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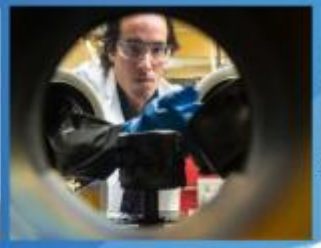


Absolute Cavity Pyrgeometer (ACP) and InfraRed Integrating Sphere (IRIS) Comparisons for CIMO Meeting in the National Physical Laboratory (NPL), UK

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Overview

- Why the ACP was developed.
- The ACP Measurement Equation.
- The Revised Calculation of the Throughput (τ).
- Field measurement process.
- Results of four comparisons between NREL's ACPs and POMD's IRISs.
- Absolute atmospheric-longwave-irradiance versus the Irradiance measured by PIR with traceability to WISG.

Why the ACP was Developed

Few years ago experimented with calibrating pyrgeometers outdoors independent from the traditional methods using blackbodies. The result of this experiment was published in 2006. The pyrgeometer was installed outdoor on aluminum plate connected to circulating temperature bath, by lowering the pyrgeometer's body temperature, while the incoming longwave irradiance is stable, the slope of the outgoing irradiance versus the pyrgeometer's thermopile output is the outdoor net irradiance responsivity (RS_{net}), independent of the absolute value of the atmospheric longwave irradiance. To evaluate this method, the calculated irradiance using the derived coefficients was compared to the irradiance measured using a pyrgeometer with traceability to the World Infrared Standard Group (WISG). Based on results from four pyrgeometers calibrations, the method agreed with the WISG within ±3W/m^2 for all sky conditions.

Why ACP: When the article was reviewed, reviewers suggested removing the word ABSOLUTE since the Pyrgeometers had domes.

Reference: I. Reda, J. R. Hickey, J. Grobner, A. Andreas, T. Stoffel. "Calibrating Pyrgeometers Outdoors Independent from the Reference Value of the Atmospheric Longwave Irradiance". *Journal of Atmospheric and Solar-Terrestrial Physics*, Vol. 68 (12) August 2006 pp. 1416-1424.

The Measurement Equation

Since $W_{net} = W_{in} - W_{out}$, then,

$$K_1 * V_{tp} = \tau * W_{atm} + (1+\varepsilon) * W_c - (2-\varepsilon) * K_2 * W_r$$

- By cooling the ACP case temperature, and since W_{atm} is stable, then,

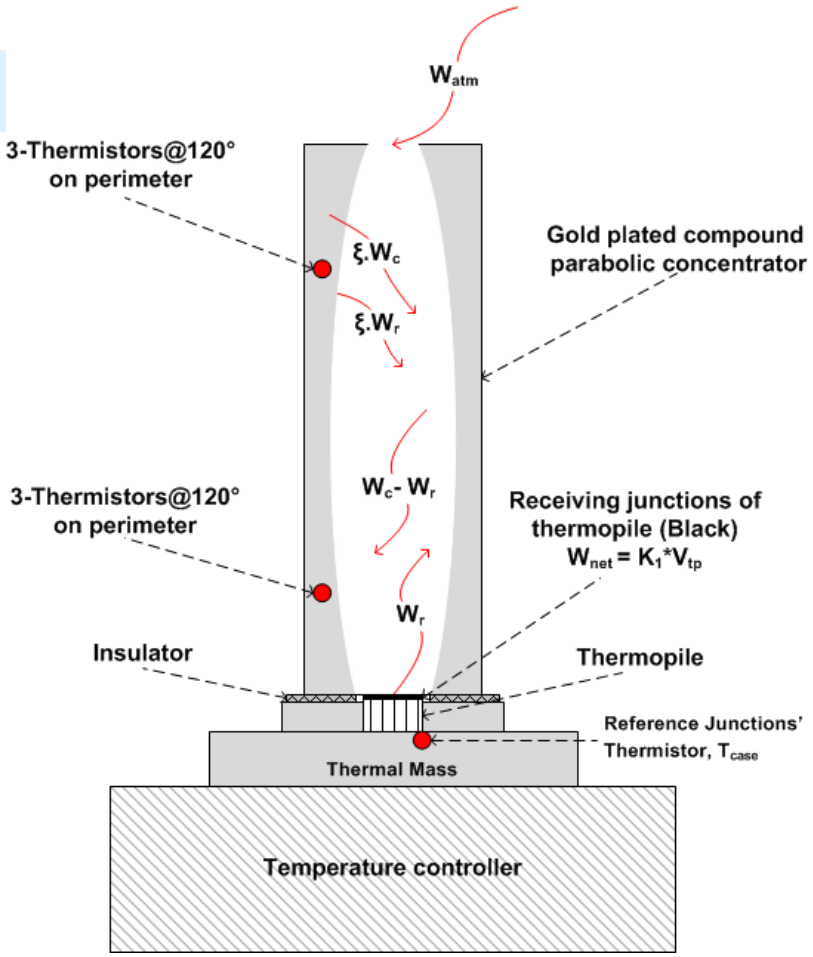
$$K_1 = \frac{(1+\varepsilon) * \Delta W_c - (2-\varepsilon) * K_2 * \Delta W_r}{\Delta V_{tp}}$$

