

Solar Radiation Atlas for Spain based on Surface Irradiance Data from EUMETSAT Climate Monitoring-SAF

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ABSTRACT

A Solar Radiation Atlas for Spain has been performed using monthly mean data provided by the EUMETSAT Satellite Application Facility on Climate Monitoring (CM-SAF) for the period 1983-2005 and 0.03°x0.03° spatial resolution. The main goal of this work was to obtain a high spacial resolution climatological characterization for incident surface irradiance in Spain. Surface incoming solar radiation (SIS) and direct irradiance (SID) variables from CM-SAF data sets have been used in order to discern direct and diffuse components from global irradiance. These data are derived from the information provided by MVIRI instrument onboard the Meteosat First Generation (MFG) satellites and using the MAGIC SOL algorithm. There are shown maps, graphics and tables of monthly, seasonal and annual means for global, direct and diffuse irradiance on horizontal plane. In addition, in order to geographically characterize SIS and SID uncertainties, derived satellite data have been validated against 29 ground-based stations belonging to AEMET (Spanish Meteorological Agency) National Radiometric Network. The estimated relative Mean Absolute Difference (MAD) is less than 7% indicating a good performance of the algorithm used and a remarkable high quality of SIS and SID datasets.

GLOBAL AND DIRECT SURFACE IRRADIANCE MEAN FIELDS (1983-2005)

SAF on Climate Monitoring (CM-SAF) was developed under the leadership of Deutscher Wetterdienst, the German Meteorological Service and entered its Continuous Development and Operations Phase in 2007 [Schulz et. al. 2009]. CM-SAF aims to provide and archive data that can be used to assess the current climate and its variability.

Monthly average daily values for Surface incoming solar radiation (SIS) and direct irradiance (SID) CM-SAF variables for the period 1983-2003 and dataset category have been used to develop this Atlas.

The Atlas includes fields showing Global and Direct irradiances reaching a horizontal plane in 0.2-4.0µm wavelength region for Iberian peninsula and Canary Islands regions.

Means for the whole period 1983-2005 (Figures 1 and 2), as well as seasonal and monthly averages along with monthly extremes fields are shown. Strong latitudinal contrasts intensified at the east-west oriented mountain ranges and being more important in summer are remarkable. Maximum values are registered in southern Spain and minimum irradiances at north of Cantabrian mountain range.

