Characteristics and Corrections of Thermal Offset for Secondary Standard Pyranometers

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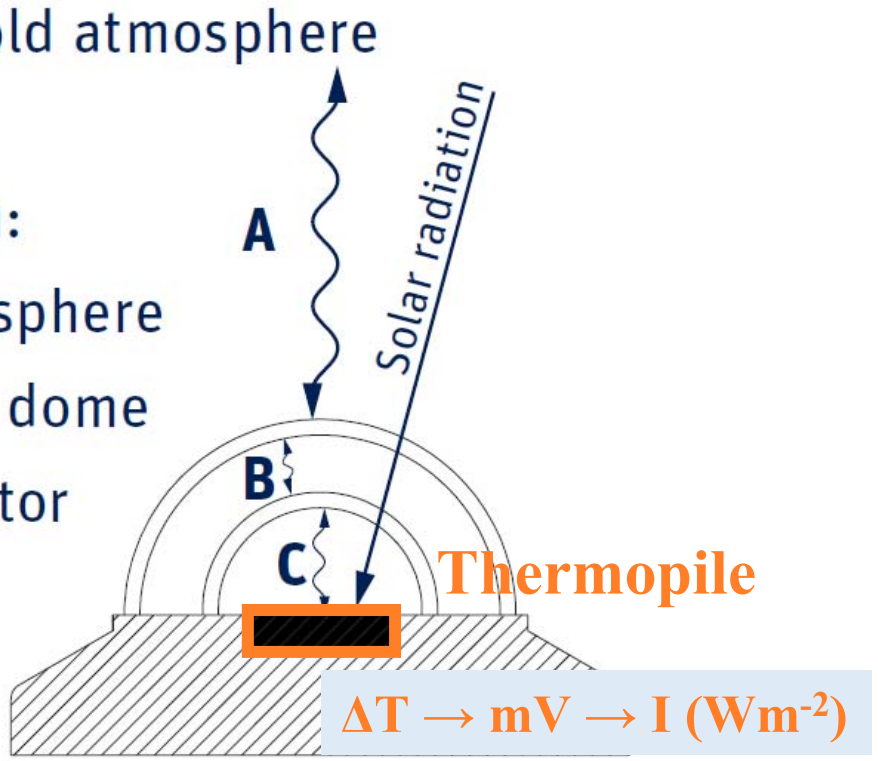
What Is Thermal Offset?

Thermal exchange between:

A Outer dome and atmosphere

B Inner dome and outer dome

C Inner dome and detector



The thermal offset is hidden within the solar radiation signal!

Inter-comparison Experiment

- We carried out an pyranometer inter-comparison experiment at NCU in cooperation with NOAA and manufactures from December 2017 to March 2018.

Objectives:

1. **To investigate the characteristics of thermal offset for different pyranometer models**
2. **To investigate the performance of different correction methods for those pyranometers**

Site: NCU solar radiation Platform

WMO standard

NCU solar radiation Platform & Lab

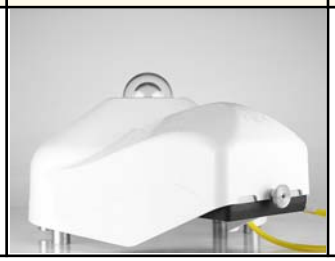
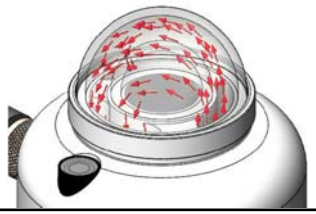
Lat: 24.97 ˚N, Lon: 121.19 ˚E; Alt: 170 m