- Then the atmospheric longwave irradiance is,

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

where:

- W_{atm} 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 = 0.02925
- 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, NIST characterization



Reference: Reda, I.; Zeng, J.; Schulch, J.; Hanssen, L.; Wilthen, B.; Myers, D.; Stoffel, T. Dec. 2011. "An absolute cavity pyrgeometer to measure the absolute outdoor longwave irradiance with traceability to International System of Units, SI". *Journal of Atmospheric and Solar-Terrestrial Physics, 77 (2012) 132-143.* http://dx.doi.org/10.1016/j.jastp.2011.12.011

The Revised Calculation of the Throughput

- τ is the ACP's throughput
  - During NIST characterization τ was calculated using $K_1 = 0.2667$, which resulted in τ values from 90.1% to 93.5%.
  - Since the pyrgeometer has no dome, the correct K_1 value was given to NIST to recalculate τ with $K_1 = 0.0784$, which resulted in τ = 99%.

Reference: Z. Jinan, L. Hanssen, I. Reda, J. Scheuch. "Preliminary Characterization Study of a Gold-Coated Concentrator for Hemispherical Longwave Irradiance Measurements". Reflection, Scattering, and Diffraction from Surfaces II: Proceedings of SPIE Conference, 3-5 August 2010, San Diego, California 12 pp.

