Independent field test of the solar monitoring system RaZON+

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INTRODUCTION

18 months of data of a Razon+ solar monitoring system have been compared to a "BSRN-type" solar measurement system; a 2AP tracker with Kipp & Zonen CHP1 pyrheliometer and ventilated CMP22 diffuse pyranometer. The component sum method has been used to obtain Global horizontal Irradiance. The Razon is installed since February 2017 at NREL SRRL site in Golden, CO. The stability, sensitivity to soiling and root mean square error (RMSE) accuracy are compared.

RAZON SYSTEM DESCRIPTION

The RaZON+ is a cost effective solar monitoring system with internal datalogger and GPS.

- Pyrheliometer for DNI
- Shaded pyranometer for diffuse component
- Global calculated using "component sum"

Installation/alignment/monitoring using:

- WiFi, Ethernet web browser, RS 485 Modbus or ASCII serial

Tracker:

- gear drive tracking system
- GPS for calculation of the solar position and accurate time synchronisation of the on-board data logger.

RADIOMETER DESIGN

PH1 Pyrheliometer:
this concept is inherently insensitive to soiling for two reasons:

1. the amount of soiling particles that reach the diffuser is lower than for the front window of a conventional pyrheliometer.
2. if the diffusor gets soiled, the effect of scattering of light on the diffusor (with thermopile detector mounted directly behind it) is less significant than scattering on a window 20 cm away from the detector.

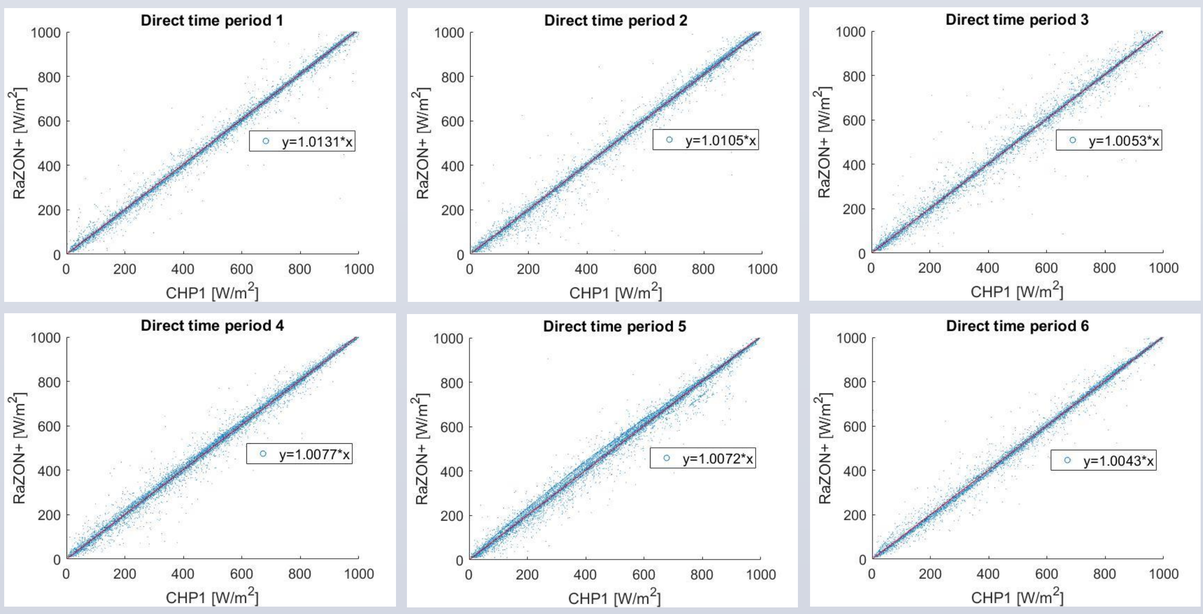
- Response time 0.2 sec (3τ)
- No front window, only diffusor directly in front of detector
- Area for soiling deposition: from 3 cm^2 front window enlarged to entire inside tube (270 cm^2) a reduction of soiling sensitivity by a factor of 90.

PR1 Pyranometer:
novel design Smart pyranometer specifically for the shaded measurement of Diffuse radiation. Use of thermopile detectors in combination with diffusors reduces zero offsets to negligible values.

