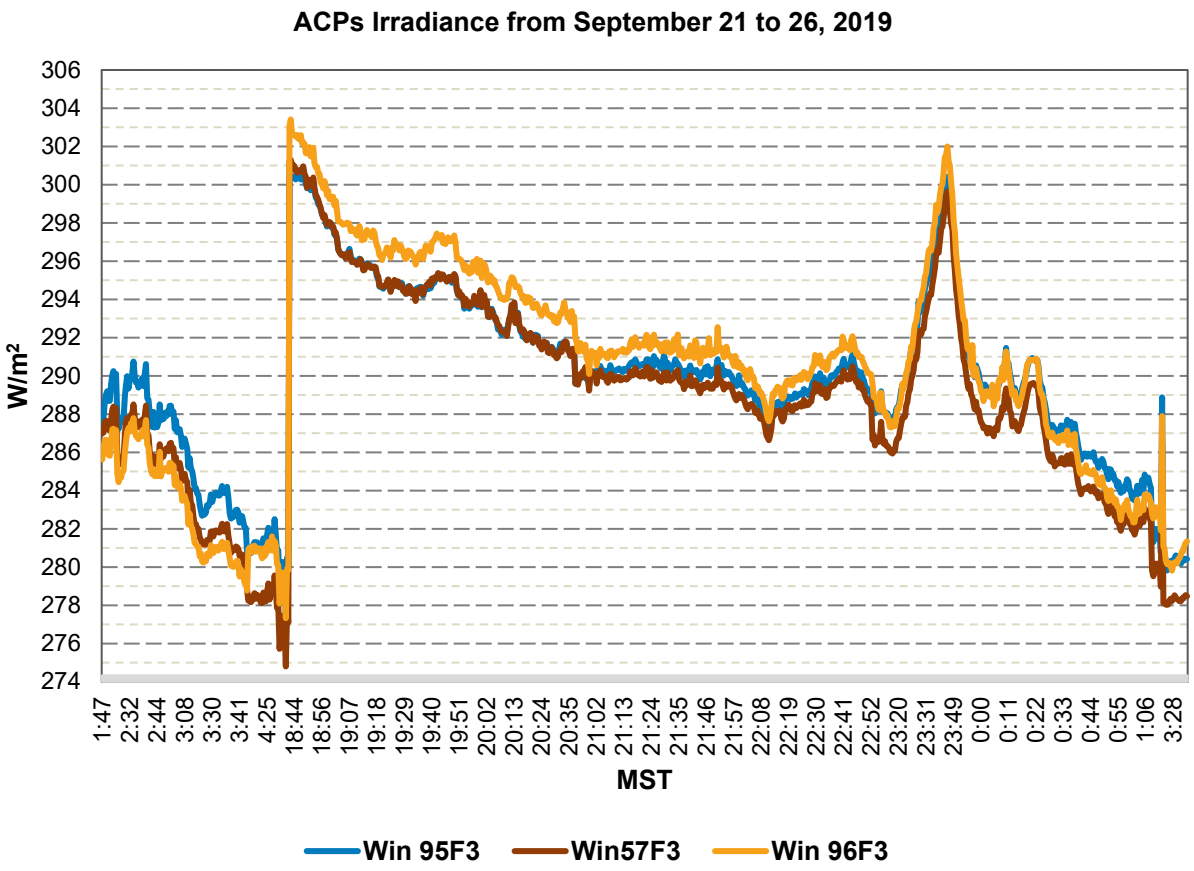

Figure 1. ACPs' irradiance

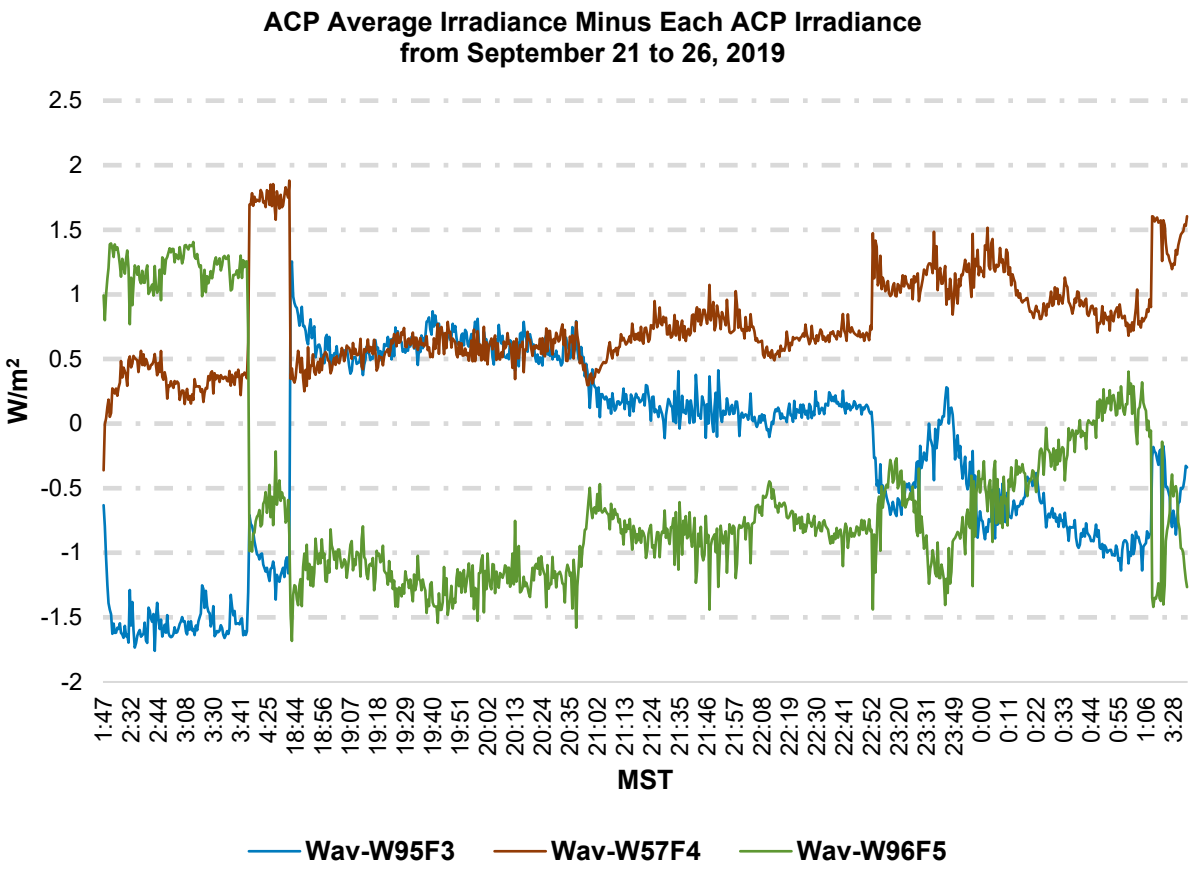

Figure 2. Average ACPs' irradiance minus the irradiance measured by each ACP