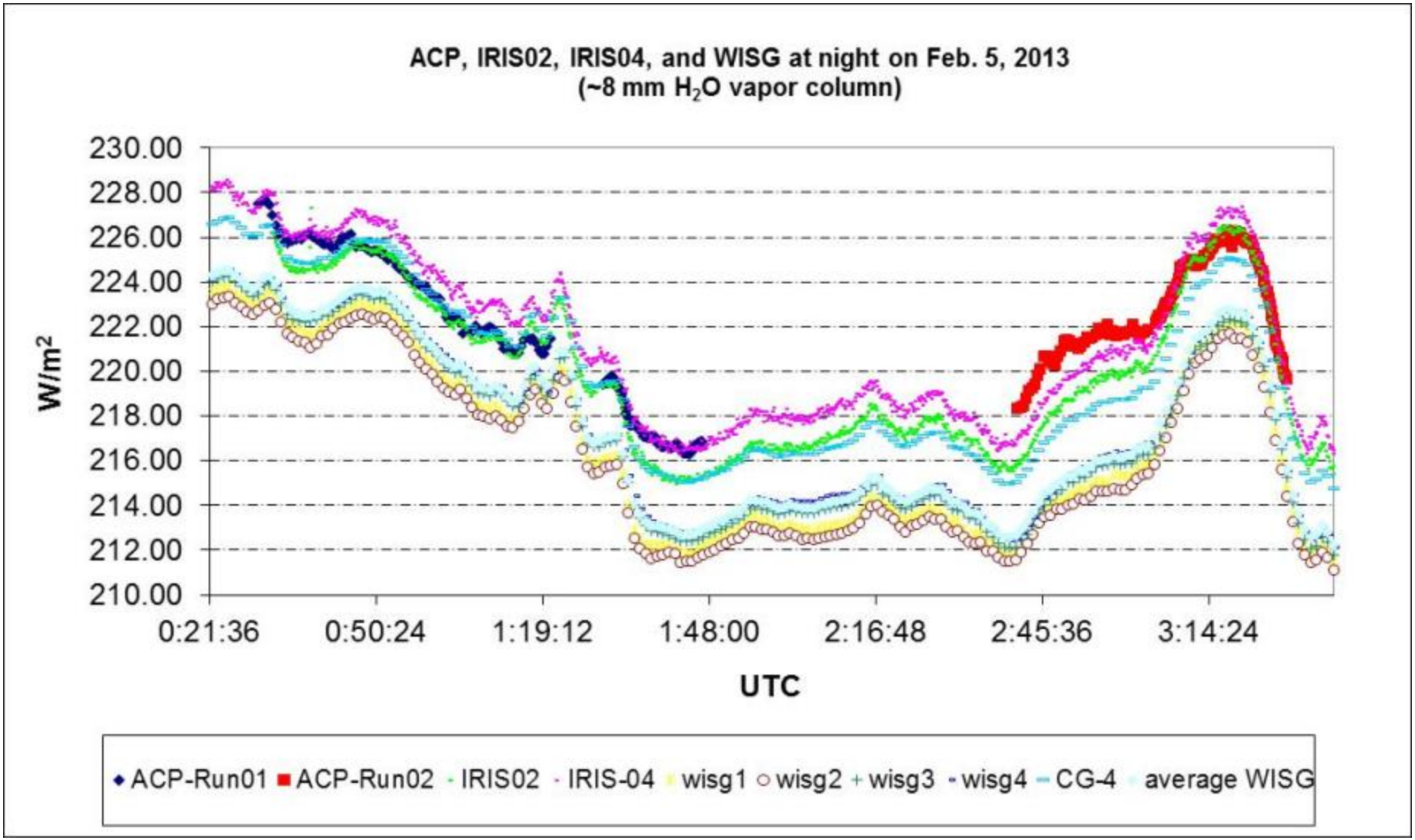
Field Measurement process

1. The ACP is deployed outdoor under clear sky conditions.
2. Once stabilized with the outdoor environmental conditions, the self calibration starts to calculate K_1.
3. K_1 is then used to calculate τ (see ACP article),