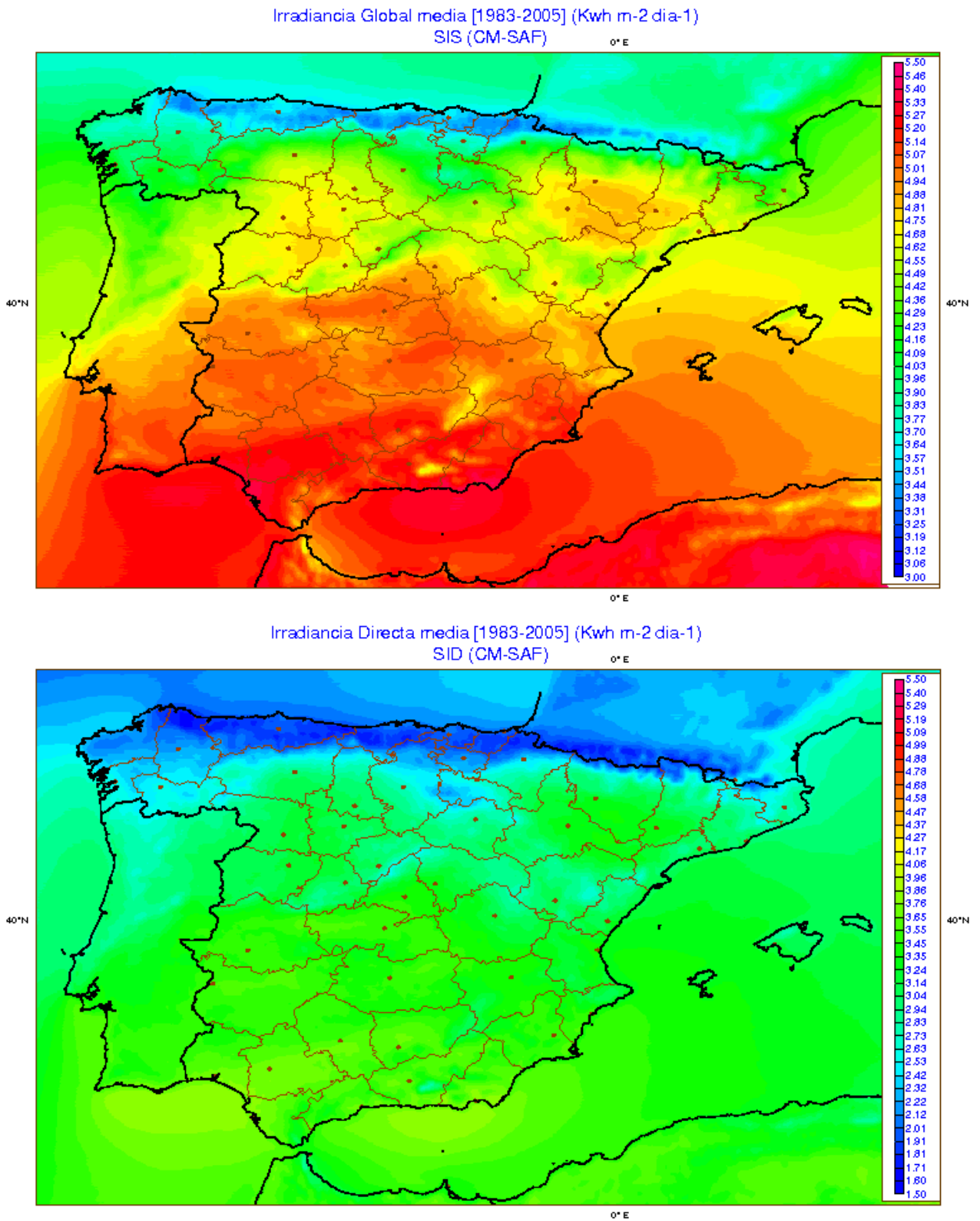


Figure 1: Mean global and direct irradiances for the period 1983-2005 (SIS and SID). Iberian Peninsula.

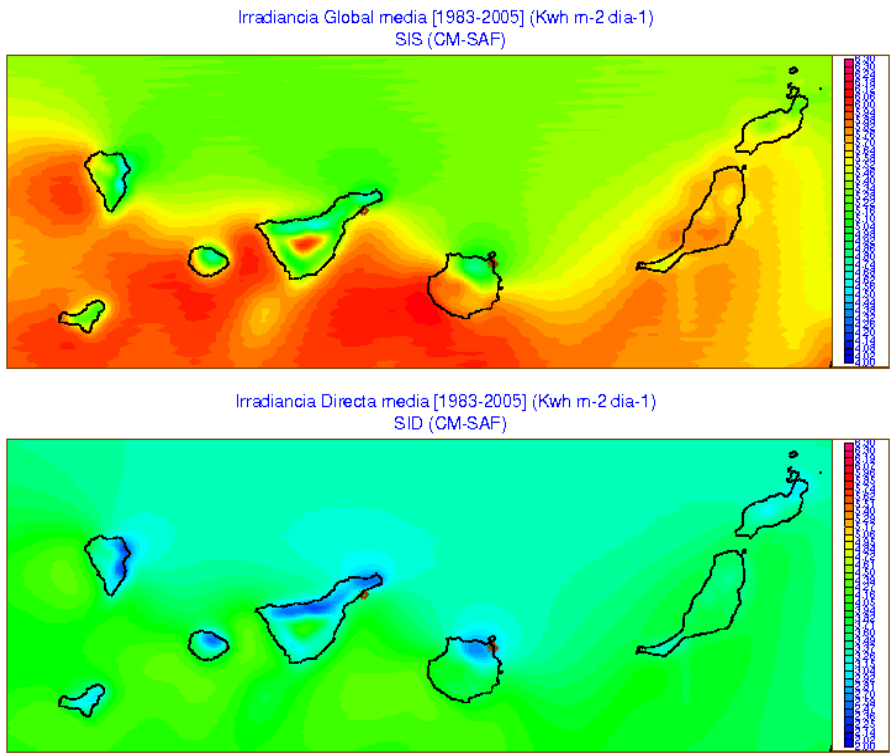


Figure 2: Mean global and direct irradiances for the period 1983-2005 (SIS and SID). Canary Islands.

