

Pyranometer & pyrliometer comparison

Benchmarking Hukseflux solar sensors by independent research

SR11, LP02 and DR01 year-round performance has been tested by outdoor intercomparison. The comparison test site is independently operated. Reference radiometers are maintained under an ISO 17025 accredited system of quality assurance. Results are excellent: the Hukseflux instruments perform well within the specification limits of their ISO 9060 class.



Figure 1 installing a DR01 first class pyrliometer

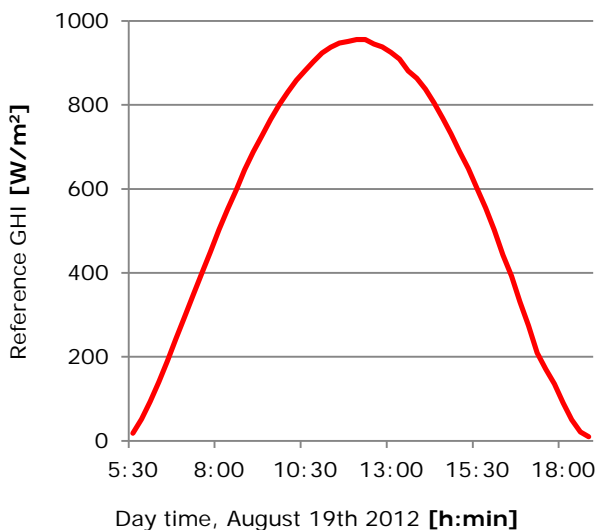


Figure 2 Reference global horizontal irradiance (GHI), obtained 19 August, 2012

Introduction

To provide the highest level of quality, Hukseflux continuously improves its instruments. One way to check progress is having independent specialists use the instruments.

Hukseflux regularly participates in pyrliometer comparisons at calibration centres such as PMOD in Davos, Switzerland and NREL / SRRL in Golden, USA. Year-round comparison studies are also organised on Hukseflux' own outdoor platform and against independent ISO 17025 accredited laboratories' reference instruments. Results for pyranometers and pyrliometers from the latter studies are presented in this document.

Pyranometer comparison

A pyranometer measures hemispherical solar radiation. When measuring in the horizontal plane this is called global horizontal irradiance (GHI). At the test site, reference GHI is calculated from reference direct normal irradiance (DNI) and reference diffuse horizontal irradiance (DHI). For radiant exposure integrated over a day in kW·h/m² we use the term "daily total".

Figure 2 shows reference GHI on 19 August 2012, a clear sunny day with a maximum GHI of 955 W/m². **Figures 4 to 10** show the results of the first class pyranometer comparison, involving Hukseflux model SR11, against reference data. In **Figure 4 and 5** a comparison is made using 1-minute averages. The graph shows that all compared instruments operate well within the ISO 9060 first class specification limit of ± 20 W/m² for directional response. This gives a clear indication of the level of compliance to the standard. **Figures 6 to 10** show comparisons of daily totals for first class instruments from June to December 2012, a total of 200 data points.

Depending on weather and time of year, reference daily totals vary between 0.5 and 3.4 kW·h/m² in winter and between 3.8 and 9.2 kW·h/m² in summer.

Figure 6 shows a scatter graph of daily totals using three first class pyranometers including Hukseflux SR11 against the reference. The relationship between results is clearly linear for all sensors. **Figure 7** shows deviations between measurement and reference data are within a range of ± 0.20 kW·h/m² for all sensors. Hukseflux SR11 pyranometer shows a deviation range of -0.08 to 0.15 kW·h/m².

In **Figures 8 to 10** the same deviations are expressed as percentages. In general lower deviations from reference data are seen when radiant exposure reaches higher levels (**Figure 8**). The standard deviation is smaller under clear sky conditions (**Figure 9**). Instruments reach a higher degree of agreement in summer due to higher solar elevation.

Figures 12 to 15 show the results of the second class pyranometer comparison. Results agree

well with the reference GHI although differences increase at sunrise and sunset (**Figures 12 and 13**). The scatter graphs for daily totals (**Figures 14 and 15**) confirm the outstanding performance of these instruments. As with first class pyranometer comparisons, deviations expressed as a percentage decrease at increasing levels of irradiance. LP02 (**Figure 11**) shows extraordinary good results (even compared to first class instruments), which explains LP02's popularity.

Notes

The measurements took place at a high level of instrument maintenance (daily cleaning). At a low level of maintenance uncertainties will be higher.

Actual instrument performance is often better than formally specified. When users obtain new instruments from Hukseflux and use the formal instrument specification limits for uncertainty assessment, this will result in a higher uncertainty estimate than the graphs in this report suggest.

(Continued for pyrhemometers on page 9)

First class pyranometers



Figure 3 SR11 first class pyranometer, the instrument used in first class pyranometer comparisons (**Figures 4 to 8**)

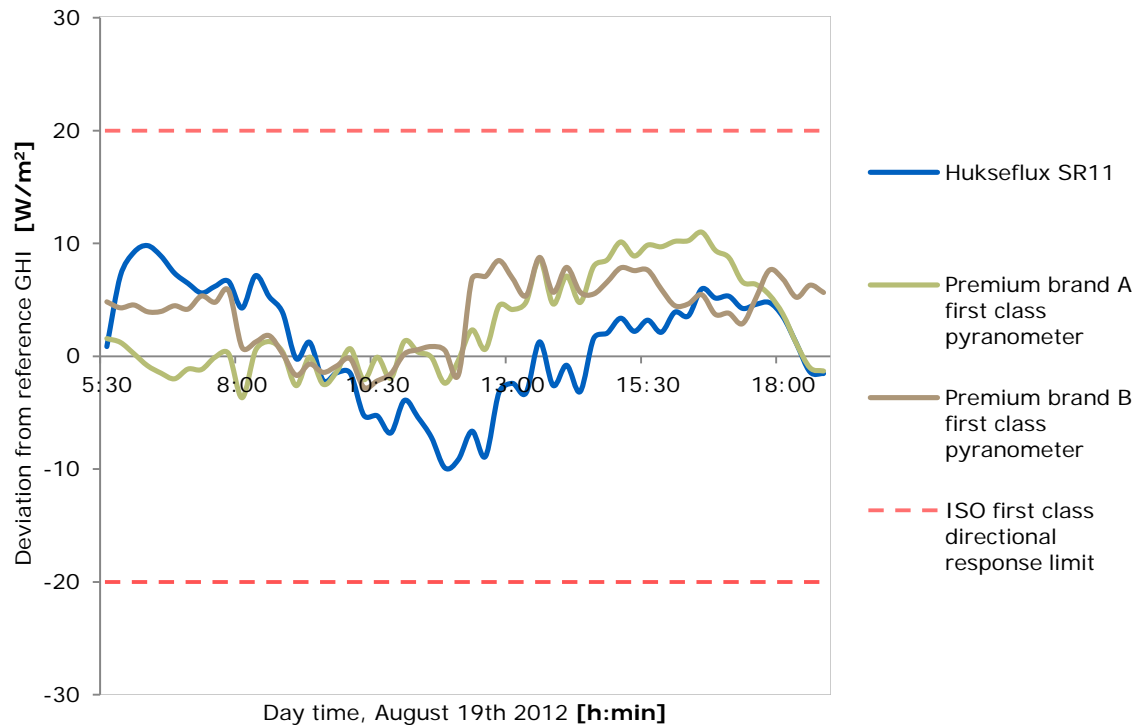


Figure 4 First class pyranometer comparison, deviation from reference GHI, also showing directional response specification limit for first class pyranometers.

