Evaluation of the Delta-T SPN1 radiometer for the measurement of solar irradiance components

Delta-T Devices

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Summary

Last years the solar industry has developed fast, and many solar power fields have been built in Europe. Monitoring of solar irradiance components is needed, both for analysis and for radiation forecasts validation. However, state-of-the-art stations are accurate but also expensive. They also need maintenance and expert operators to keep its data within quality standards. Therefore, a compromise between accuracy and operating costs is convenient. In this regard, more simple and less-expensive instruments can provide similarly accurate estimations of the radiation components.

In this work we have validated the radiation measurements of a SPN1 instrument in comparison to state-of-the art tracking systems. The SPN1 is a robust but small, inexpensive and versatile instrument for the measurement of the broadband global, diffuse and direct components of the solar radiation at ground, without any mobile parts. For the validation, a two year database of global, diffuse and direct radiation measurements, performed with Kipp&Zonen CMP21 and CHP1 in the Burjassot site (a urban site in coast of the Spanish Mediterranean) have been used.

The SPN1 radiometer

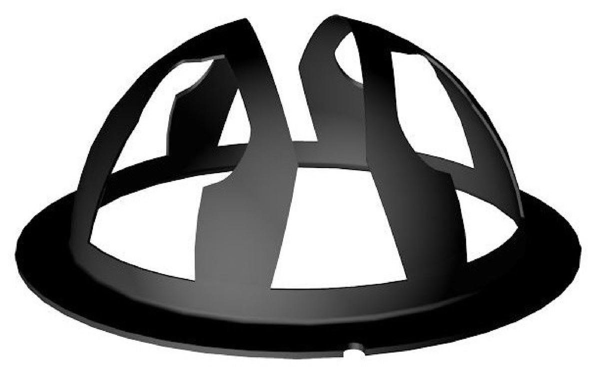


Figure 1. Radiometer SPN1 (up, scale ~1:1) with a detailed view of the computer generated shadow mask (right) and the 7 thermopiles distributed on a hexagon.

At any moment, at least one of the sensors will be in total shade and another one completely under the sun beam

The SPN1 is a radiometer with convenient specifications:

- Measures global, diffuse and direct irradiance without moving parts
- It is small, robust and lightweight so it can be installed on a simple mast.
- No need for azimuthal adjustments
- Easy maintenance
- Inexpensive

On the counterpart it offers also:

- Sensitivity from 400 to 2700 nm
- Time resolution: 1 minute averages (5s readings)
- "Good Quality Pyranometer" (WMO) with overall accuracy 8% (±10 W/m²) for instantaneous readings
- Cosine response accuracy: ±2%
- Zero offset: < 3 W/m²

Methodology

- The SPN1 #A672 was deployed in the Burjassot/Valencia site from Jan 2013 to Dec 2015 to be compared with a K&Z solar tracker system.
- Collocated with a Kipp&Zonen solar station (CMP21/CHP1 radiometers)
- K&Z radiometers ventilated, and correction of zero offset applied
- Pre and Post calibration applied for CMP21 and CHP1. Calibration every 1-2 years.
- Cloud screening from Xia et al. (2007) applied, based on Long and Ackerman (2000).
- Maximum zenith angle of 80º to avoid cosine errors
- The CMP21 radiometer nominally has error of 2% and a directional error of 10 W/m².