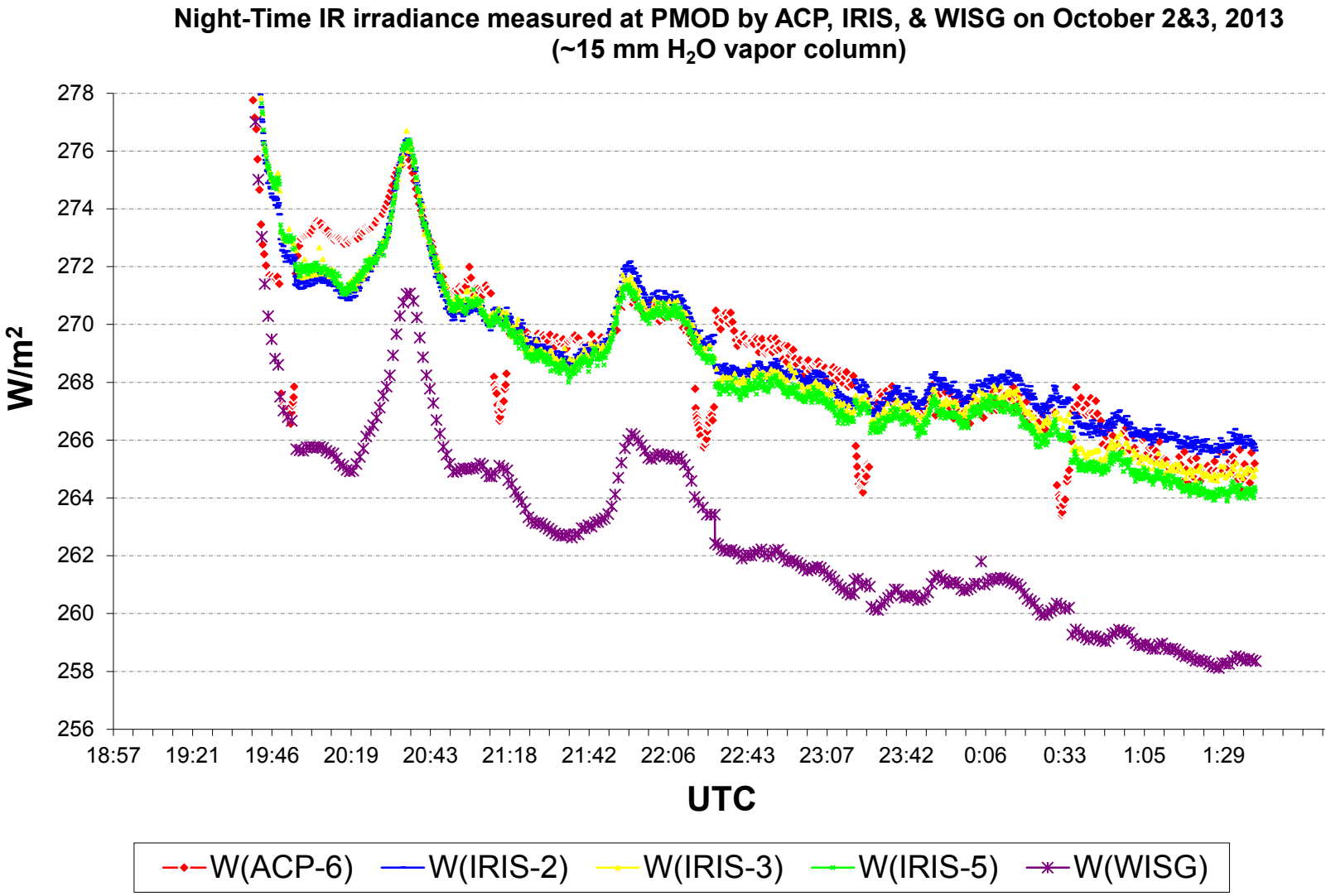
$$\tau = \frac{0.004903 * K_1 + .004419}{.007548 * K_1 + .004242}$$

4. The atmospheric longwave irradiance is then calculated using the Measurement Equation in slide 4.
5. Steps 2 through 4 are repeated every 1 to 2 hours based on the outdoor conditions.