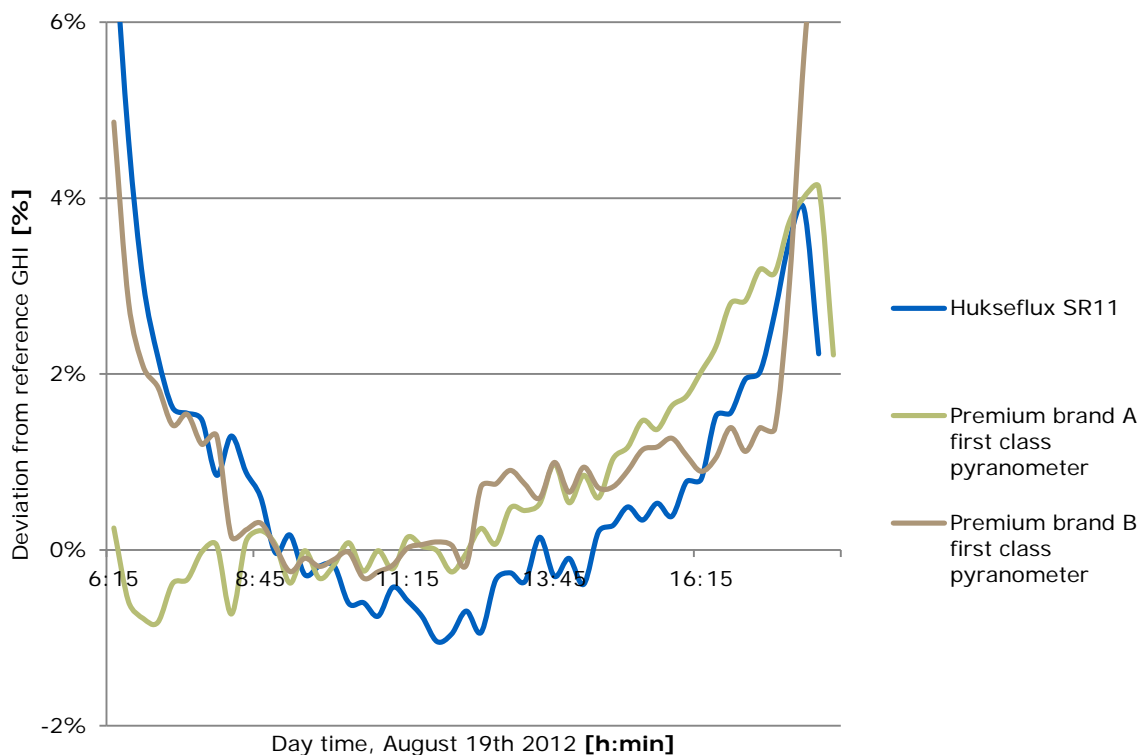


Figure 5 First class pyranometer comparison, relative deviation from reference GHI.

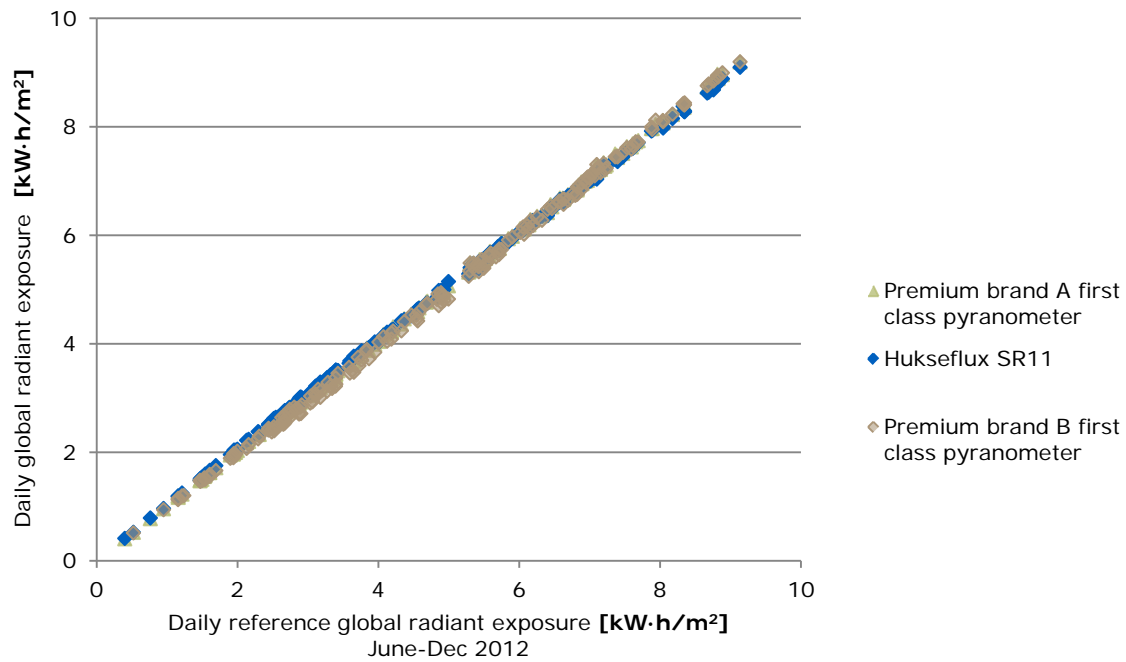


Figure 6 First class pyranometer comparison, daily totals. Three first class pyranometers compared to reference, 200 days. Hukseflux SR11 compared to two other premium brand first class pyranometers. (Approximately 5 outliers per sensor are excluded from the graph)