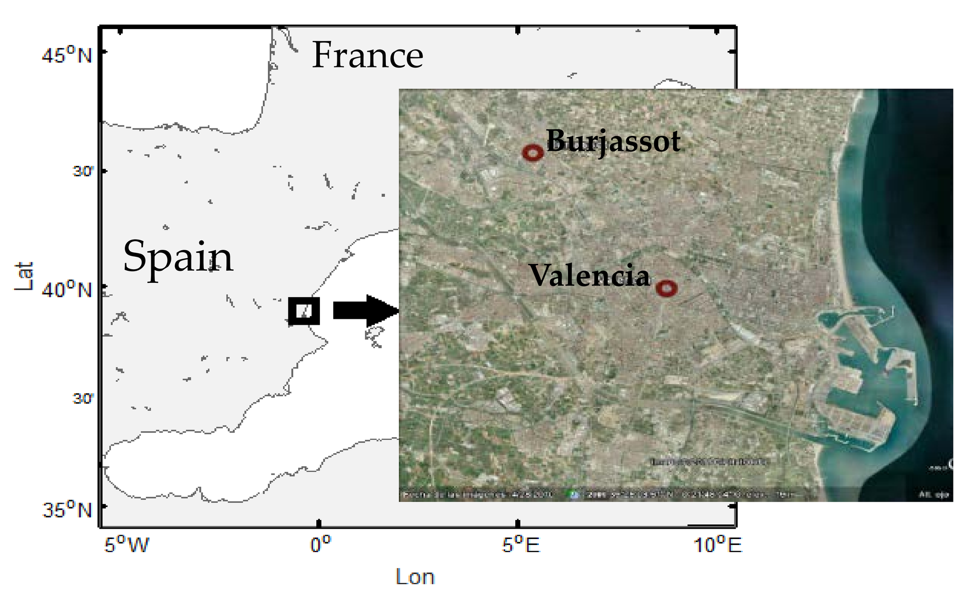
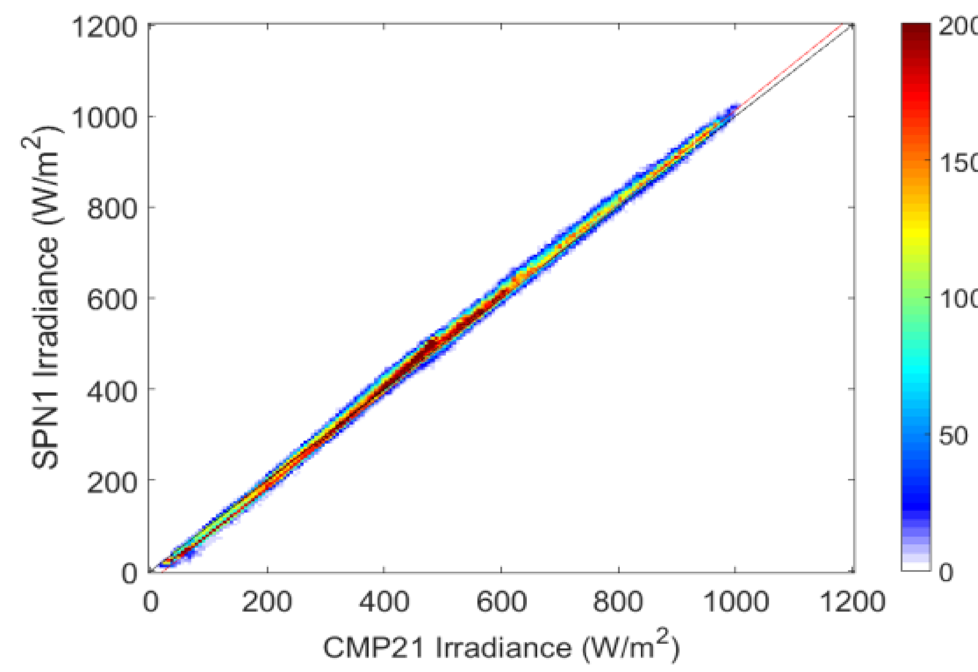


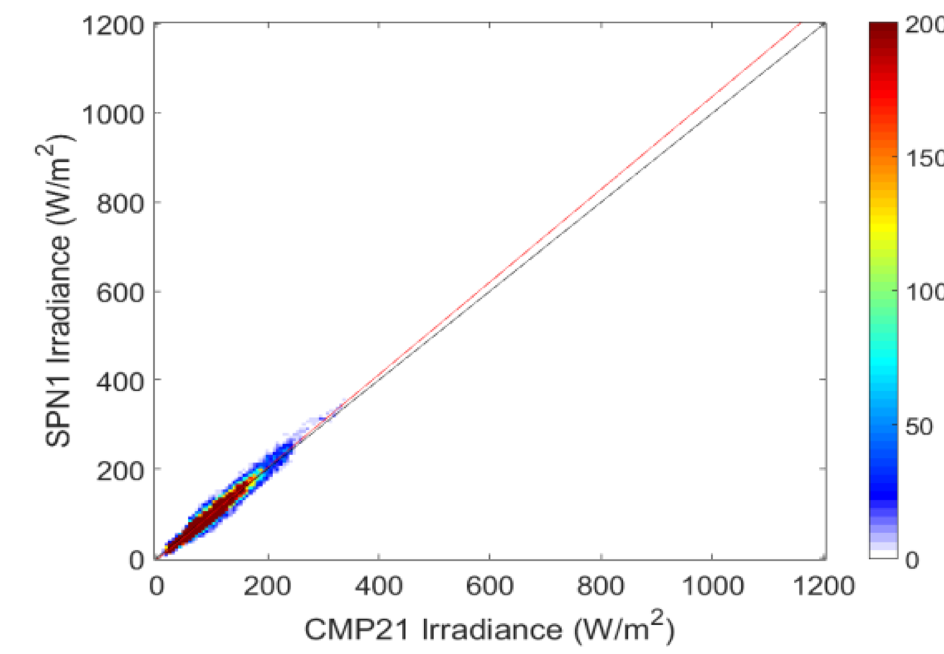
Figure 2. Burjassot site in Eastern Spain, suburban area of Valencia city

