A Study of IR Loss Correction Methodologies for Commercially Available Pyranometers

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IR Loss In Pyranometers

- IR loss introduces a bias error in solar irradiance measurements
- ARM has been using the Younkin and Long (2004) methodology for IR loss correction
  - Methodology was developed using ARM data with 120V AC ventilator fans known to increase IR loss
  - ARM has more recently switch to 12V DC fans with smaller magnitude IR loss
- Questions:
  - How well does the Y&L2004 methodology correct IR loss with DC fans and does the daylight enhancement factor still apply?
  - What are the IR loss characteristics of other commercially available pyranometer models?
  - How effective are various permutations of IR loss correction methodologies for the various models of pyranometers?
  - How well does the use of an average RSnet and "effective" instrument net IR as used in BORCALs correct for IR loss?

Younkin K and CN Long. 2004. "Improved Correction of IR Loss in Diffuse Shortwave Measurements: An ARM Value Added Product." Atmospheric Radiation Measurement Program Technical Report, ARM TR-009. Available via http://www.arm.gov.

IR Loss Correction Study

NOAA ESRL GMD and NREL SRRL are collaborating on a campaign to study the IR loss magnitude and various correction methodologies for the more commonly used makes/models of pyranometers operating in both free air and forced ventilation modes.

Model	Ventilation	Provider
PIR	Ventilated DC	SRRL
PIR	Ventilated AC	SRRL
PIR	Unventilated	SRRL
CGR4	Ventilated DC	SRRL
CG4	Unventilated	SRRL
SR-75	Ventilated DC	NOAA
SR-75	Unventilated	NOAA
MS-80	Ventilated	SRRL
MS-80	Unventilated	SRRL
PSP	Ventilated DC	SRRL
PSP	Ventilated AC	SGP
PSP	Unventilated	SGP
CMP 11	Ventilated DC	SRRL
CMP 11	Unventilated	SRRL
CMP22	Ventilated DC	SRRL
CMP22	Unventilated	SRRL
SR-25	Unventilated	SRRL
Direct CHP1	N/A	SRRL
Diffuse B&W	Ventilated DC	SRRL
Diffuse CMP22	Ventilated DC	SRRL

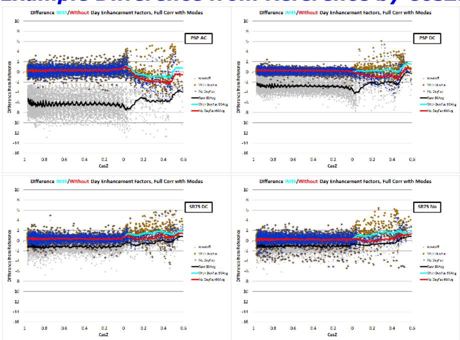
Table 1: Instruments used in study and ventilation

- Reference instruments are DC ventilated, test instruments are DC ventilated and non-ventilated, with one PSP AC ventilated
- Test methodologies include:
  - All-data detector only
  - All-data detector plus case-dome temperature difference term
  - Above , but also using wet/dry modes separate fits and corrections
  - Above with and without the day time enhancement factor of Younkin and Long
  - NREL average RSnet and an "effective" pyrgeometer detector instrument net IR
  - Calibration formula by SZA determined during the BORCAL process

Preliminary Results

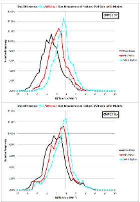
The data collection is still ongoing. Analysis of data to date shows at night (SZA > 100°) moist mode has occurred about 10-11% of the time, while day (SZA < 80°) data screened for no direct SW has 50% occurrence of moist mode. For these analyses we use the shaded Eppley 8-48 "Black & White" as the reference.

Example Difference from Reference by CosZ:



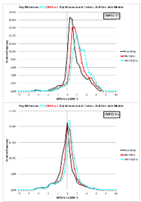
As in the ARM original configuration of PSP with a 120V AC fan in the ventilator (upper left) the day time enhancement factor significantly improves the daytime correction (light blue running average) compared to no enhancement factor (red). While the magnitude of the IR loss is significantly reduced (black) using a 12V DC fan (upper right) compared to the AC fan, the use of the day time enhancement factor still significantly improves the day time IR loss correction for PSPs. By comparison these SpectraSun SR75 pyranometers used for global SW by SURFRAD exhibit even less IR loss whether with a DC fan (lower left) or no ventilator (lower right), and in this case use of a day time enhancement factor over-corrects for IR loss during daytime in either case, with no day time enhancement giving best results.

Example Difference Frequency Histograms:



Examples of frequency of differences from the reference for daytime for CMP11 with DC fan (top) and no ventilator (bottom) for raw (black) and with (blue) and without (red) daylight enhancement factor.

For the model CMP11 pyranometers, again use of the daylight enhancement factors significantly improves the correction for both DC ventilated (top left) and non-ventilated (bottom left). On the other hand, the test CMP22s (right) have very little IR loss at all, and applying any IR loss corrections ends up over correcting for a virtually non-existent IR loss problem, particularly for the DC ventilated unit (top) but also for non-ventilated (bottom).



Examples of frequency of differences from the reference for daytime for CMP22 with DC fan (top) and no ventilator (bottom) for raw (black) and with (blue) and without (red) daylight enhancement factor.