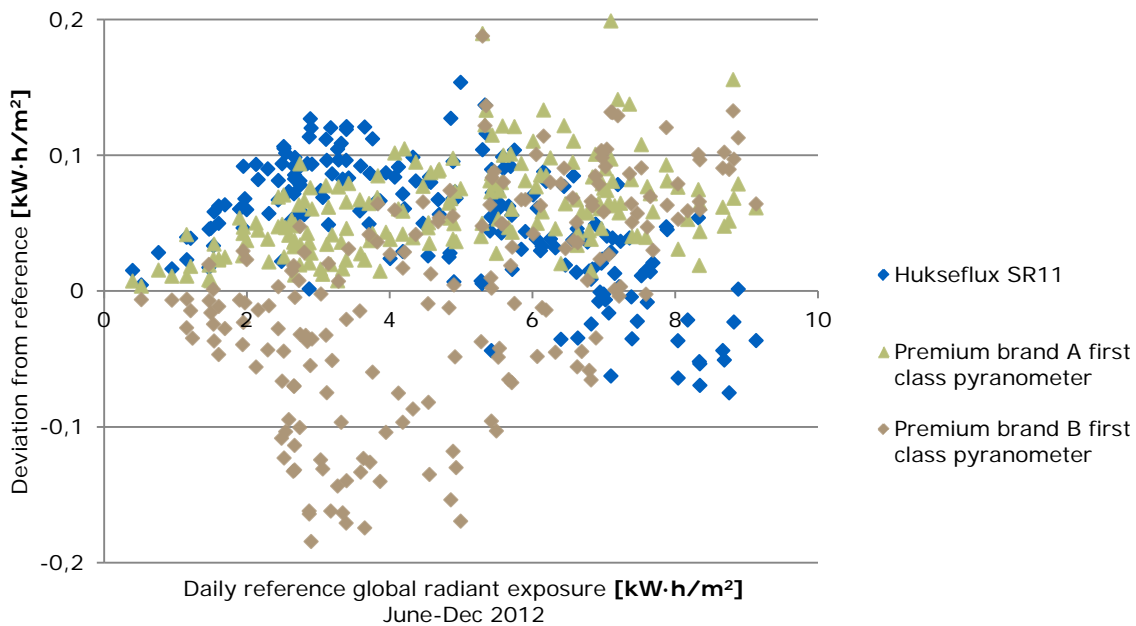


Figure 7 First class pyranometer comparison, daily totals, deviation from reference, 200 days. Hukseflux SR11 compared to two other premium brand first class pyranometers. (Approximately 5 outliers per sensor are excluded from the graph)

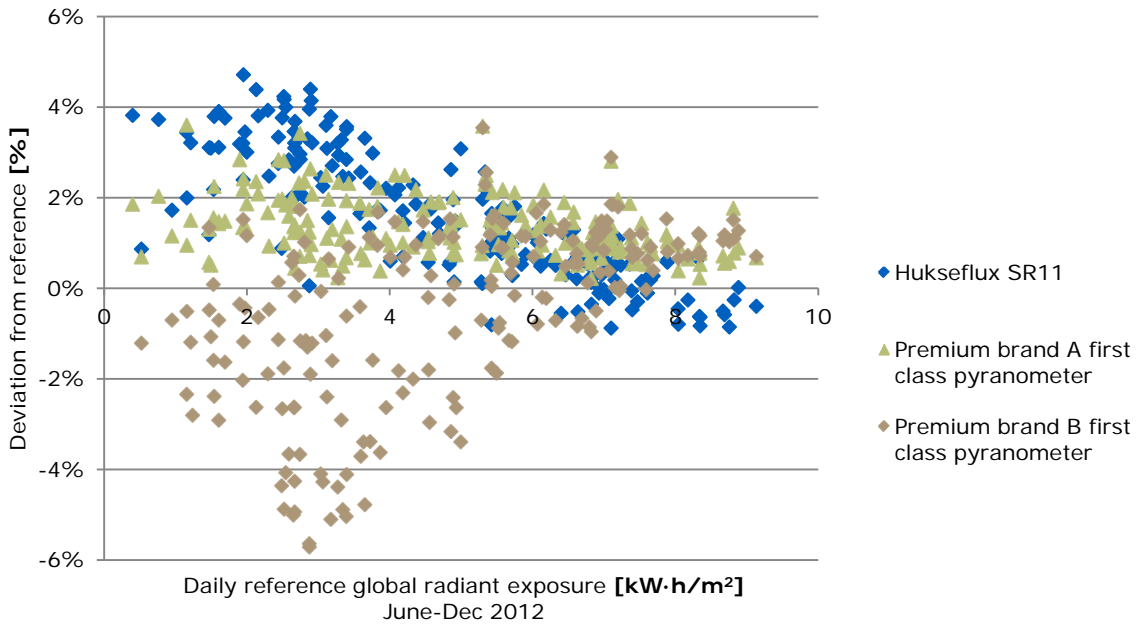


Figure 8 First class pyranometer comparison, daily totals, relative deviation from reference. Three first class pyranometers compared to reference, 200 days. Hukseflux SR11 compared to two other premium brand first class pyranometers. (Approximately 5 outliers per sensor are excluded from the graph)

