# Rotating Shadowband Irradiometer (RSI): Accurate Measurement of Direct Normal, Global and Diffuse Irradiance with a Single Device


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## Functionality

In solar irradiance measurements, typically used instruments are thermopile pyrheliometers and pyranometers as specified in ISO 9060. For measurement of global, diffuse and direct irradiance, three individual sensors and a solar tracker are required, causing high investment costs. RSI sensors provide high-quality solar irradiance measurements with a single device at much lower cost. The RSI sensor consists of two redundant horizontally leveled silicon photodiode radiation detectors, situated in the center of a spherically curved shadowband (Fig. 1). While the shadowband is in its rest position below the sensor (Fig. 2), the photodiodes measure Global Horizontal Irradiance (GHI). In fixed intervals, the shadowband rotates around the radiation sensors (Fig. 3). During the rotation, the shadowband blocks the direct beam irradiation from the sun for a brief moment. This causes a momentary drop of the photodiode signals (Fig. 4) and thus allows the determination of the Diffuse Horizontal Irradiance (DHI) and the subsequent calculation of the Direct Normal Irradiance (DNI) from GHI, DHI and the known solar incidence angle. An advanced feature of the RSI is the optional sunshape measurement[1].

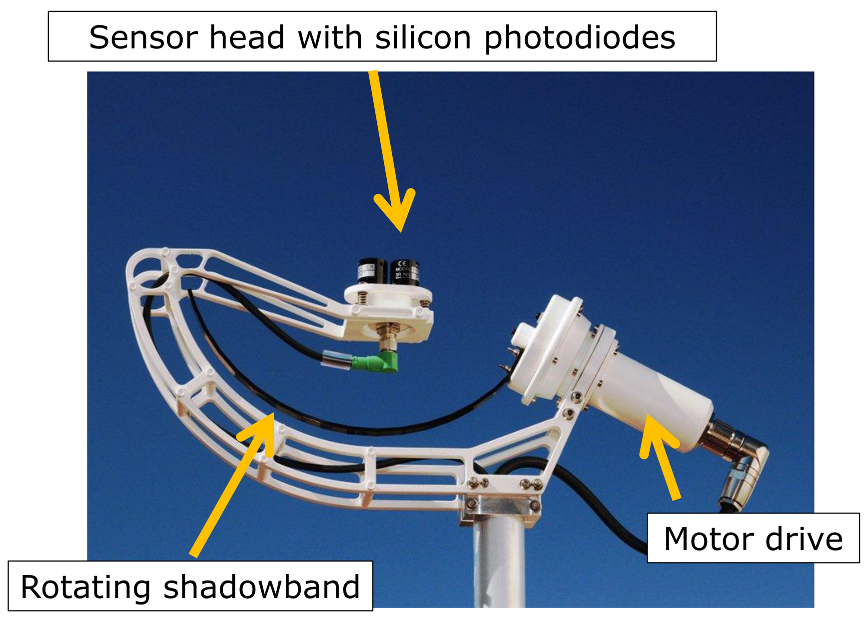


Fig. 1: Components of RSI sensor

Fig. 2: RSI sensor in rest position

Fig. 3: RSI sensor during rotation

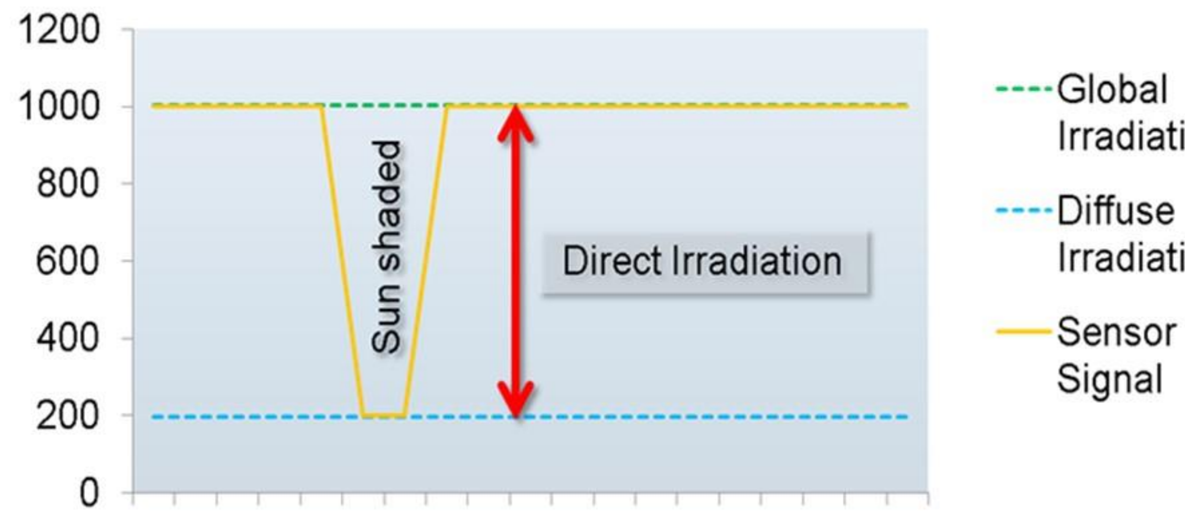


Fig. 4: Schematic sensor signal during rotation

## Accuracy and Correction Functions

Silicon photodiodes have a lower primordial accuracy than thermopile sensors resulting in systematic deviations. Main causes are a limited spectral sensitivity (see Fig. 5), air mass, cosine and temperature effects (Fig. 6). The detailed dependencies vary among individual photodiodes and need to be adjusted individually for each sensor. Hence, individual calibration of each instrument is recommended. Different correction functions have been developed to overcome these systematical deviations and achieve very good measurement accuracy (Fig. 7 and 8). The reachable measurement uncertainty for irradiance measurements with RSI sensors in field conditions are given in Table 1.

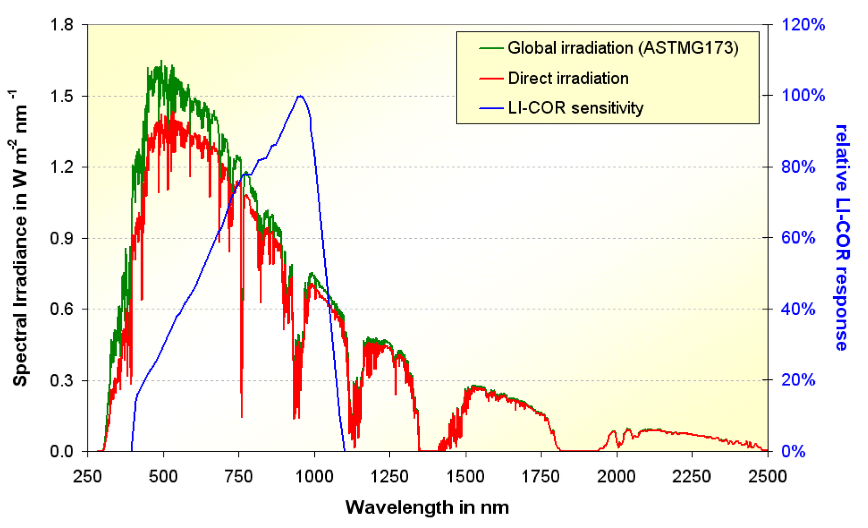


Fig. 5: Spectral dependency of a Licor Li-200 photodiode (Li-Cor Inc.)