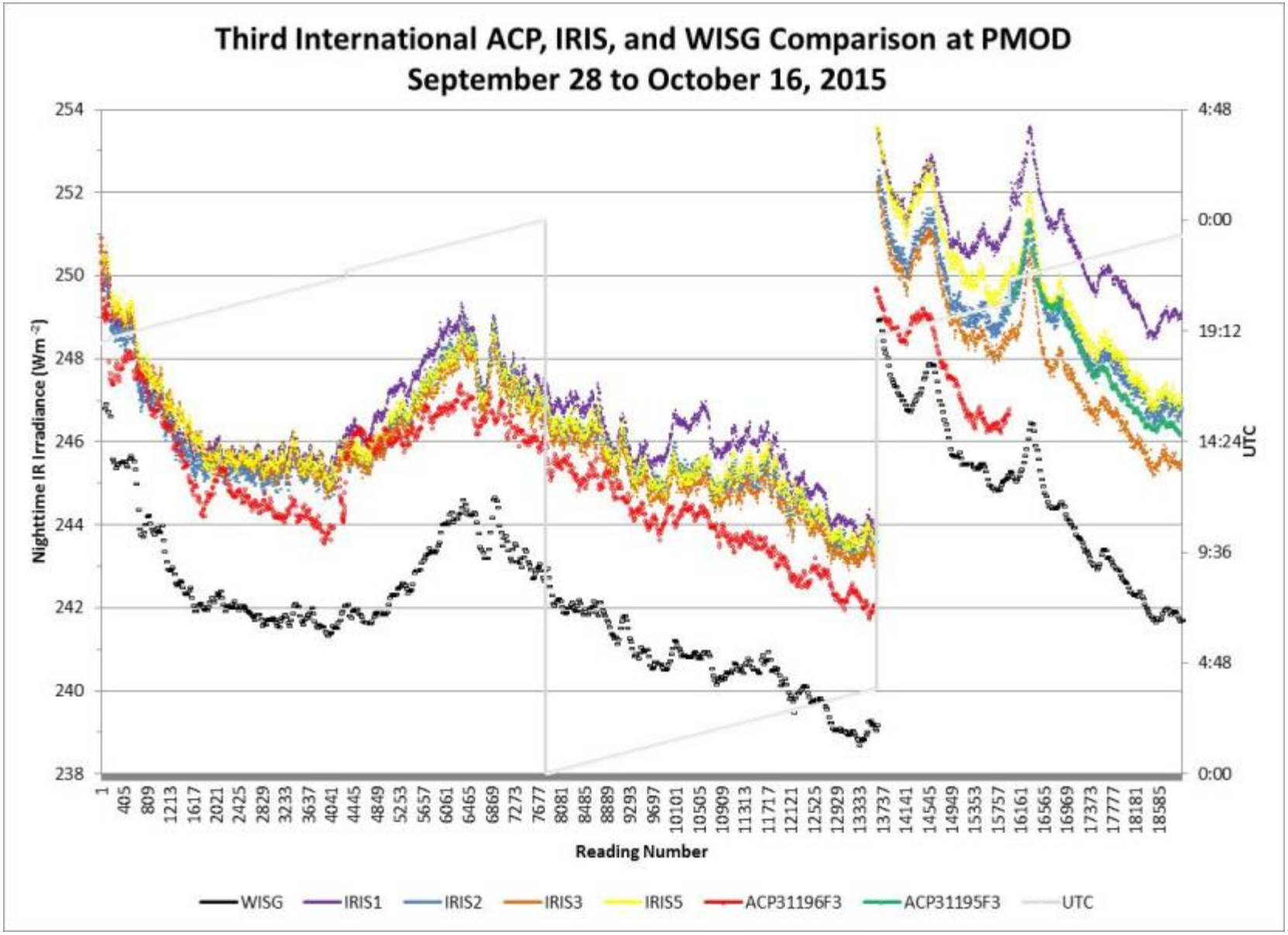
Results of First Comparison between ACPs and IRISs-Davos