- Response time 0.2 sec (3τ)
- Zero offset A < 0.5 W/m^2
- Use "component sum" to obtain global radiation so directional errors are avoided [1].

SENSITIVITY TO SOILING OVER 18 MONTHS

The PH1 # 160009 DNI radiation has been compared to the CHP1. The instrument has never been cleaned in 18 months, and its DNI is compared to that of a weekly cleaned CHP1 at NREL:



The data has been cut into 6 blocks of approx. 3 months. For each block the DNI of the PH1 is plotted vs the reference irradiance measured by the CHP1. The change in slope is due to built up of soiling. The slope changes from 1.013 to 1.004.

So the soiling reduces transmission for PH1 by 0.9% over 18 months at this test location.

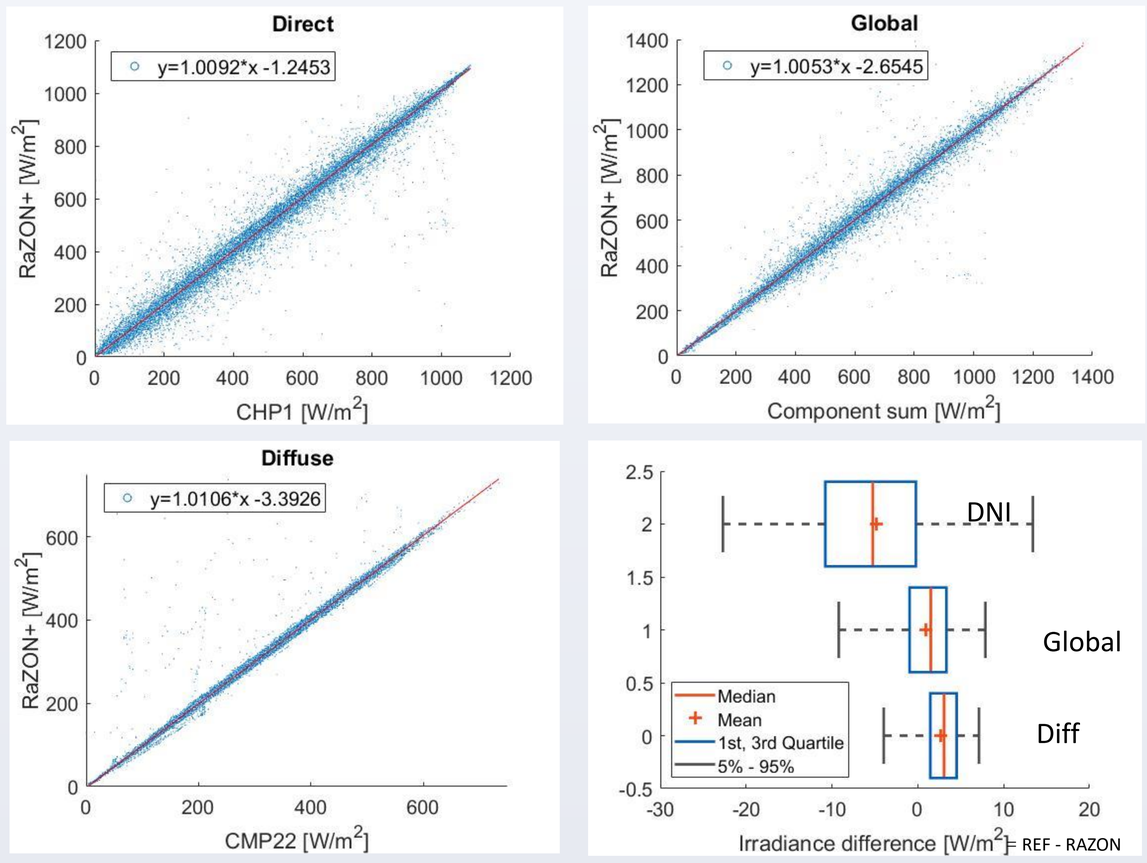
STABILITY OF THE NEW DETECTORS

To determine the stability of the detector, Pyrheliometer PH1 # 160002 has been calibrated against our PMO-6 cavity # 103, in October 2016 on Long Island, USA and again in June 2018 at PSA in Spain:

Initial calibration: S = 20.70 µV/(W/m^2)
Re-calibration: S = 20.72 µV/(W/m^2)

The change in sensitivity of 0.09% is well within the calibration uncertainty (0.3 %)

COMPARISON OF RADIATION COMPONENTS OVER 18 MONTHS



The comparison of the RaZON+, with the reference system is shown above.