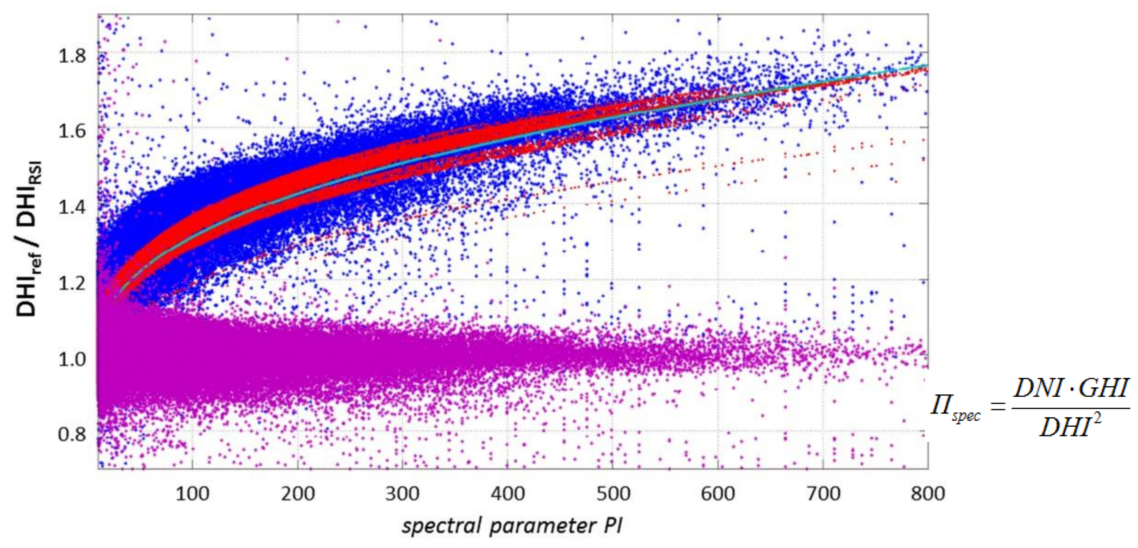


Fig. 6: Spectral correction of diffuse irradiance (blue: raw values; red: variation with air mass and altitude; purple: corrected values)[2]

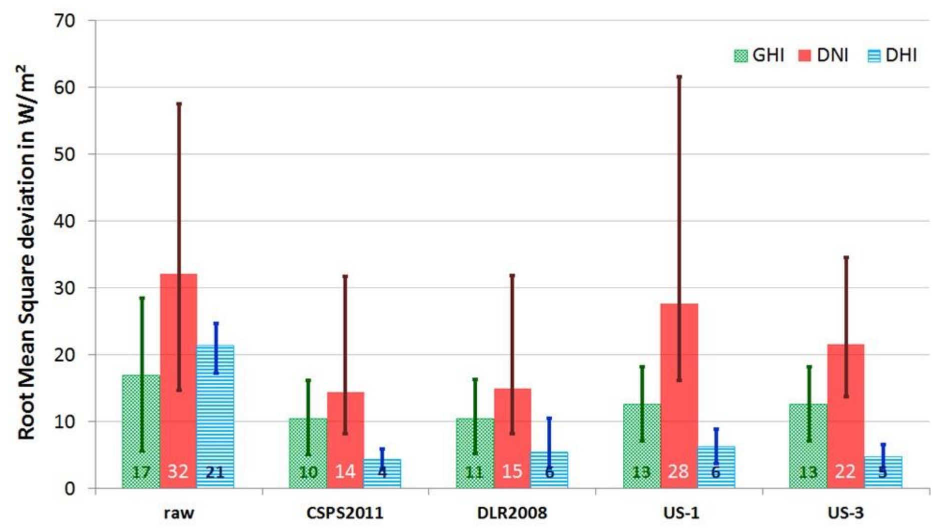


Fig. 7: Measurement accuracy of different RSI correction functions (RMSD in W/m² compared against high-precision pyrheliometer and pyranometers)[2]

Tab. 1: Measurement uncertainty with applied RSI correction function (DLR 2008 function)

| **Measured Quantity** | **Uncertainty** | |
|---|---|---|
| | Instantaneous values | Annual sum |
| Global Horizontal Irradiance GHI | < 3.5% | < 2% |
| Diffuse Horizontal Irradiance DHI | < 6% | < 2% |
| Direct Normal Irradiance DNI | < 3.5% | < 2% |