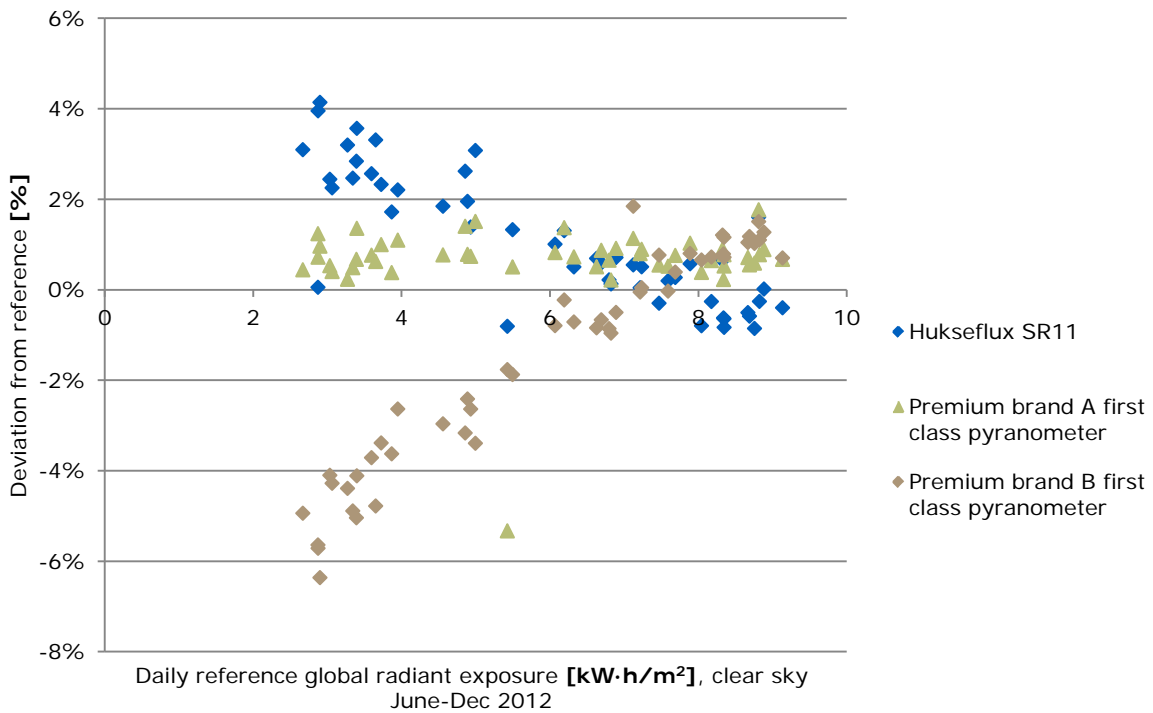


Figure 9 First class pyranometer comparison, daily totals, relative deviation from reference. Deviation from reference, 200 days. Hukseflux SR11 compared to two other premium brand first class pyranometers. (Approximately 5 outliers per sensor are excluded from the graph)

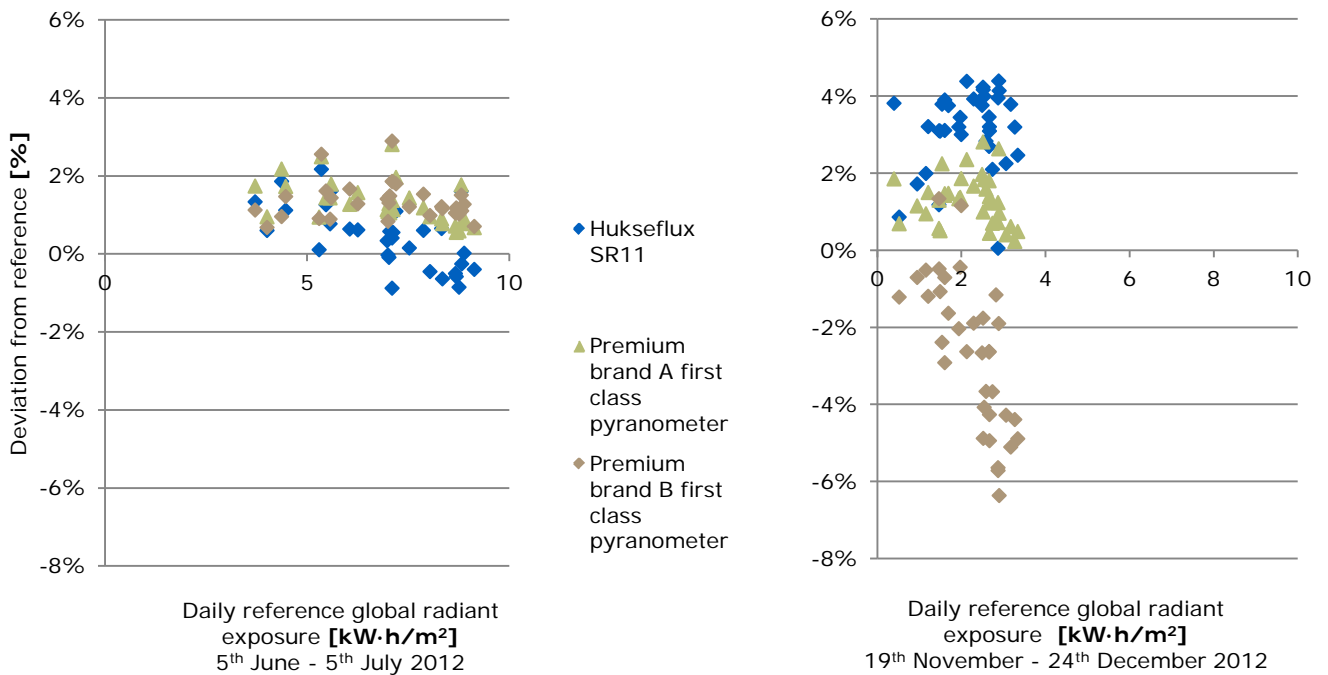


Figure 10 First class pyranometer comparison, daily totals, relative deviation from reference. Separated between summer and winter. Deviation from reference, 200 days. Hukseflux SR11 compared to two other premium brand first class pyranometers.
(Approximately 5 outliers per sensor are excluded from the graph)

Second class pyranometers



Figure 11 LP02 second class pyranometer, the instrument used in second class pyranometer comparisons (Figures 12 to 15)

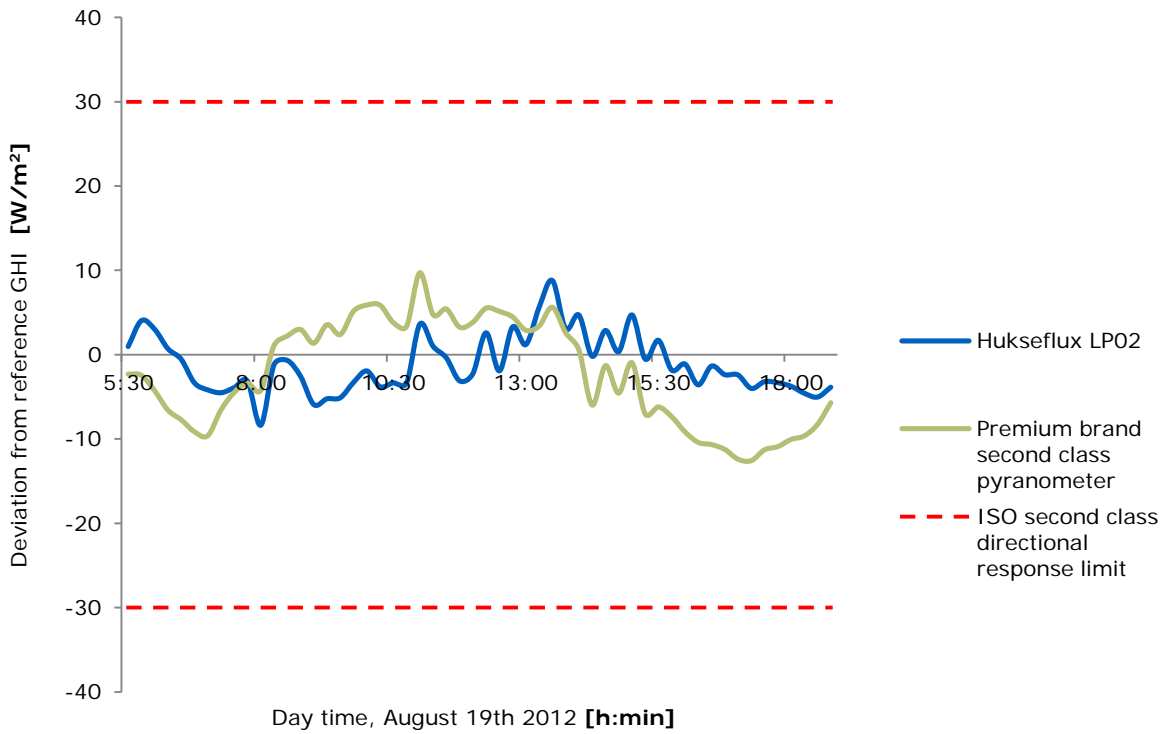


Figure 12 Second class pyranometer comparison, deviation from reference GHI, also showing directional response specification limit for second class pyranometers.