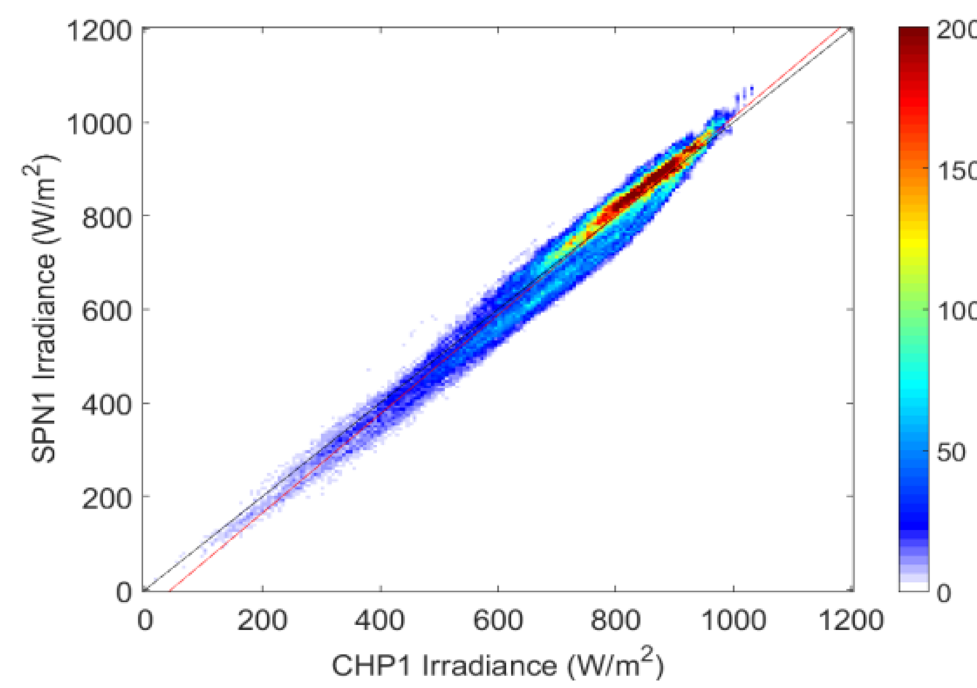
Figure 3. CMP21 and CHP1 radiometers on Solys tracker

Results

Figures 4, 5 and 6 show the correspondence between the global, diffuse and direct irradiance measured with the SPN1 and the CMP21/CHP1 radiometers, only for cloudless skies.







Statistics	Global	Diffuse	Direct
RMSD (W/m²)	15	9.6	34
RMSD (%)	3.2	11	4.6
MBD (W/m²)	5.4	1.1	4.4
MBD (%)	1.1	1.3	0.6
Slope	1.035	1.042	1.057
Intercept (W/m²)	-22.6	-4.64	-46.5
Pearson R	0.998	0.960	0.970
Slope (forced)	0.998	0.999	0.997
R (forced)	0.996	0.958	0.966

Table 1. Fitting parameters and statistics for the global, diffuse and direct irradiance comparison. The number of data pairs is 113442. A 3σ filter was applied to get rid of anomalous data (shades from near masts, cleaning, etc).

Both the global and diffuse irradiances are well measured in comparison to CMP21 and CHP1 radiometers (15 and 9.6 W/m²), well within the combined uncertainty. The absolute differences are higher for the direct component, although the relative differences are lower than diffuse. The linear parameters show also a very good correspondence, mainly for global and diffuse irradiances.

Conclusions

- Global and diffuse irradiances are measured well within the instrument uncertainties. Relative deviation for the direct component is also small in cloudless skies.
- Good correspondence with previous comparisons reported by Badosa et al. (2014) for a multisite study in different environments (Table 2).
- The SPN1 has shown a very good potential to measure the solar irradiance, mainly for distributed networks, where maintenance and operation are critical.
- Operation and deployment is extremely easy. Deployment on vessels is made feasible.

	Our study	Badosa et al (2014)
Slope – Global	0.998	0.955 – 1.021
Slope – Diffuse	0.999	0.901 – 0.976
Slope – DNI	0.997	1.009 – 1.076
RMSD (%) – Global	3.2	3.4 – 4.5
RMSD (%) – Diffuse	11	7.4 – 9.3
RMSD (%) – DNI	4.4	8.7 - 14

Table 2. Our results are in agreement with a multi-site comparison performed by Badosa et al. (2014)

Acknowledgements

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