Summary

The IR Loss Corrections Study is investigating how various correction methodologies work for several makes and models of commercially available pyranometers in common use, both when operated in ventilators with DC fans and without ventilators, as when they are typically calibrated. Preliminary results so far suggest:

- The current ARM IR loss correction VAP methodology works well for the newer ARM paradigm of using DC fan ventilation

We will be continuing the study through spring, and additional analysis will include the various NREL methodologies, and use of the CGR4 pyrgeometer which does not have a dome temperature thus only detector-only correction methodologies can be applied.

Tabulated Results

Method		000_DC	CMP11_DC	CMP22_DC	PSP_AC	PSP_DC	SR75_DC	000_No	CMP11_No	CMP22_No	PSP_No	SR25_No	SR75_No
Det All No	Mean	1.851	-2.434	1.539	-2.309	-0.948	0.489	0.077	-1.489	-0.053	1.943	1.199	0.508
	StDev	1.681	1.719	1.82	1.716	1.967	1.888	1.959	2.068	1.874	2.616	1.786	1.991
Full All No	Mean	2.092	-2.349	1.726	-1.956	-1.4	0.958	0.131	-1.527	-0.078	1.879	1.224	0.543
	StDev	1.668	1.698	1.784	2.583	1.962	1.772	2.071	2.123	1.864	2.431	1.81	2.03
Det Modes No	Mean	1.961	-2.014	1.703	-1.608	-0.654	0.594	0.059	-1.392	0.009	2.088	1.134	0.542
	StDev	1.644	1.834	1.799	2.131	2.017	1.868	1.963	2.061	1.866	2.652	1.784	2.007
Full Modes No	Mean	2.014	-1.911	1.828	-1.835	-0.903	0.864	0.277	-1.579	-0.08	1.736	1.512	0.781
	StDev	1.716	1.8	1.763	2.437	2.044	1.808	2.113	2.134	1.863	2.478	1.876	2.066
Det All DyAdj	Mean	1.866	-2.118	1.706	-1.042	-0.481	0.72	0.069	-1.159	0.103	2.338	1.213	0.726
	StDev	1.687	1.677	1.845	1.825	1.862	1.92	1.955	2.049	1.902	2.644	1.787	2.012
Full All DyAdj	Mean	2.239	-1.518	2.227	-1.434	-0.462	1.755	0.367	-0.91	0.211	2.278	1.731	1.371
	StDev	1.718	1.667	1.874	2.484	1.922	1.908	2.203	2.089	1.914	2.397	2.001	2.27
Det Modes DyAdj	Mean	2.02	-1.528	1.934	-0.058	-0.068	0.866	0.044	-1.024	0.191	2.541	1.123	0.774
	StDev	1.638	1.812	1.808	2.235	1.889	1.886	1.962	2.029	1.887	2.677	1.784	2.026
Full Modes DyAdj	Mean	2.169	-0.854	2.364	-0.692	0.352	1.669	0.696	-1.029	0.209	2.011	2.329	1.904
	StDev	1.799	1.702	1.818	2.782	1.924	2.017	2.412	2.082	1.903	2.515	2.353	2.486
Raw Data	Mean	1.815	-3.228	1.123	-5.478	-2.114	-0.088	0.099	-2.315	-0.444	0.956	1.162	-0.041
	StDev	1.668	2.01	1.813	2.774	2.537	1.905	1.968	2.319	1.858	2.805	1.783	2.031

The frequency analysis includes calculation of the average (white cells) and standard deviations (gray cells) of the difference from reference for all instruments tested, given in the above table for the day time data. Yellow highlights are the smallest average difference for that instrument and ventilation mode. The test "0000", CMP22, and SR75 with DC fans; and PSP and SR75 with no ventilator, worked best on average with no IR loss correction. All the rest, except for the CMP22 with no ventilator, saw significant improvement in day time corrections when including the daylight enhancement factor.

Method		000_DC	CMP11_DC	CMP22_DC	PSP_AC	PSP_DC	SR75_DC	000_No	CMP11_No	CMP22_No	PSP_No	SR25_No	SR75_No
Det All No	Mean	0.335	0.328	0.29	0.065	0.299	0.313	0.364	0.377	0.325	0.146	0.393	0.323
	StDev	0.727	0.526	0.45	1.291	0.522	0.919	0.866	0.639	0.396	1.182	1.389	1.02
Full All No	Mean	0.361	0.316	0.304	0.256	0.198	0.366	0.318	0.435	0.335	0.238	0.157	0.176
	StDev	0.617	0.478	0.35	0.801	0.526	0.706	0.774	0.584	0.389	0.985	1.173	0.923
Det Modes No	Mean	0.356	0.374	0.3	0.126	0.321	0.321	0.368	0.394	0.321	0.122	0.3	0.249
	StDev	0.723	0.443	0.43	1.036	0.473	0.914	0.867	0.627	0.385	1.17	1.387	1.011
Full Modes No	Mean	0.356	0.377	0.315	0.277	0.264	0.36	0.325	0.432	0.334	0.214	0.159	0.214
	StDev	0.59	0.421	0.357	0.741	0.461	0.675	0.704	0.587	0.393	0.944	1.057	0.859
Raw Data	Mean	0.239	-1.748	-0.804	-6.222	-2.735	-1.202	0.417	-1.645	-0.661	-2.367	0.289	-1.071
	StDev	0.719	0.519	0.454	1.738	1.092	0.993	0.87	0.876	0.436	1.469	1.386	1.114

All methods worked about equally well in correction for IR loss at night. This is not surprising since the night data is used to determine each method's correction coefficients.

2017 ARM/ASR PI Meeting
Vienna, Virginia
March 13-16, 2017
NREL/PO-5D00-68117