Data < 20W/m2 for the Razon system has been neglected. No other filtering has been applied.

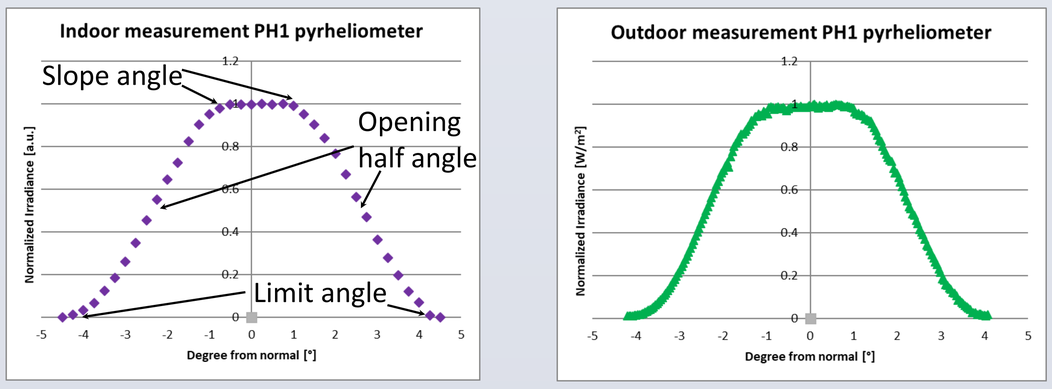
Scattering in the data might be caused by differences in response time: 0.2 vs 5 sec. [2,3,4]

The statistical analysis shows a "box and whisker" analysis [5] in figure 4. Irradiance Difference is calculated as Reference – Razon value.

50% of the datapoints are within the box.

90% of the datapoints are within the Whiskers. So 10% the data points has a larger deviation than depicted in this plot.

PH1 PYRHELIOMETER EFFECTIVE PENUMBRA FUNCTION



The PH1 pyrheliometer angular response or effective penumbra function was measured in the lab and outside. In the lab a lamp and an angle indicator was used. Outside the PH1 was pointed to a point where the sun would pass at a later moment and then measured over time. The measured slope angle, opening half angle and limit angle [6] are in good agreement with the expected values of 1°, 2.5° and 4°.

CONCLUSIONS

- The Razon+ shows stable behaviour over 18 months
- Calibrations of PH1 160002, performed 20 months apart show no drift in sensitivity
- PH1 # 160009 initial calibration is off by 1.4%. Improvement of this would lead to better comparison results
- Soiling reduction design of PH1 looks promising (only 0.9% soiling built up in 18 months)
- Differences in diffuse radiation between CMP22 and PR1 most likely due to calibration or zero offset behaviour
- The measured effective penumbra function shows good agreement with the geometric expected function
- This simple, integrated system with new radiometers delivers promising results

ACKNOWLEDGEMENTS

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REFERENCES

[1] L.J.B. McArthur, "BSRN operators manual", version 2.1, 2005, https://www.wmo.int/pages/prog/gcos/documents/gruanmanuals/WCRP/WCRP21_TD1274_BSRN.pdf

[2] D.R. Myers, "Comparison of direct normal irradiance derived from silicon and thermopile global hemispherical radiation detectors", NREL.

[3] C.A. Gueymard, "Direct Normal Irradiance for CSP/CPV: Modeling Challenges", presentation.

[4] A. Habte et al., "Evaluation of Radiometers Deployed at the National Renewable Energy Laboratory's Solar Radiation Research Laboratory", NREL.

[5] L. Vuilleumier et al., "Performance Evaluation of Radiation Sensors for the Solar Energy Sector", MACC-II Open Science Conference Brussels Belgium, 2014.

[6] P. Blanc et al., "Direct normal irradiance related definitions and applications: The circumsolar issue", Solar Energy, 2014