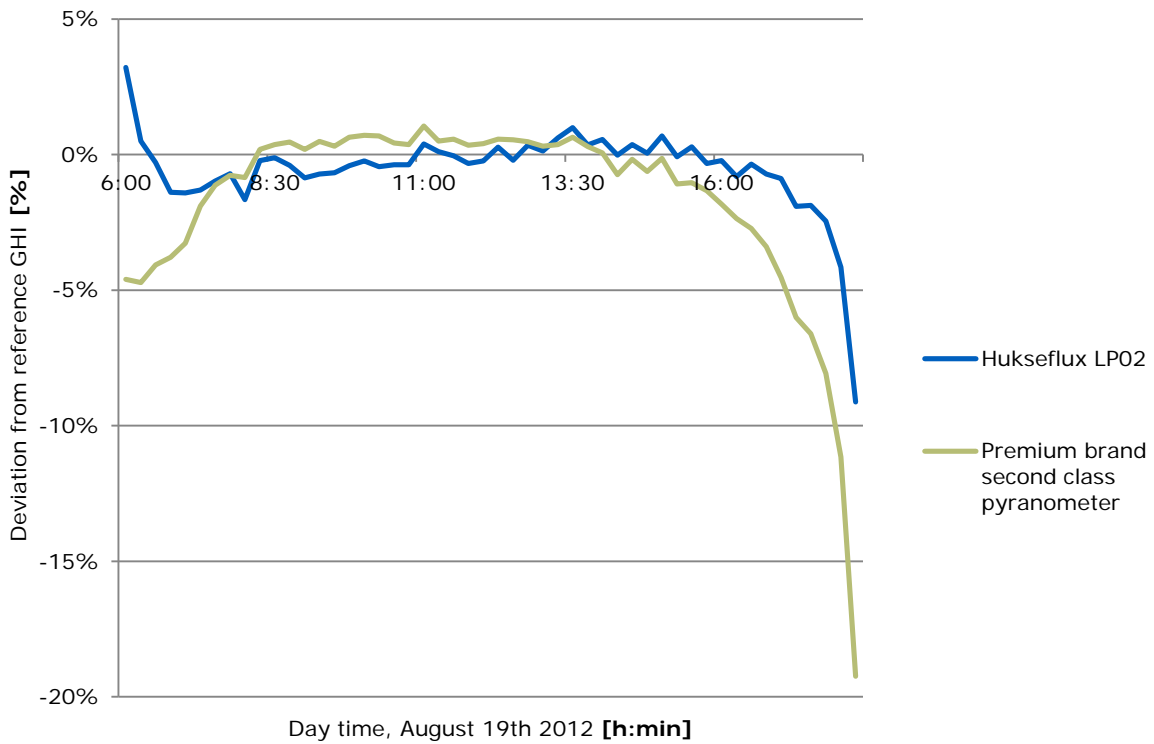


Figure 13 Second class pyranometer comparison, relative deviation from reference GHI.

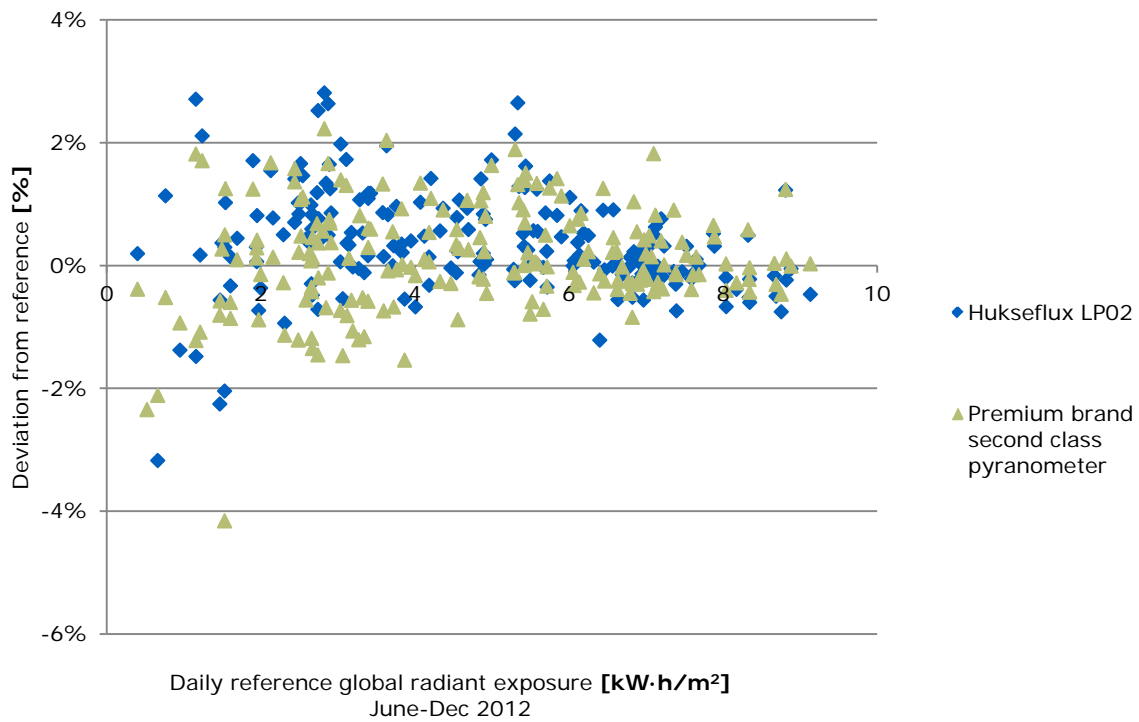


Figure 14 Second class pyranometer comparison, relative deviation from daily reference global radiant exposure. LP02 is compared to another premium brand second class pyranometer, 200 days from June – December 2012