MEAN ANNUAL OSCILLATION AT MAIN SPANISH CITIES

Direct and Global irradiances are interpolated at the location of the 17 main spanish cities and depicted in bar diagrams differenciating direct and diffuse components (see example for 2 cities in Figure 3). These graphics show the mean annual oscillation at main cities and lines in red and blue indicating average values for the whole region and for global an direct irradiances respectively, are also shown for reference. The ratio diffuse/global is around 1/3, being the contribution of diffuse radiation to the global more important in northern Spain and Canary Islands.

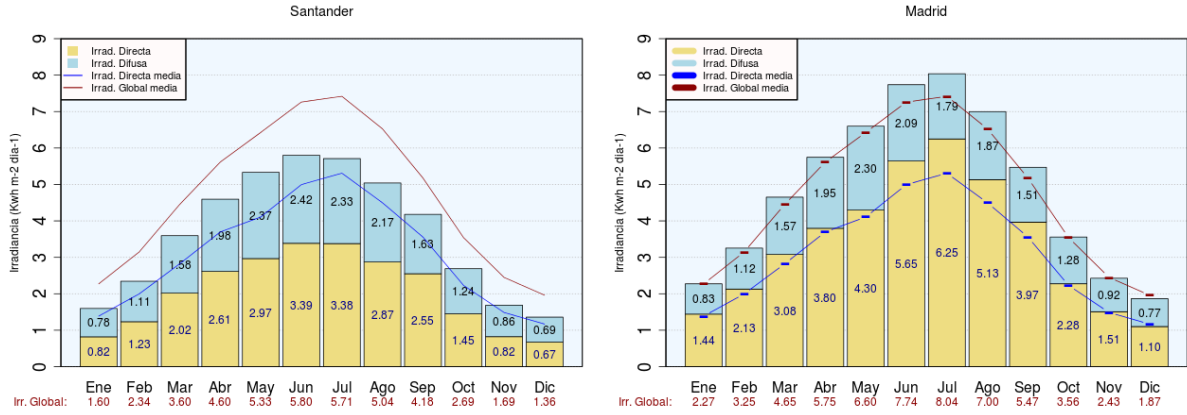


Figure 3: Mean annual oscillation for Madrid and Santander cities along with averages SIS and SID values for the whole domain (red and blue lines). Period :1983-2005