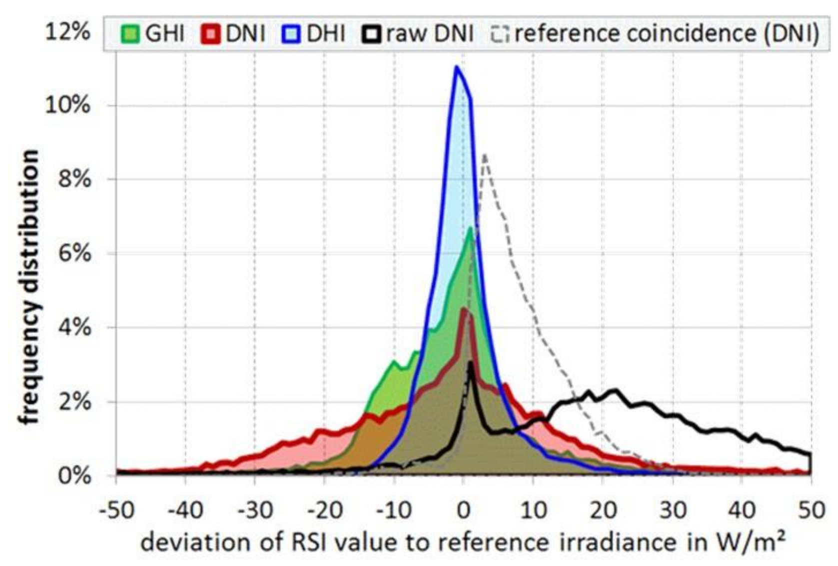


Fig. 8: Frequency distribution of deviation of RSI measurement values to high-precision pyrheliometer and pyranometers[3]

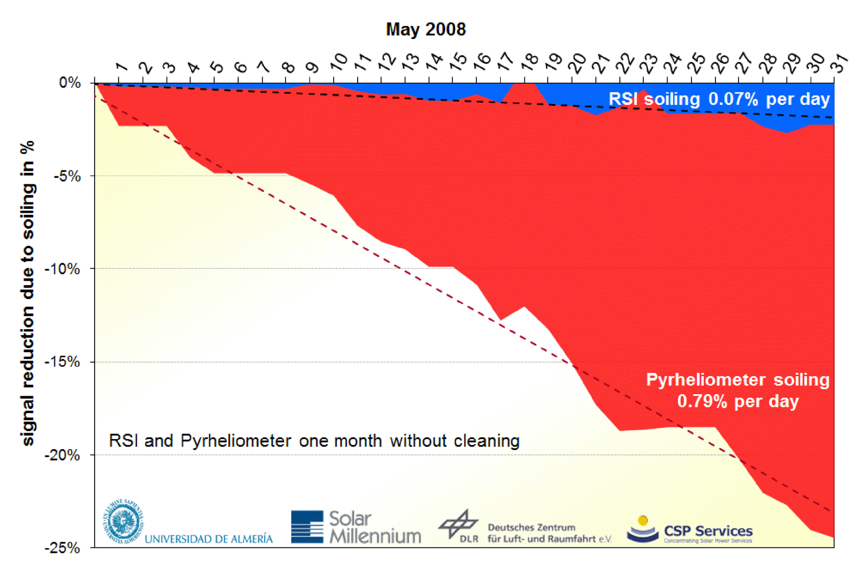


Fig. 9: Comparison of signal reduction due to soiling on RSI sensor and pyrheliometer (in % against a cleaned reference pyrheliometer)[4]

## Soiling Sensitivity

For the measurement accuracy, soiling of sensors is usually an important factor. First class pyrheliometers have a high nominal precision, but are severely affected by soiling, see Fig. 9. Non-ventilated pyranometers can suffer from non-uniform soiling of the glass dome covering the sensing element. To achieve the high nominal measurement accuracy, a stringent maintenance with daily cleaning is required. This increases the operational costs and the uncertainty of the irradiance measurement. RSI sensors have a low soiling sensitivity so that the maintenance frequency can be reduced to monthly.

## Conclusion

Due to their low investment cost, low soiling sensitivity, low power demand and high reliability, Rotating Shadowband Irradiometers (RSI) show significant advantages over thermopile sensors for the measurement conditions of remote weather stations. CSP Services now offers an RSI sensor which can be connected to most data loggers commonly used in automatic weather stations via RS485 interface or with three analogue inputs (GHI, DHI, DNI). This allows addition of scientific-grade solar irradiance measurement to new and existing weather stations at reasonable cost.

## References


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