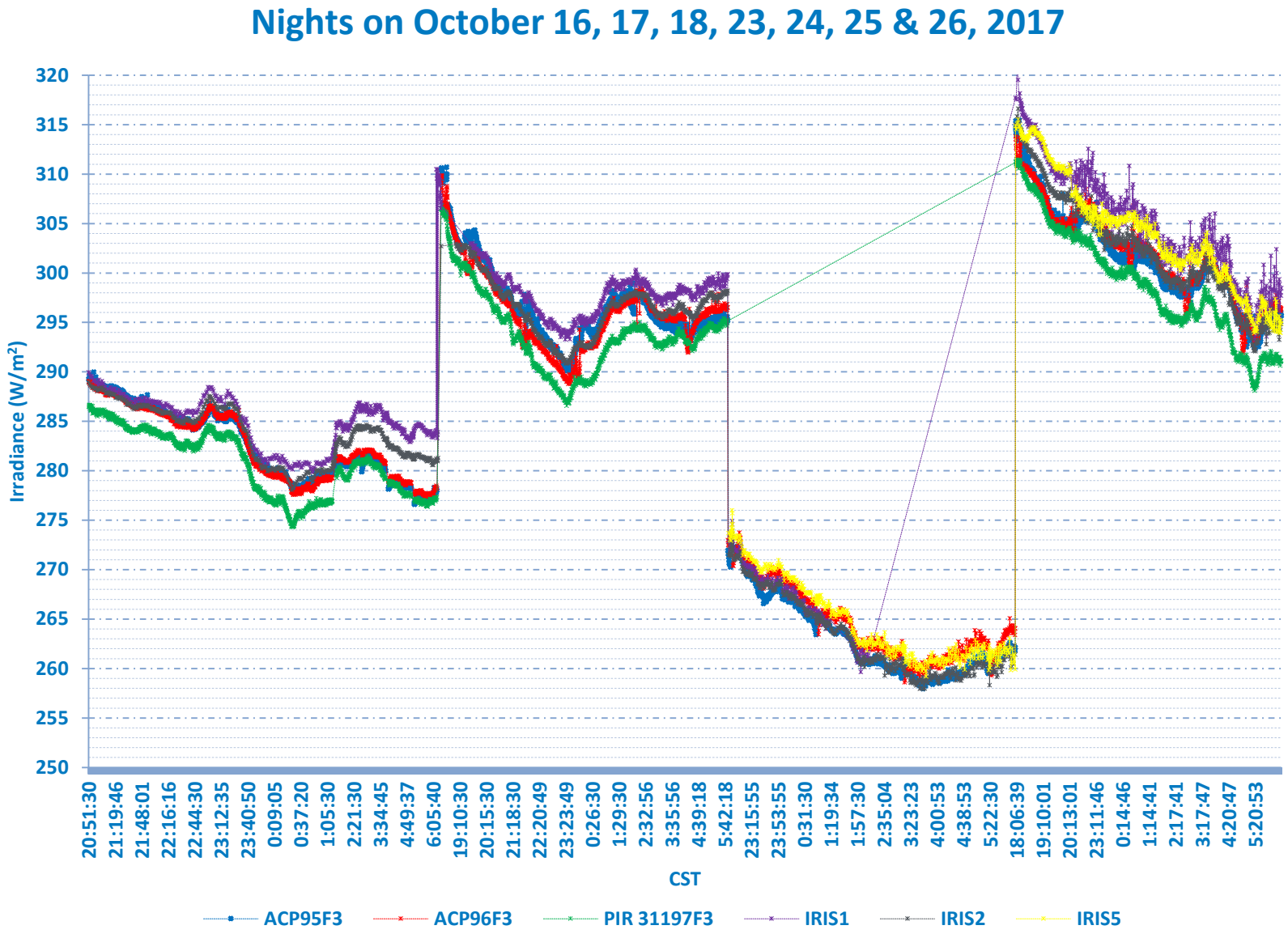
Results of Second Comparison between ACPs and IRISs-Davos