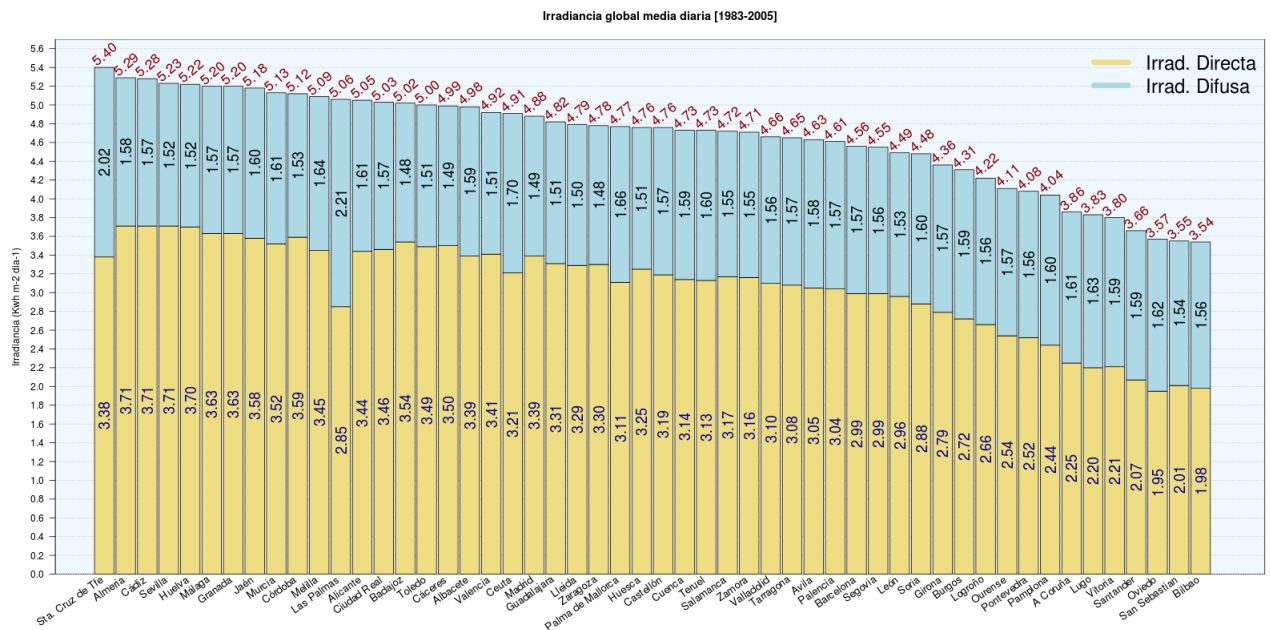


Figure 4: Mean global (blue+yellow) and direct (yellow) irradiances for main spanish cities sorted in descending order (1983-2005).

LOOKUP TABLES

Statistical values for the most populated cities are also included showing monthly and total averages as well as extremes, quartiles and standard deviations for 1983-2005 (Table 1)

IRRAD. GLOBAL <i>kwh m⁻² día⁻¹</i>	PERÍODO COMPLETO [1983-2005]					
	MIN.	P ₂₅	P ₅₀	P ₇₅	MAX.	σ
ACoruña	0.97	2.00	3.83	5.69	7.26	1.86
Albacete	1.68	3.00	5.14	6.88	8.52	2.03
Alicante	1.92	3.11	4.99	6.89	8.16	1.94
Almería	2.17	3.36	5.36	7.12	8.41	1.95
Avila	1.39	2.66	4.75	6.47	8.25	2.04
Badajoz	1.49	3.03	5.22	6.94	8.52	2.11
Barcelona	1.53	2.65	4.60	6.33	7.94	1.91
Bilbao	1.06	1.95	3.68	4.90	6.88	1.58
Burgos	1.11	2.26	4.32	6.24	8.20	2.13
Cáceres	1.62	3.00	5.21	6.93	8.45	2.13
Cádiz	1.76	3.33	5.49	7.19	8.57	2.00
Castellón	1.61	2.97	4.81	6.48	8.37	1.89
Ceuta	1.57	2.91	4.95	6.71	8.16	1.97
CiudadReal	1.46	3.00	5.21	6.99	8.50	2.11
Córdoba	1.60	3.12	5.33	7.09	8.61	2.05
Cuenca	1.33	2.79	4.76	6.63	8.53	2.06
Girona	1.50	2.59	4.49	5.97	7.65	1.79
Granada	1.73	3.27	5.29	7.13	8.54	2.00
Guadalajara	1.34	2.80	4.95	6.79	8.33	2.14
Huelva	1.70	3.27	5.40	7.16	8.66	2.03
Huesca	1.33	2.71	4.97	6.61	8.21	2.07
Jaén	1.83	3.19	5.35	7.11	8.58	2.04
LasPalmas	2.64	3.91	5.27	6.06	7.68	1.19
León	1.09	2.45	4.56	6.43	8.21	2.13
Lleida	1.20	2.64	5.01	6.66	8.23	2.13
Logroño	1.18	2.15	4.37	5.99	7.74	1.95
Lugo	1.05	2.08	3.82	5.50	7.38	1.81
Madrid	1.22	2.83	4.98	6.84	8.42	2.14
Málaga	1.80	3.22	5.40	7.08	8.37	1.98
Melilla	2.24	3.28	5.30	6.74	7.95	1.74
Murcia	2.00	3.19	5.16	6.91	8.35	1.95
Ourense	1.01	2.17	4.02	5.93	7.80	2.00
Oviedo	1.29	2.07	3.71	4.86	6.54	1.45
Palencia	1.31	2.51	4.74	6.63	8.28	2.15
PalmadeMallorca	1.66	2.76	4.78	6.69	8.21	1.99
Pamplona	1.15	2.09	4.05	5.75	7.80	1.93
Pontevedra	0.93	2.15	4.07	5.95	7.53	1.96
Salamanca	1.41	2.60	4.88	6.66	8.35	2.12
SanSebastian	1.07	1.92	3.70	4.92	6.81	1.62

Table 1: Statistical values for the most populated spanish cities.