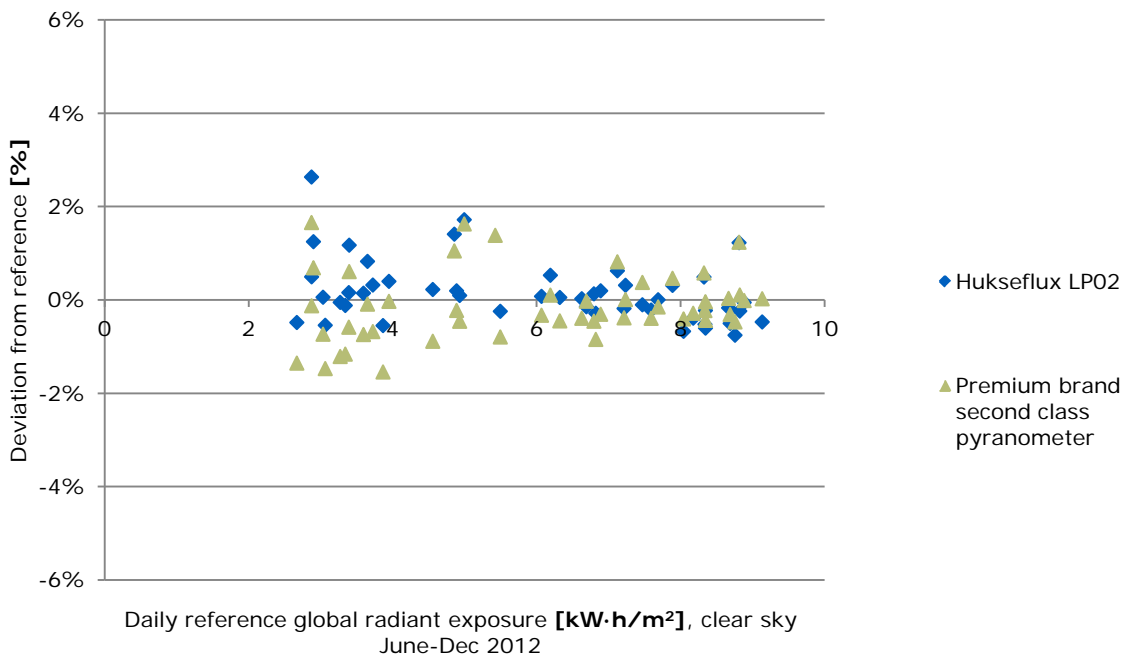


Figure 15 Second class pyranometer comparison, relative deviation from daily reference global radiant exposure, 47 clear sky days from the period June – December 2012

First class pyrheliometers

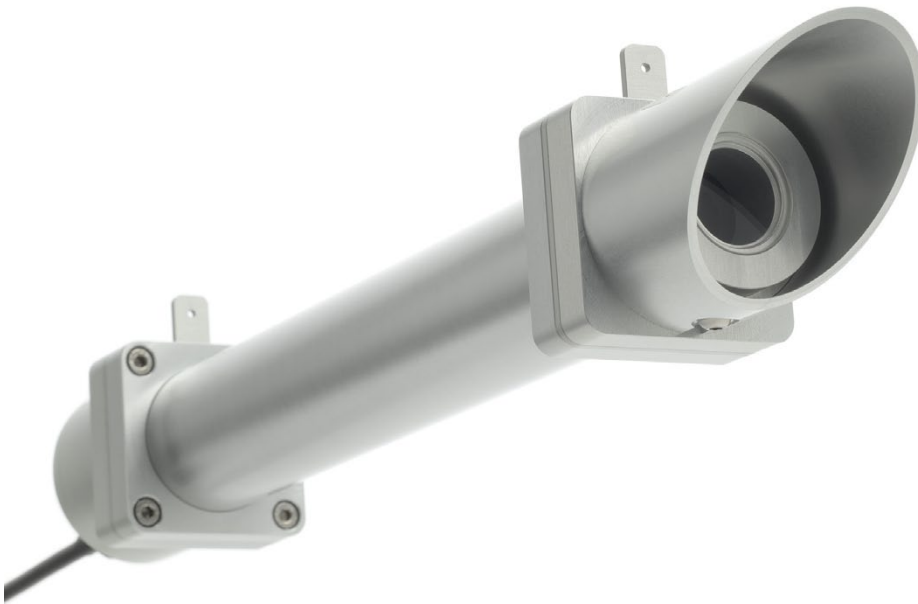


Figure 16 DR01 first class pyrheliometer, the instrument used in pyrheliometer comparisons (Figures 17 to 21)