Site: NCU solar radiation Platform

WMO standard

NCU solar radiation Platform & Lab

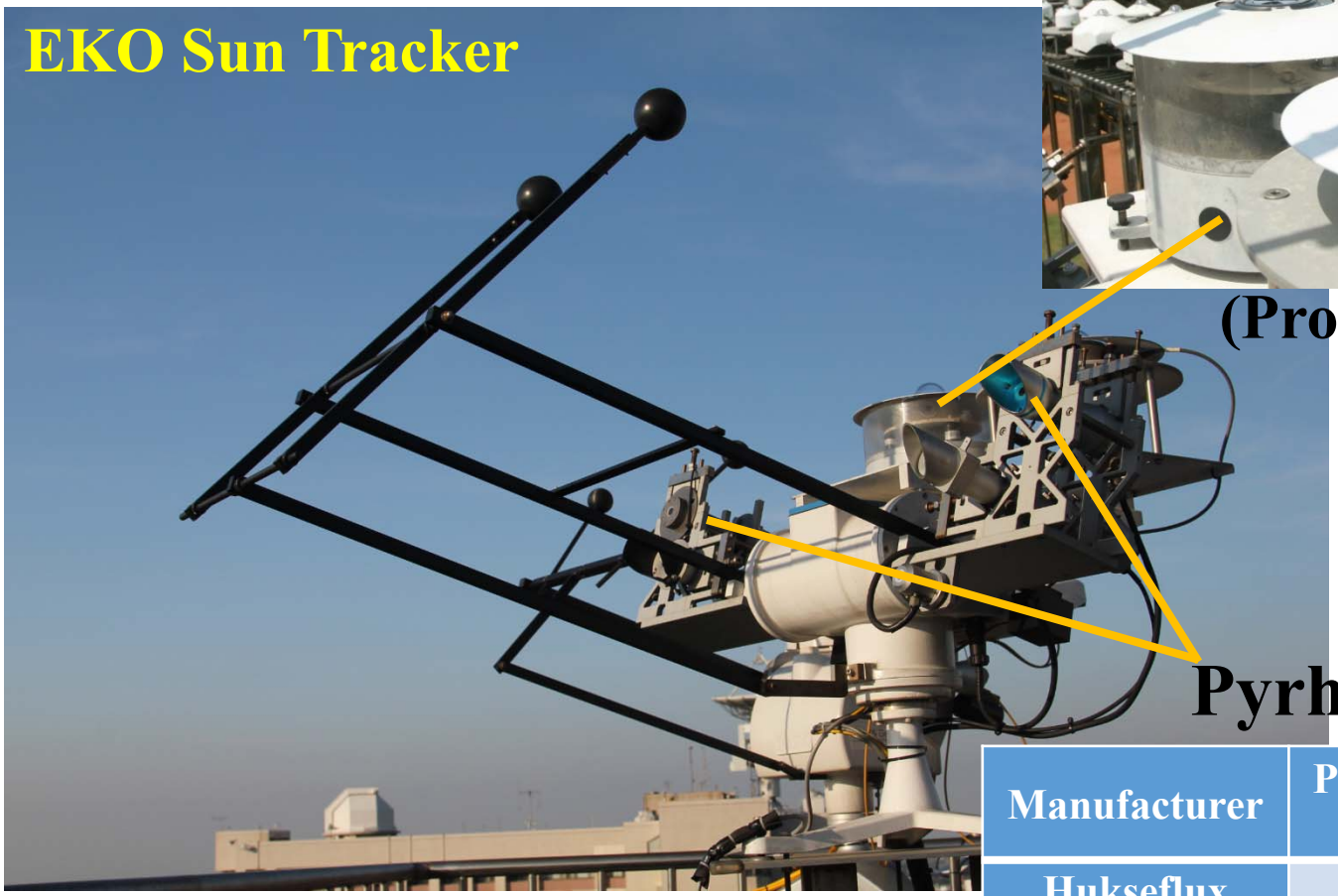
Pyranometers

Pyranometer	CMP22	SR30-D1	SR25-T2	MS-80
Spectral range (nm)	200 to 3600	285 to 3000	285 to 3000	285 to 3000
Inner dome material	Quartz	Glass	Glass	N/A
Outer dome meterial	Quartz	Glass	Sapphire	Glass
Ventilation unit (DC) 				

Reference Units

Shaded Pyranometer

(Provided by NOAA)



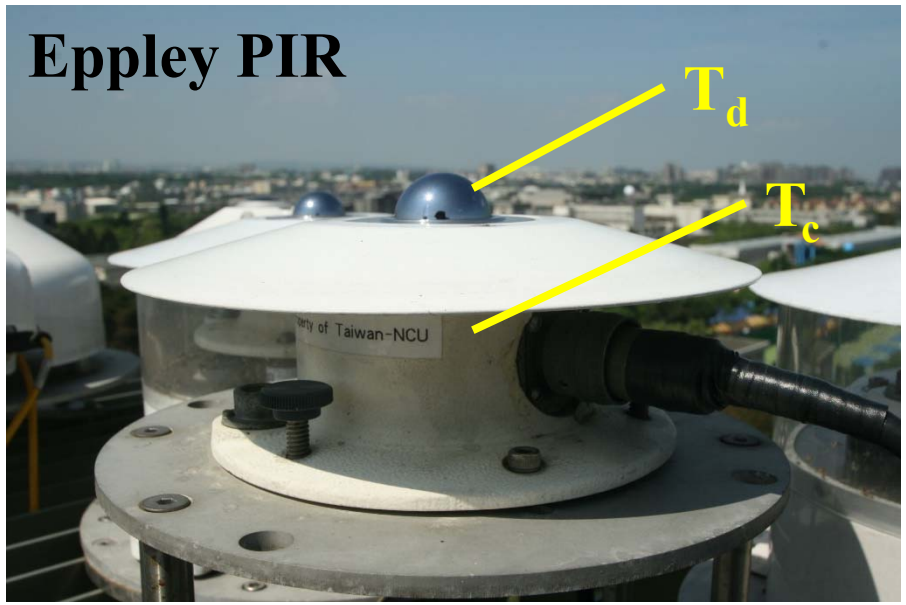
Pyrheliometer

Manufacturer	Pyrheliometer Model	Calibration
Hukseflux	DR02-T2	2015 IPC
Kipp & Zonen	CHP1	2016 NPC

Pyrgeometers

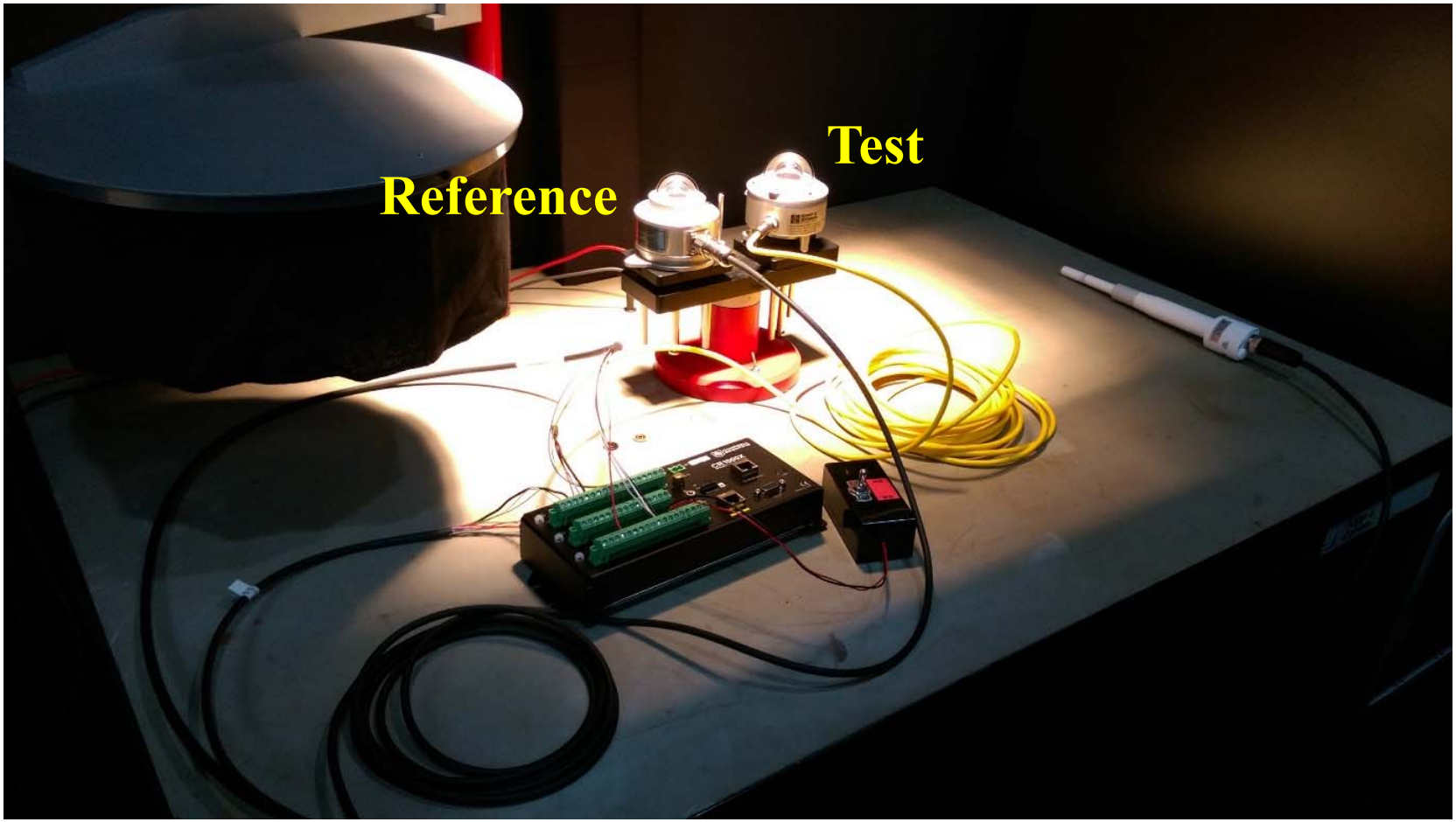
$$LW_{down} = LW_{net} + LW_{up} = \frac{V}{S} + \sigma T_c^4 - k\sigma(T_d^4 - T_c^4)$$