SOLAR RADIATION IN EUROPE

In order to have a global european picture for incident global irradiance, the mean irradiance field is shown for the whole 1983-2005 period (Figure 5) and interpolated mean values at the location of the european capitals are depicted in bar diagrams differentiating direct and diffuse components (Figure 6).

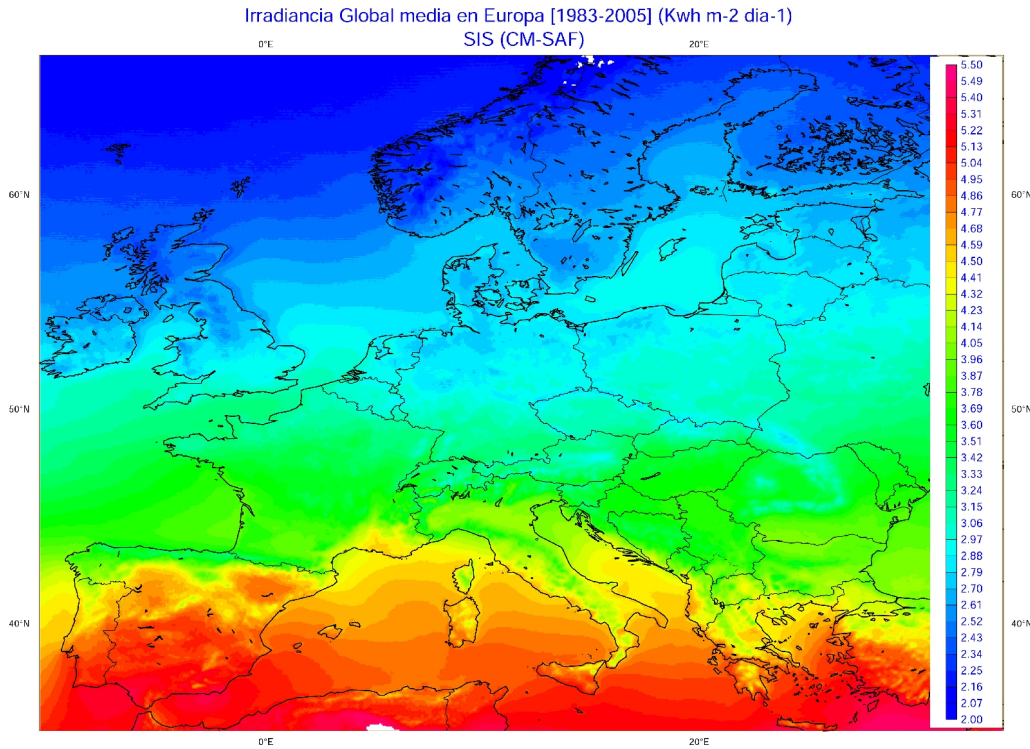


Figure 5: Mean global (SIS) and direct (SID) irradiances in Europe for the period 1983-2005.