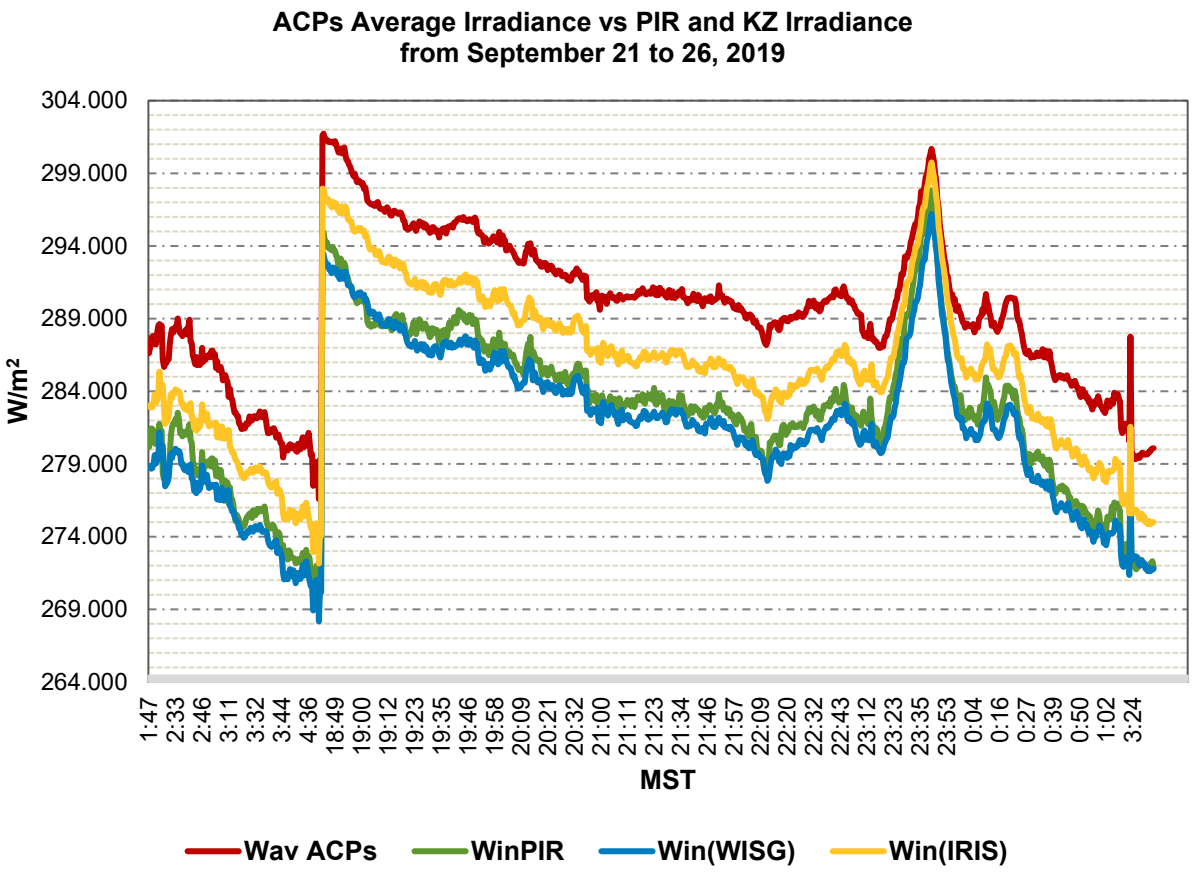

Figure 3. Average ACPs' irradiance vs irradiance measured by PIR and KZ

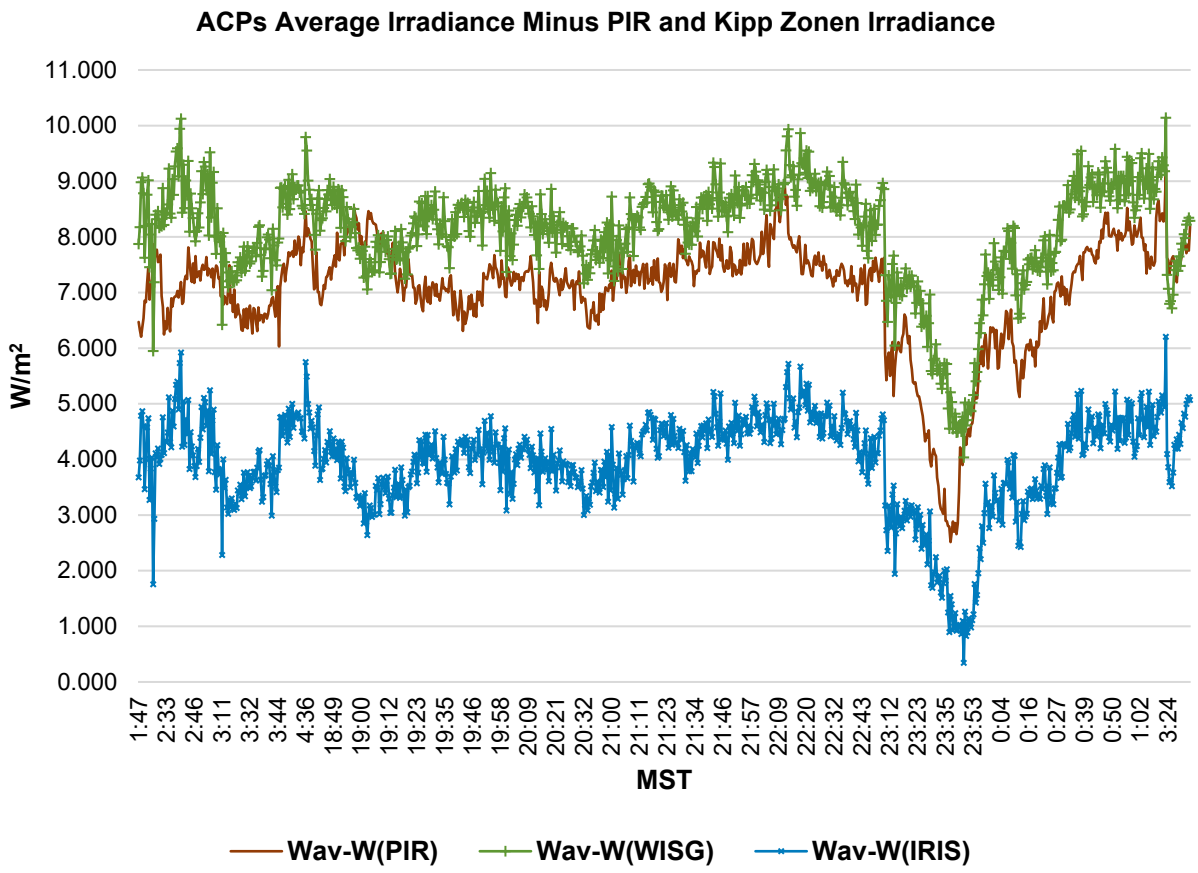

Figure 4. Average of ACPs' irradiance minus