S: sensitivity (uV/Wm^{-2})
σ: Stefan-Boltzman Constant 5.68*10^{-8} (Wm^{-2}/K^{-4})
k = 3.5



Calibrations

Indoor calibration (ISO 9847)

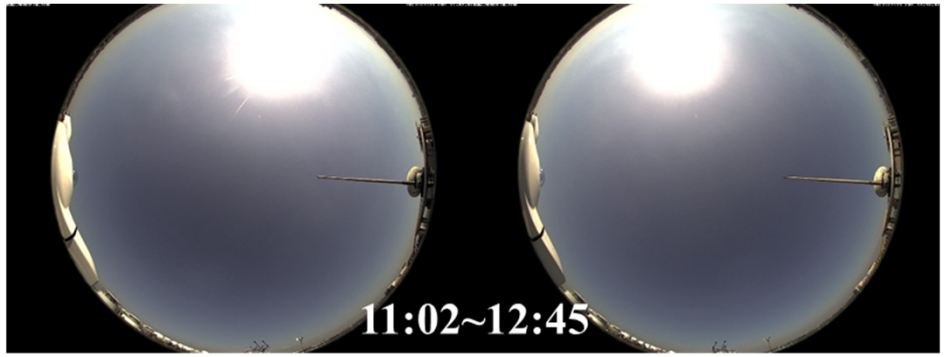


Calibrations

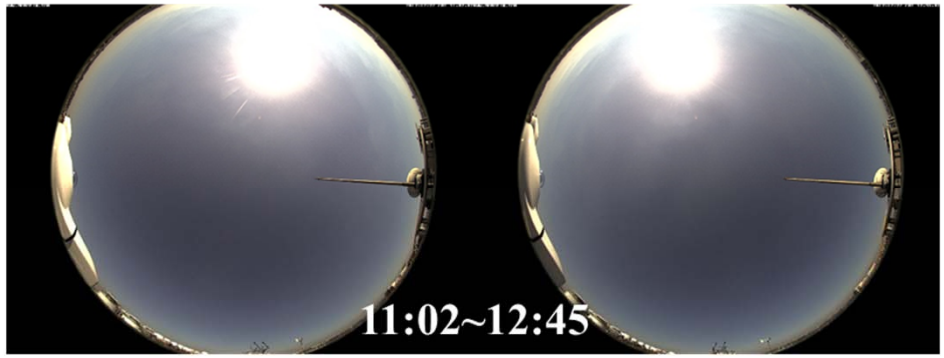
Outdoor calibration (ISO 9846)