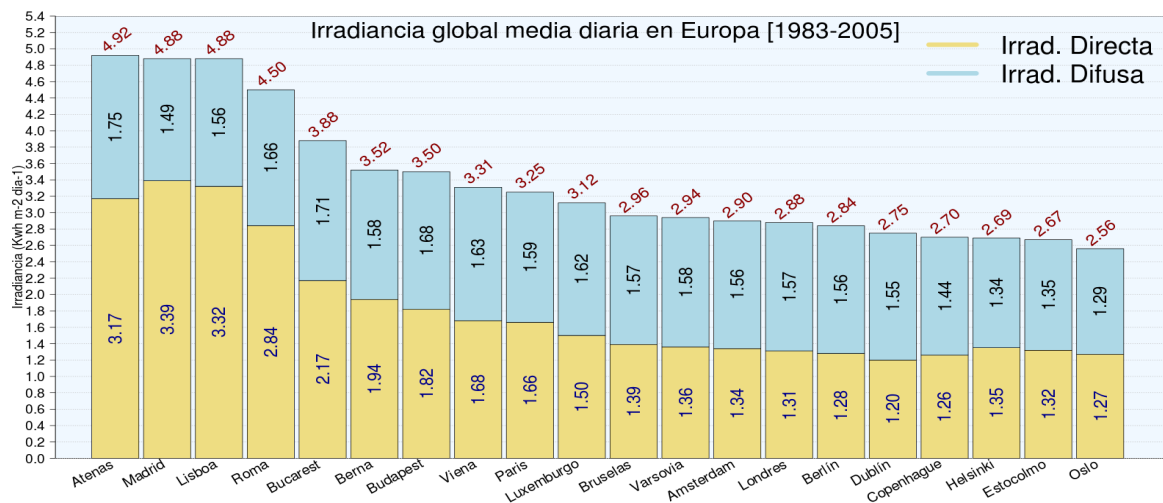


Figure 6: Interpolated mean values of global (SIS) and direct (SID) irradiances in european capitals for the period 1983-2005.

VALIDATIONS AGAINST AEMET RADIOMETRIC NETWORK

Spanish Meteorological Agency (AEMET) maintains a network of 51 radiometric stations providing ground-based radiation measurements. Figure 7 shows the location and different variables obtained in each station. Main radiometric stations measure the following set of variables: Global and diffuse irradiances, as well as infrared and UVB irradiances. Direct, global and diffuse sensors are installed on an automatic solar tracker (see Figure 8). It consists on shading units (the two black balls linked by a dipstick to the tracker) which casts shadows on the diffuse sensors.



Figure 7: AEMET radiation network.

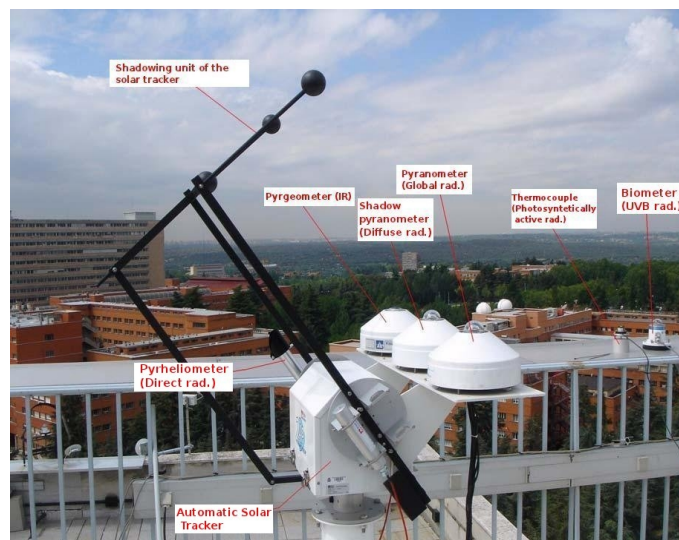


Figure 8: Sensors placement in a AEMET main radiometric station.

Global irradiance (SIS) and Direct irradiance (SID) have been validated using 2003-2005 observations from 29 ground based stations belonging to AEMET National Radiometric Network.

Figure 9 shows the linear regression analysis (SIS vs. ground-based observations) indicating a Pearson correlation coefficient of 0.99, and Figure 10 shows the Mean Absolute Deviation (MAD) at radiometric station's location.