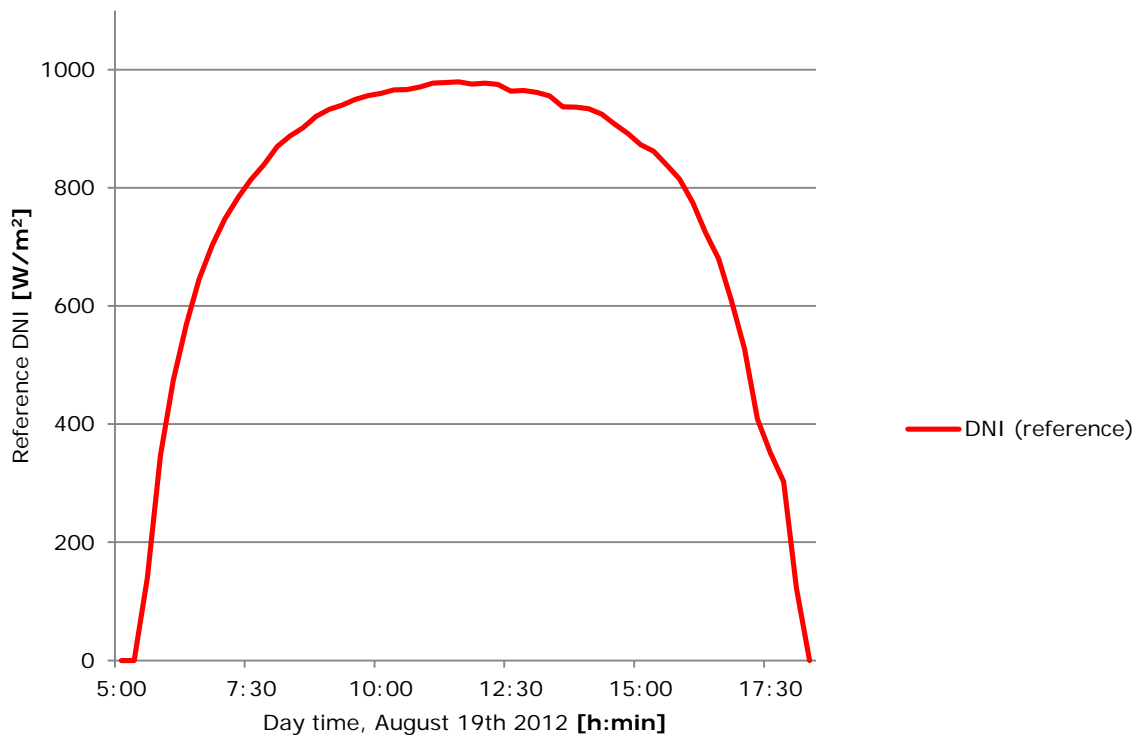


Figure 17 Reference Direct Normal Irradiation, DNI, measured on 19 August, 2012

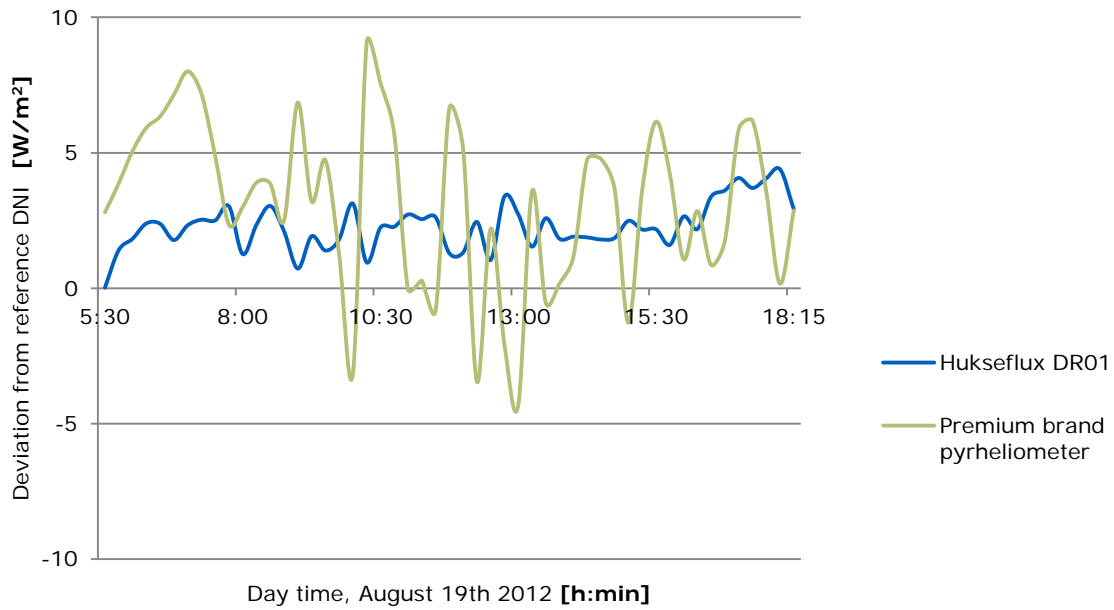


Figure 18 Pyr heliometer comparison, deviation from reference DNI in W/m^2 . DR01 is compared to another premium brand pyr heliometer.

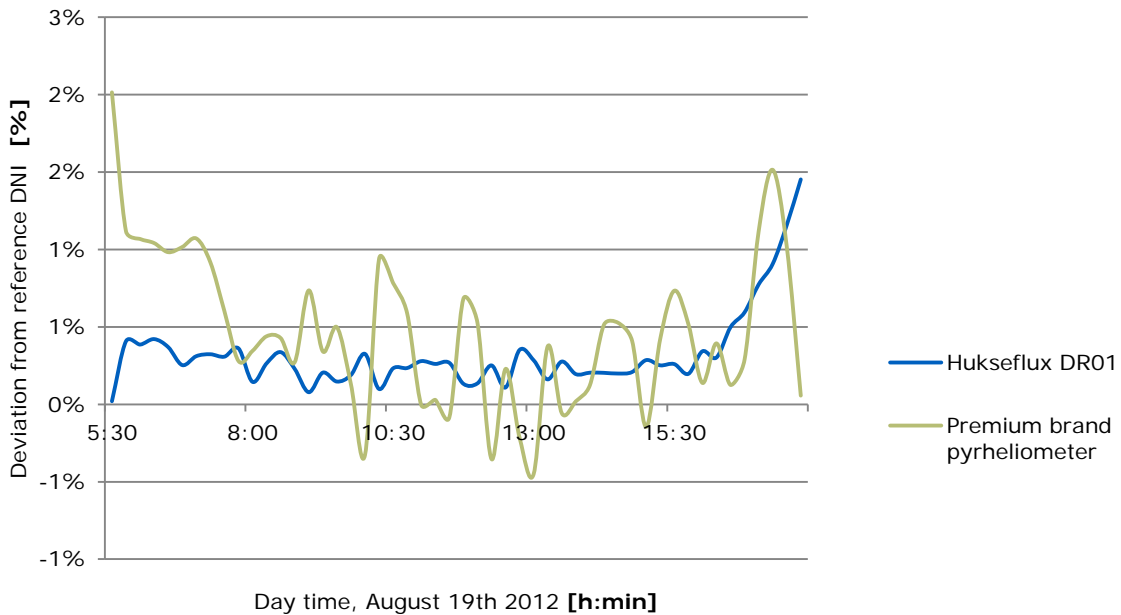


Figure 19 Pyr heliometer comparison, relative deviation from reference DNI. DR01 is compared to another premium brand pyr heliometer.