Clear sky
SZA: 40~50°

2017/12/21



2017/12/22

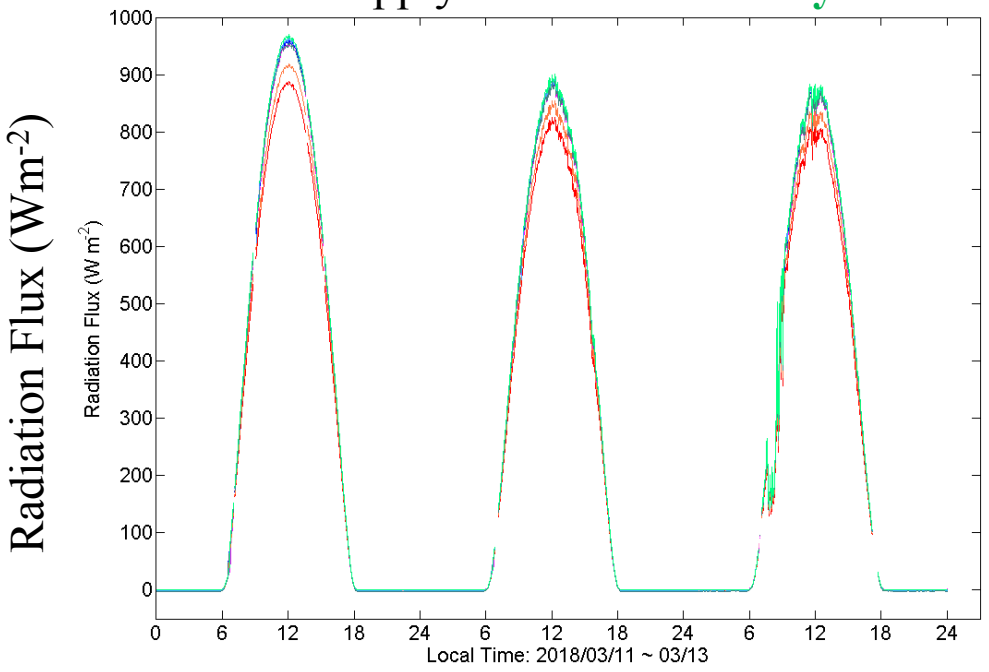


2017/12/23

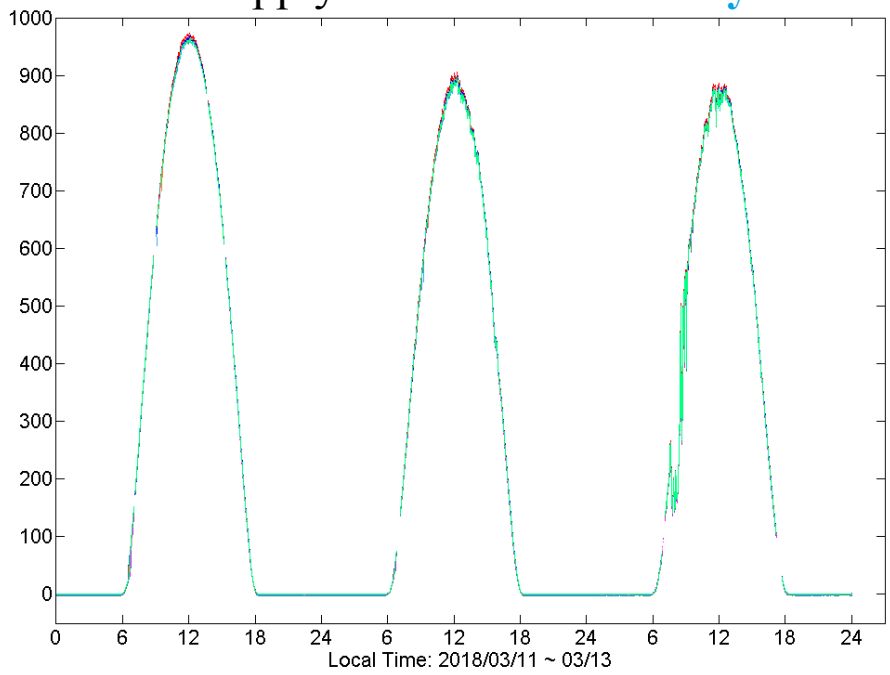
Calibration Results

	Indoor Calibration	Outdoor Calibration
Mean percentage change in sensitivity (%)	0.75	**-0.34**
Mean expanded uncertainty (%)	2.33	**1.28**

Apply **Indoor Sensitivity**



Apply **Outdoor Sensitivity**



Thermal Offset Corrections

Offset: Pyranometer nighttime offset (Wm^{-2})
Net IR: Pyrgeometer (PIR) nighttime net IR (Wm^{-2})

Detector only correction

At nighttime (cosSZA < -0.2), calculate **detector only correction coefficients** for each pyranometer:

$$\text{Offset} = b_1 \cdot \text{Net IR} + b_0$$

Full correction

At nighttime (cosSZA < -0.2), calculate **full correction coefficients** for each pyranometer:

$$\text{Offset} = b_2 \cdot \sigma(T_d^4 - T_c^4) + b_1 \cdot \text{Net IR} + b_0$$