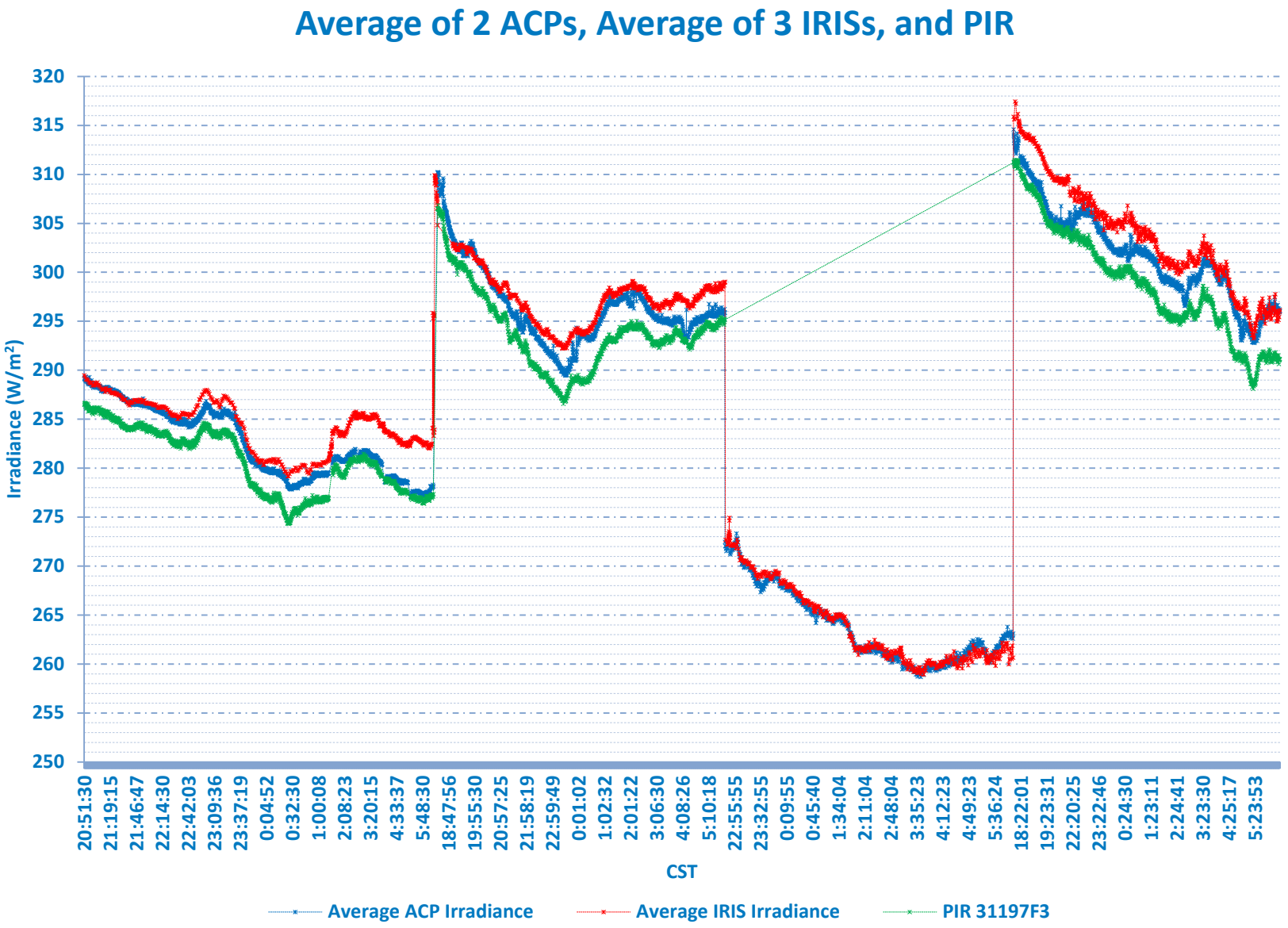
Results of Third Comparison between ACPs and IRISs-Davos