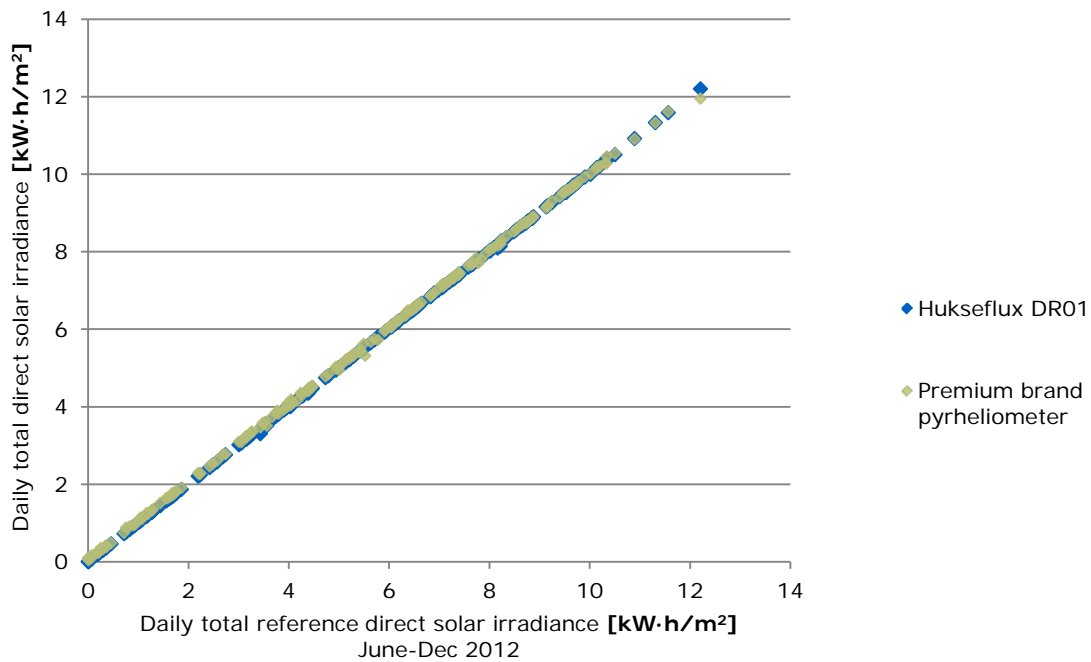


Figure 20 Pyrheliometer comparison, daily totals, deviation from reference. DR01 is compared to another premium brand pyrheliometer.

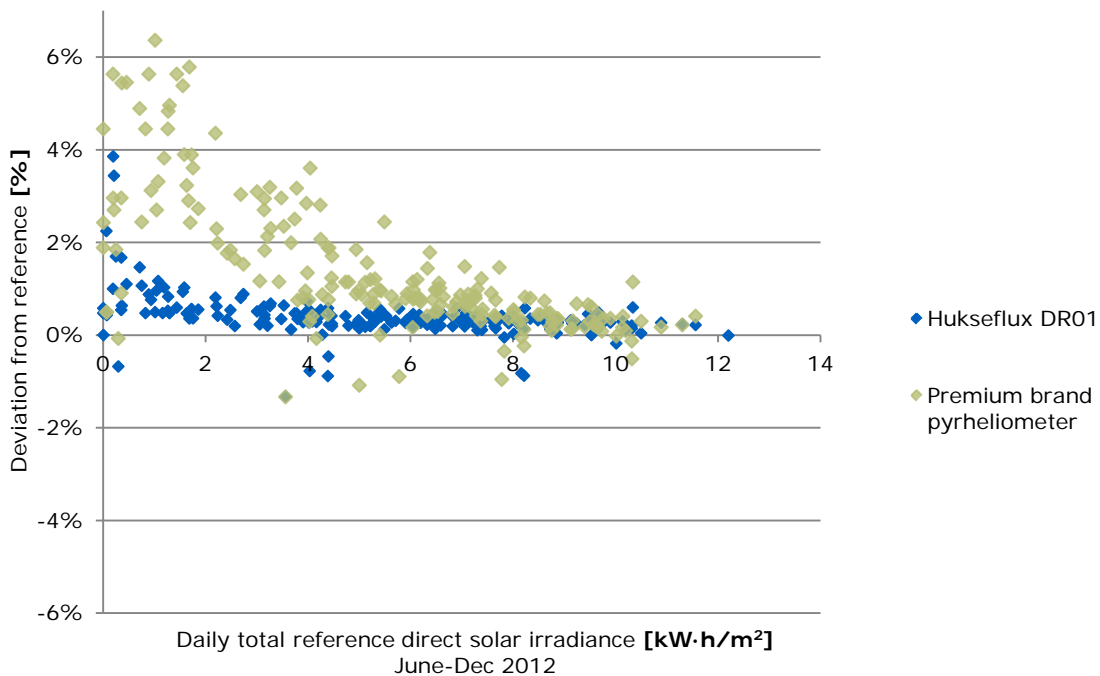


Figure 21 Pyrheliometer comparison, daily totals, deviation from reference, DR01 compared to another premium brand pyrheliometer, 200 days.

Pyrheliometer comparison

A pyrheliometer is used to measure direct normal irradiance (DNI). **Figure 17** shows the reference DNI for a nice sunny day, 19 August 2012.

Figure 18 shows the deviation from reference DNI of Hukseflux DR01 and a competing premium brand pyrheliometer. Around noon, at an irradiance level of 980 W/m^2 , the measured differences were $\pm 5 \text{ W/m}^2$ for the competing model and $\pm 2 \text{ W/m}^2$ for the DR01. In **Figure 19** the deviations of the different instruments are expressed as percentages. The DR01 signal clearly has a smaller deviation from the reference. Reference daily totals are compared to the measured values. **Figure 20** shows that measured daily totals closely agree with reference data. In order to compare different pyrheliometers it is valuable to look into the differences as a percentage of the total. This is shown in **Figure 21**. DR01 operates within 1 % from the reference instrument as soon as the sky is reasonably clear.

For further reading “An Extensive Comparison of Commercial Pyrheliometers under a Wide Range of Routine Observing Conditions” by Michalsky et al. is recommended. Performances of 33 commercially available instruments, including four Hukseflux pyrheliometers, were tested by comparison against four electrical-substitution cavity radiometers.

Conclusions

The tested instruments perform well within claimed instrument specifications. Compared to competing premium brand instruments Hukseflux sensors often perform better.

Hukseflux pyranometer benefits

Hukseflux offers you the best measurement accuracy in every class. In more detail, superior instrument design allows us to claim:

- the best calibration uncertainty
- lowest “zero offset a”
- reduction of measurement errors caused by early morning dew deposition; the top models include a heater

Uncertainty evaluation

The uncertainty of a measurement under outdoor conditions depends on many factors. Guidelines for uncertainty evaluation according to the “Guide to Expression of Uncertainty in Measurement” (GUM) can be found in our manuals. We provide spreadsheets to assist in the process of uncertainty evaluation of your measurement.

Choosing the right instrument

Pyranometers are subject to classification in three classes according to ISO 9060.

From second class to first class and from first class to secondary standard, the achievable accuracy improves by a factor 2.

Measurement accuracy does not only depend on instrument properties, but also on measurement conditions. A very accurate instrument will quickly underperform without a regular schedule of maintenance.

Our pyranometer [selection guide](#) assists you in choosing the right instrument.

Whatever your application is: Hukseflux offers the highest accuracy in every class at the most attractive price level.

See also

- view our complete [product range of solar sensors](#)

About Hukseflux

Hukseflux Thermal Sensors, founded in 1993, aims to advance thermal measurement. We offer a complete range of sensors and systems for measuring heat flux, solar radiation and thermal conductivity. We also provide consultancy and services such as performing measurements and designing instrumentation according to customer requirements. Customers are served through the main office in Delft in the Netherlands, and locally owned representations in the USA, China and Japan.

Need more information?
E-mail us at: info@hukseflux.com