Detector Only Correction

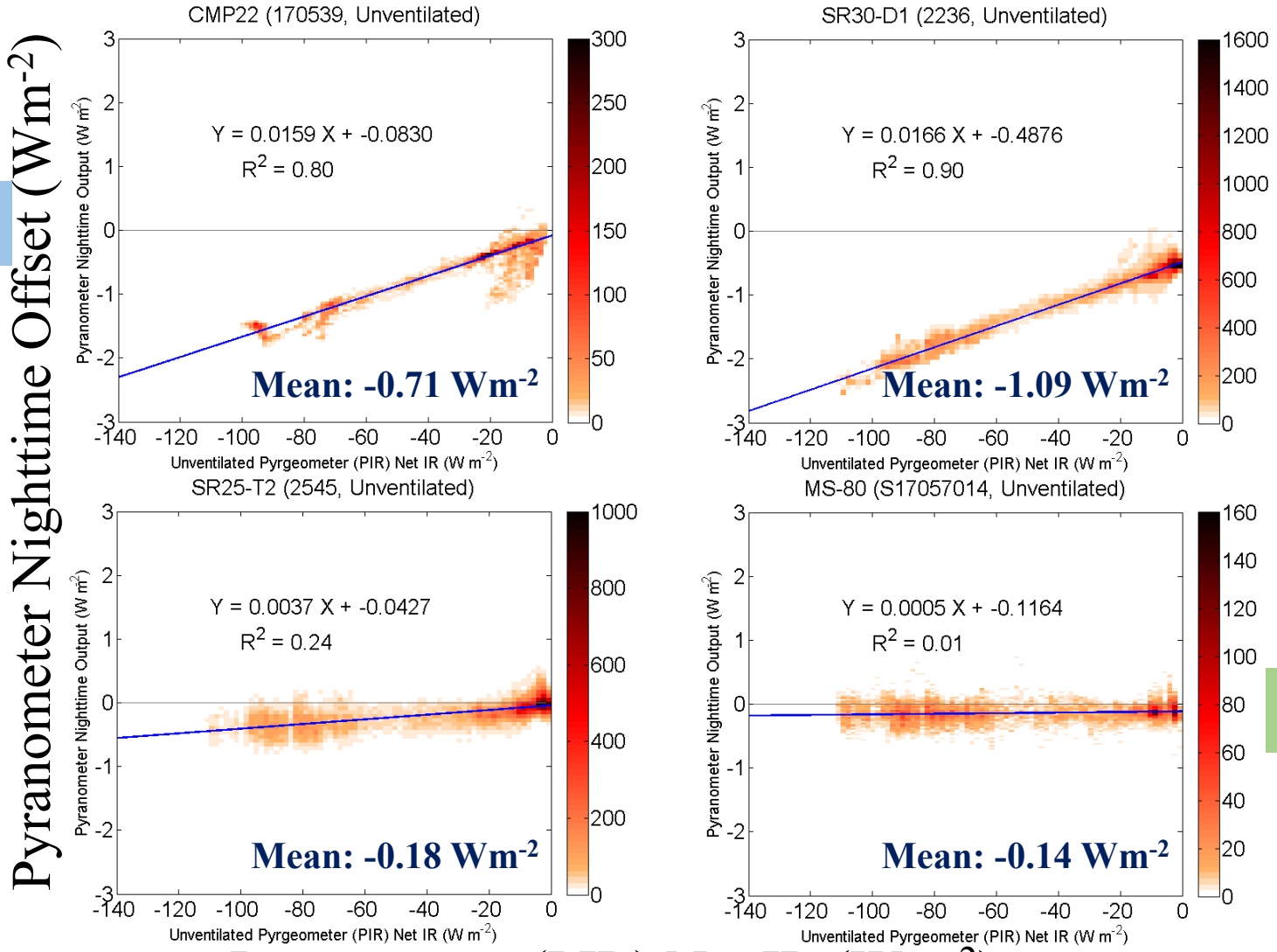
Nighttime-fitted Models

CMP22

SR30

SR25

MS-80



Pyranometer Nighttime Offset (Wm^{-2})

Pyrgeometer (PIR) Net IR (Wm^{-2})