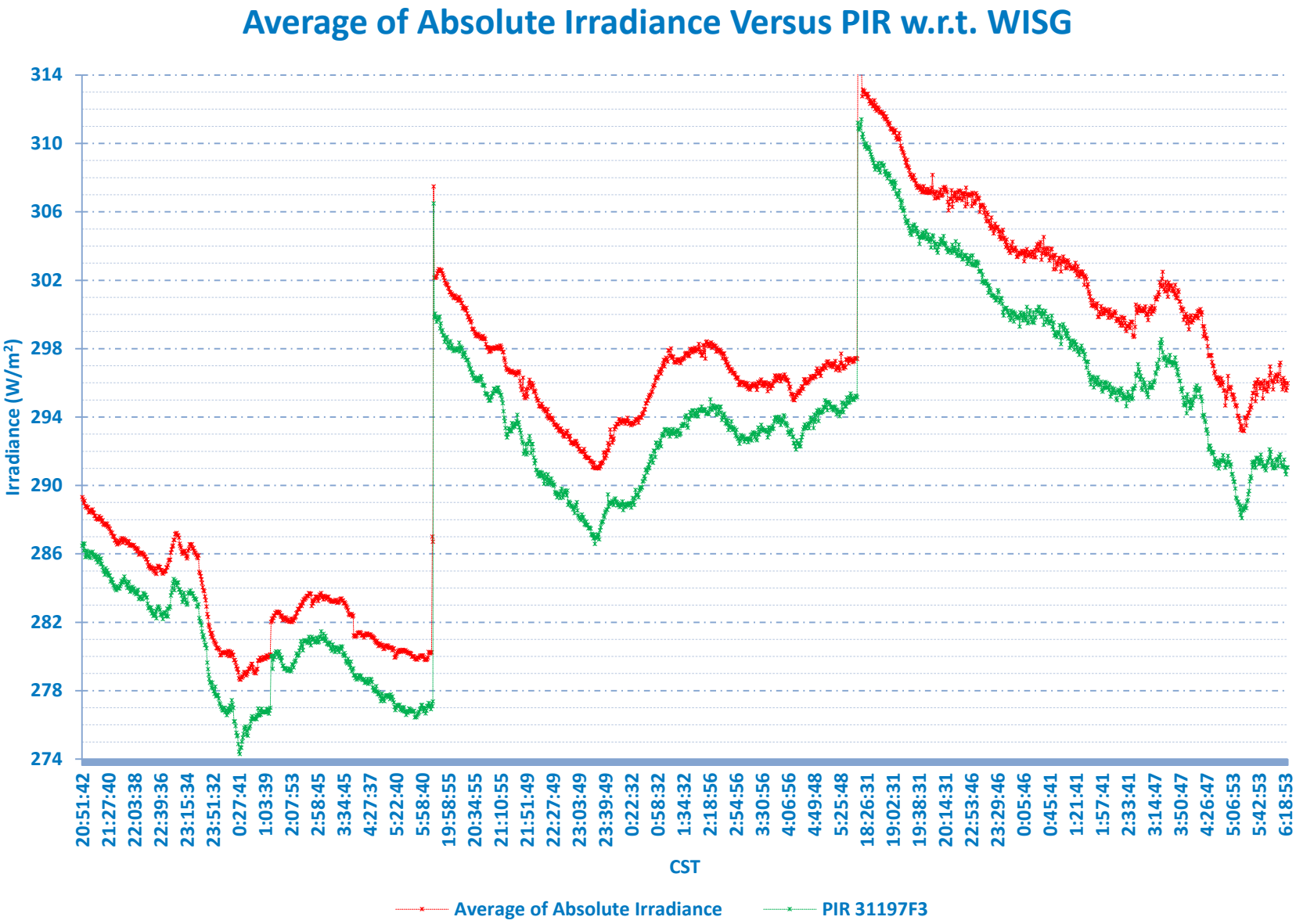
Results of Fourth Comparison between ACPs and IRISs-SGP



Results of Fourth Comparison between ACPs and IRISs-SGP, cont.



Results of Fourth Comparison between ACPs and IRISs-SGP, cont.



Conclusion

- *The difference between the irradiance measured by the ACPs and the IRISs is within ± 3 W/m^2, which is within the stated uncertainties of the ACPs and IRISs.*

- *The irradiance measured by the PIR with traceability to WISG is lower than the absolute atmospheric-longwave-irradiance by 3-5 W/m^2.*

Set-up at DOE-ARM-SGP

Julian, Craig (SGP), Mike (NREL), Allison, and Chuck

PIR, ACPs, IRISs, PIRs, and CG4s

Fifth comparison will be held at SGP from November 27th to December 8th, 2017