irradiance measured by PIR and KZ

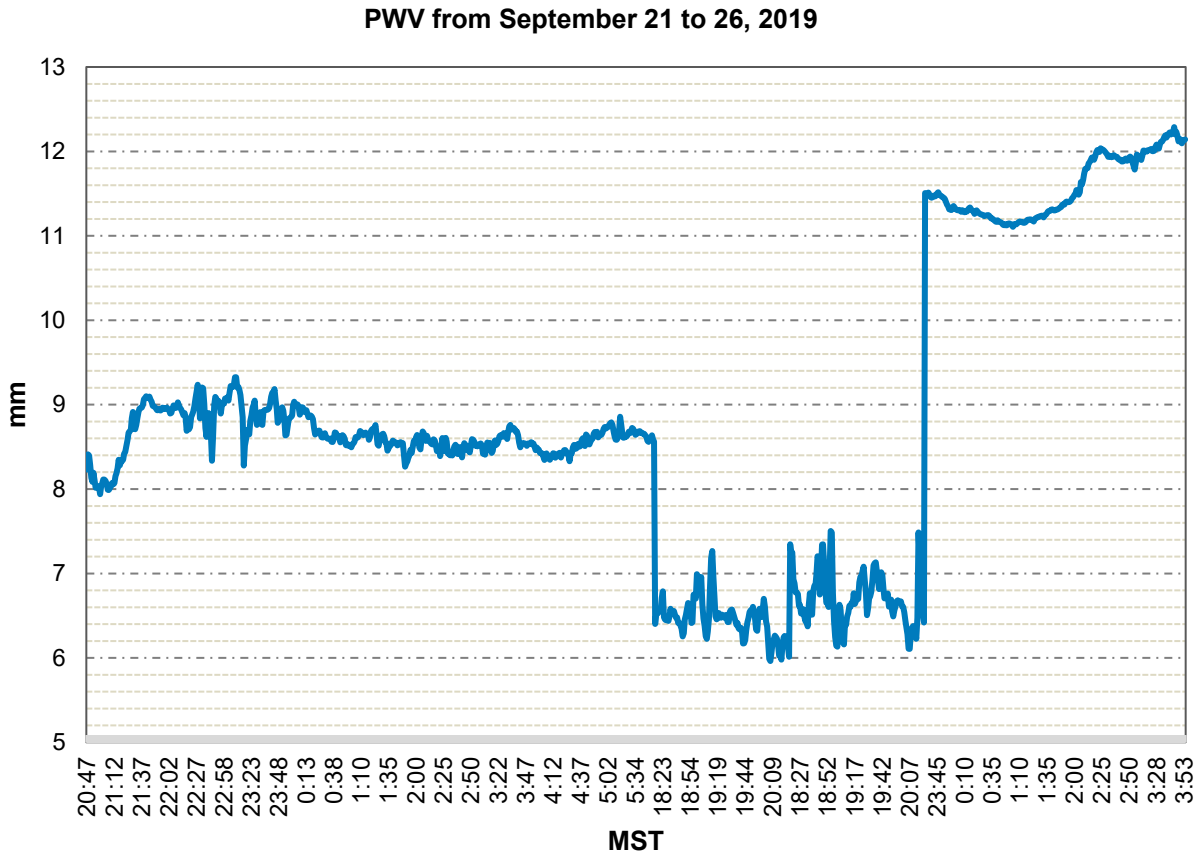

Figure 5. Water vapor content

Table 1. Average ACPs' Irradiance Minus the Irradiance Measured by Each ACP

W/m²	Wav-W95F3	Wav-W57F4	Wav-W96F5	Wav-W PIR	Wav-W(WISG)	Wav-W(IRIS)
av	-0.2	0.8	-0.5	7.0	8.1	4.0
sd	0.7	0.4	0.8	1.0	0.9	0.9
U_{95}	1.5	1.0	1.7	7.3	8.3	4.3
nrdg	**870**	**870**	**870**	**970**	**870**	**870**