Detector Only Correction

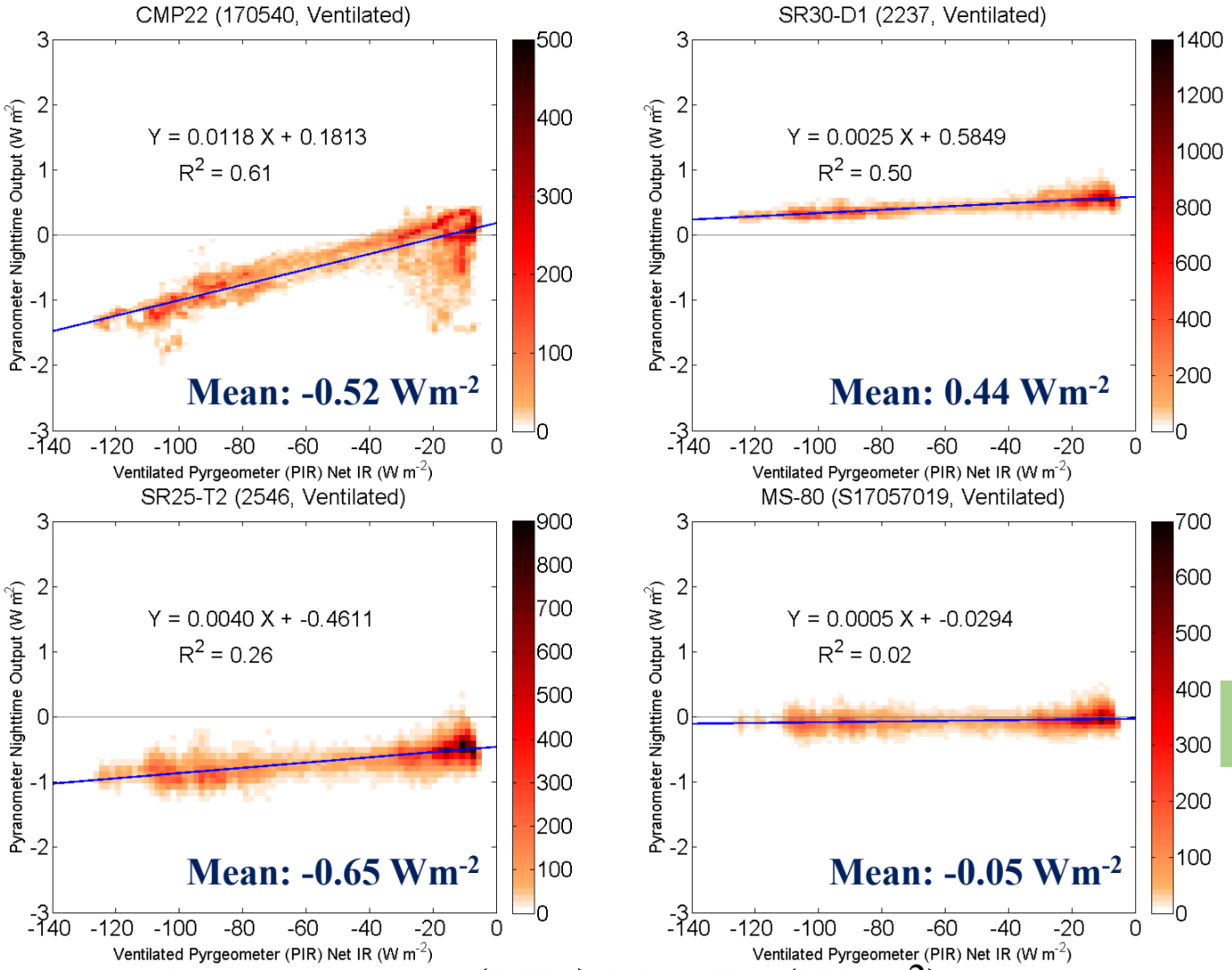
Nighttime-fitted Models

CMP22

SR30

SR25

MS-80

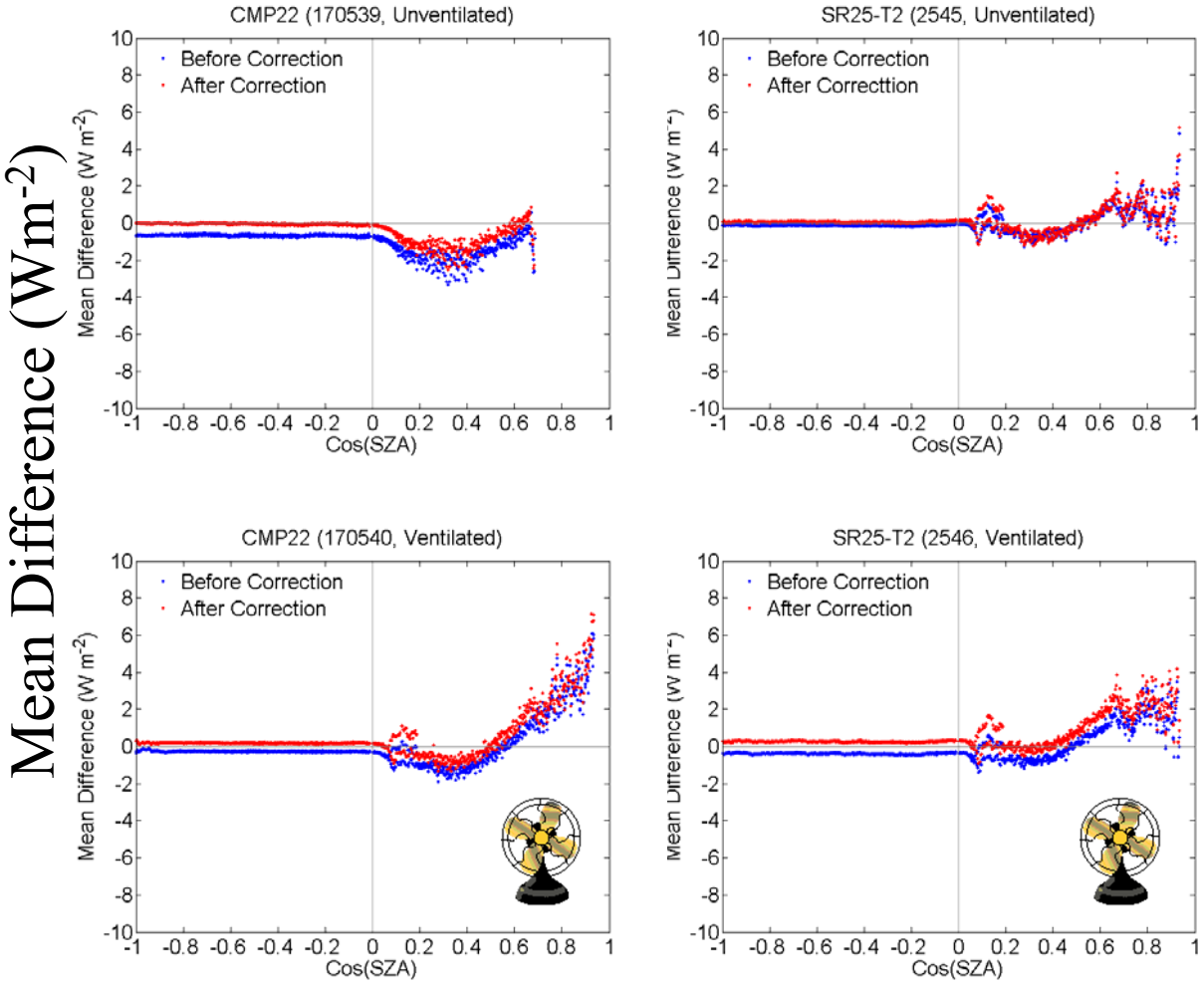


Pyranometer Nighttime Offset (Wm^{-2})

Pyrgeometer (PIR) Net IR (Wm^{-2})

Detector Only Correction Results

CMP22 | **SR25-T2**



Detector Only Correction Results

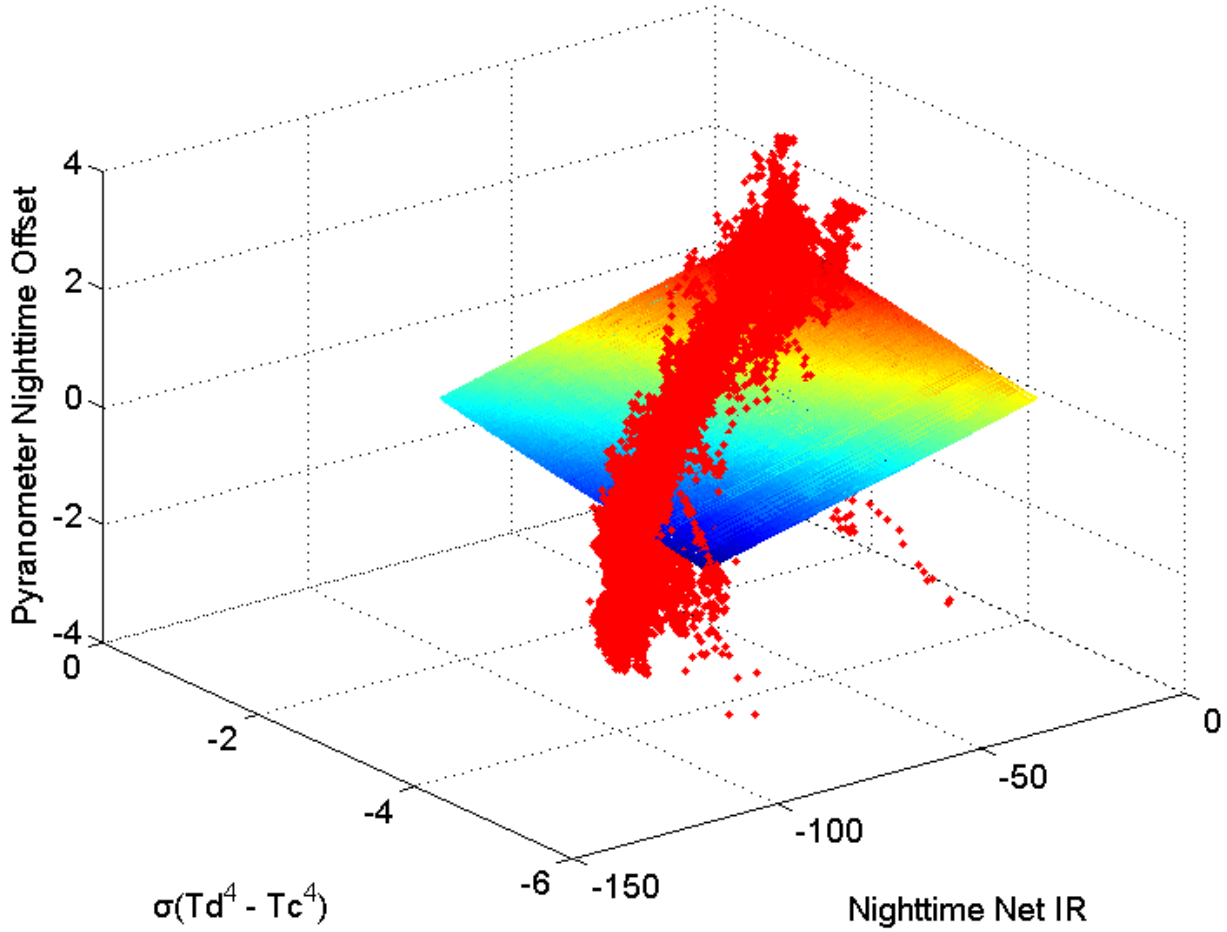
Pyranometer Model	Serial Number	Ventilation (Y/N)	Mean Absolute Difference (Wm^{-2})	
			before Correction	after Correction
CMP22	170539	N	1.50	0.83
CMP22	170540	Y	1.54	1.59
SR25-T2	2545	N	0.57	0.66
SR25-T2	2546	Y	0.91	1.14
SR30-D1	2236	N	1.01	1.25
SR30-D1	2237	Y	1.63	1.30
MS-80	S17057014	N	1.57	1.55
MS-80	S17057019	Y	2.07	2.04