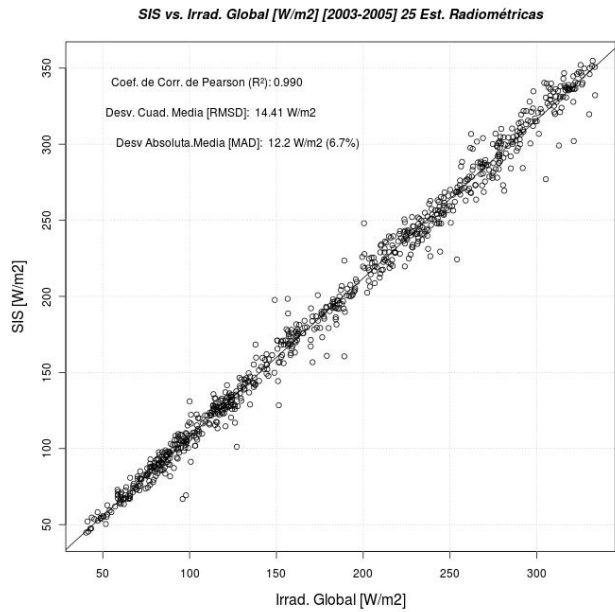


Figure 9: Linear regression SIS vs. ground-based observations.

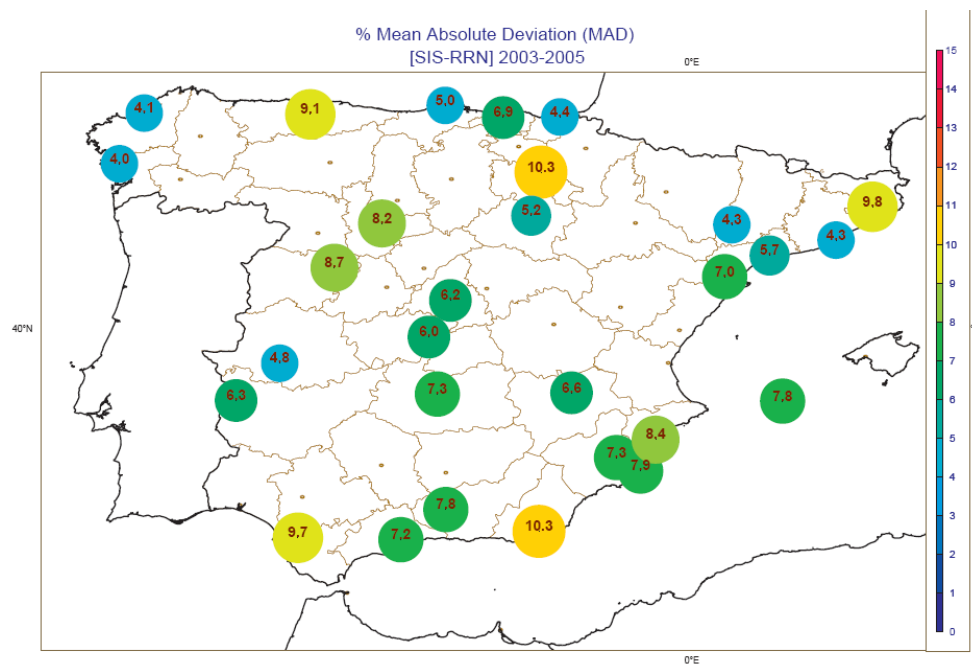


Figure 10: Mean Absolute Deviation (MAD) in percentage at the radiometric station's location.

	Meses	BIAS (Wm^{-2})	BIAS (%)	MAD (Wm^{-2})	MAD (%)	SD (Wm^{-2})	R^2
25 Est. Penín	770	11,14	6,2	12,23	6,7	14,41	0,990
4 Est. Can	77	16,24	7,84	16,47	7,9	19,36	0,976

Table 2: Summary of the validations using 25 radiometric stations in Iberian Peninsula and 4 Stations in Canary Islands.

In summary, these are the main conclusions about the results of the validations:

- Mean Absolute Differences (MAD) of SIS for 25 peninsular stations is 12.23Wm-2 (6.7%).
- Higher MAD values found for the 4 Canary stations: 16.47Wm-2 (7.9%).
- Accuracy decreases in general towards the south especially in summer and autumn.
- Improvements are needed in aerosol and water vapor information.

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For more details download the complete Atlas from:

http://www.aemet.es/es/serviciosclimaticos/datosclimatologicos/atlas_radiacion_solar