The values in red are the smaller mean difference from the reference for the pyranometer.

Full Correction

Nighttime-fitted Models

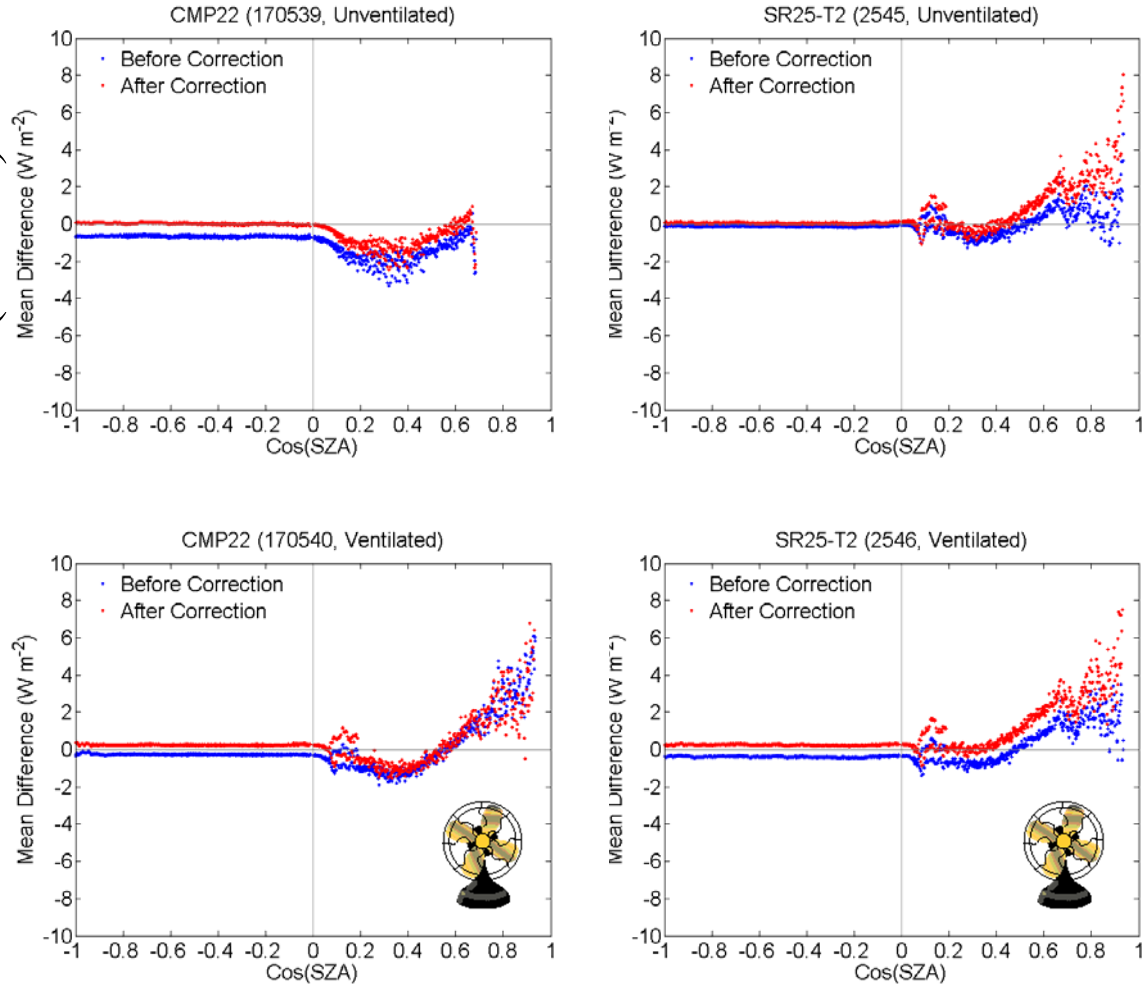
Take CMP21 as example



Full Correction Results

CMP22 | **SR25-T2**

Mean Difference (Wm^{-2})



Full Correction Results

Pyranometer Model	Serial Number	Ventilation (Y/N)	Mean Absolute Difference (Wm^{-2})	
			before Correction	after Correction
CMP22	170539	N	1.50	0.77
CMP22	170540	Y	1.54	1.28
SR25-T2	2545	N	0.57	1.43
SR25-T2	2546	Y	0.91	1.73
SR30-D1	2236	N	1.01	1.51
SR30-D1	2237	Y	1.63	1.68
MS-80	S17057014	N	1.57	1.40
MS-80	S17057019	Y	2.07	1.81

The values in red are the smaller mean difference from the reference for the pyranometer.

Identify the Suitable Correction Method

Pyranometer Model	Serial Number	Ventilation (Y/N)	Suitable Correction Method
CMP11	130616	N	Full correction
CMP11	130785	Y	Full correction
CMP21	080107	N	Full correction
CMP21	080108	Y	Full correction
CMP22	170539	N	Full correction
CMP22	170540	Y	Full correction
SR-75	73-66	N	Neither is suitable
SR-75	73-68	Y	Full correction
MS-80	S17057014	N	Full correction
MS-80	S17057019	Y	Full correction
SR20-D2	4604	N	Detector only correction
SR20-T2	3810	Y	Neither is suitable
SR25-T2	2545	N	Neither is suitable
SR25-T2	2546	Y	Neither is suitable
SR30-D1	2236	N	Neither is suitable
SR30-D1	2237	Y	Detector only correction
EQ08-S	5069	N	Neither is suitable
SPP	38569F3	Y	Full correction
PSP	29468F3	N	Detector only correction
PSP	34153F3	Y	Full correction

The Effect of Ventilation

Pyranometer Model	Serial Number	Ventilation (Y/N)	Mean (Wm^{-2})	SD (Wm^{-2})
CMP11	130616	N	0.61	0.66
CMP11	130785	Y	0.50	0.41
CMP21	080107	N	0.76	0.41
CMP21	080108	Y	0.64	0.37
CMP22	170539	N	0.84	0.53
CMP22	170540	Y	0.35	0.31
SR-75	73-66	N	0.81	0.70
SR-75	73-68	Y	1.91	0.36
MS-80	S17057014	N	0.56	0.45
MS-80	S17057019	Y	0.30	0.26
SR20-D2	4604	N	1.08	0.48
SR20-T2	3810	Y	1.91	0.49
SR25-T2	2545	N	0.68	0.16
SR25-T2	2546	Y	0.20	0.13
SR30-D1	2236	N	1.22	0.60
SR30-D1	2237	Y	0.45	0.10
EQ08-S	5069	N	0.69	0.71
SPP	38569F3	Y	0.96	0.69
PSP	29468F3	N	1.45	1.17
PSP	34153F3	Y	1.03	0.72

Summary

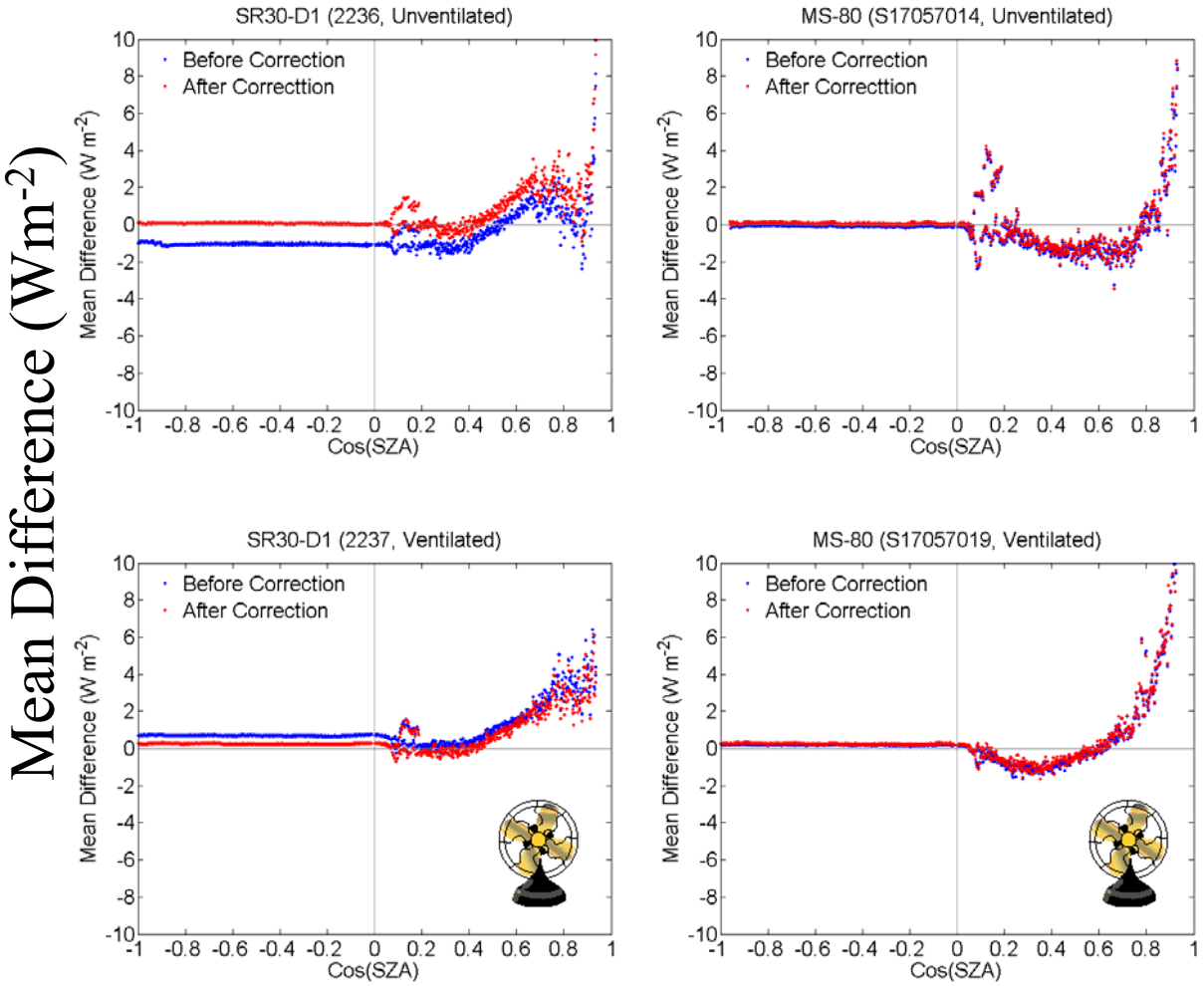
- For the modern pyranometer models (CMP22, SR25-T2, SR30-D1, and MS-80), the mean magnitude of nighttime thermal offset for unventilated ones is 0.53 Wm^{-2}, and 0.42 Wm^{-2} for ventilated ones.
- The full correction method is suitable for more than half the pyranometers in the experiment because the method can obtain more information about the thermal exchange in a pyranometer. The correction can improve the accuracy on average of 0.17-2.51 Wm^{-2}.
- Ventilation may not guarantee the reduction in the thermal offset.

Thanks for your attention.

Detector Only Correction Results

SR30-D1

MS-80



Full Correction Results

SR30-D1 **MS-80**