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Long term HelioClim-3 global, beam and diffuse irradiance validation

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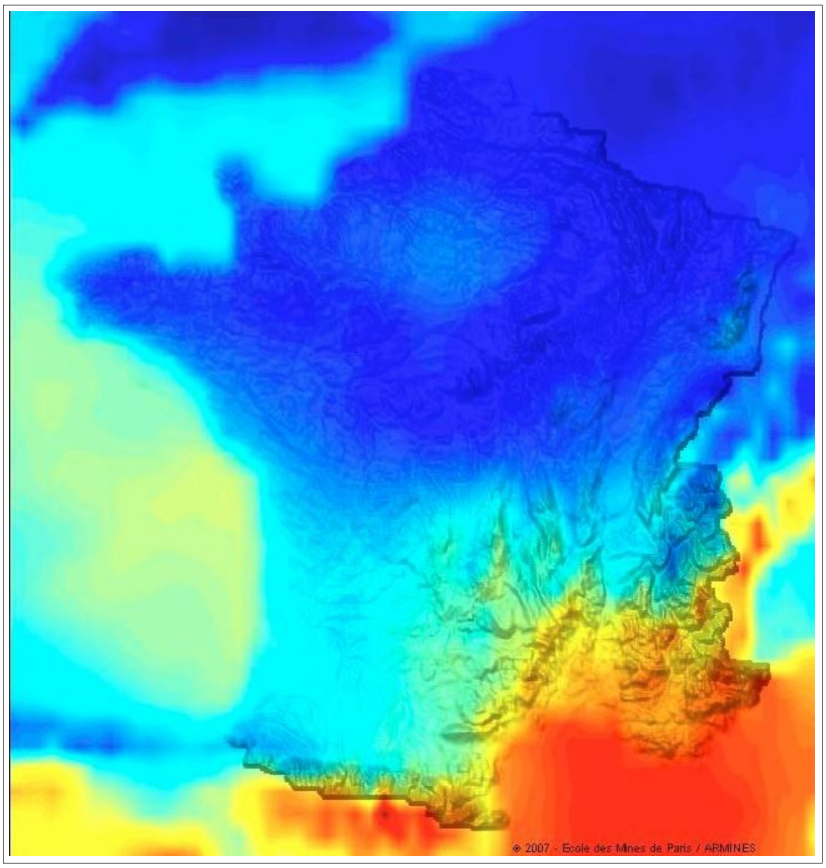
February 2016



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Abstract

Satellite derived solar radiation is nowadays a good alternative to ground measurements for renewable energy applications. It has the advantage to provide data with a good accuracy, the best time and space granularity, in term of real time series and average year such as TMY.

This report presents results of a long term validation in the European and Mediteranean regions of the irradiance evaluated by the HelioClim-3 scheme in hourly, daily and monthly values, and seven average products on an annual basis. The performance is also put forward with the natural interannual variability.

The main results are:

- the accuracy of the derived hourly global irradiance reaches 20% (standard deviation) with no bias, and 46% for the beam component with a 6% to 9% mean bias,
- the main improvement from version 4 to version 5 comes from the use of a new clear syk model with sub-daily aerosol data as input,
- some systematic patterns are pointed out, depending on the sky type, the site latitude, the aerosol optical depth and the ground snow cover,
- the overall annual uncertainty of the HelioClim-3 scheme is situated within one interannual variability standard deviation for the global component, and within two standard deviations for the beam irradiation,
- the overall performance for the beam component is slightly worse for version 5, but the frequency distributions are improved, particularly for high irradiance values.

Nomenclature

G_h or *GHI*	global horizontal solar irradiance or irradiation
G_{hc}	clear sky global horizontal solar irradiance or irradiation
B_n or *DNI*	normal beam (or direct) solar irradiance or irradiation
D_h or *DIF*	diffuse horizontal solar irradiance or irradiation
B_{nc}	clear sky normal beam solar irradiance or irradiation
G_{sat}	modeled solar irradiance or irradiation
G_{mes}	measured solar irradiance or irradiation
I_o	extra-atmospheric solar irradiance
K	clearness or clear sky index
K_t	global clearness index (G_h normalized by $I_o \sin h$)
$K_{t'}$	modified global clearness index
K_c	global clear sky index (G_h normalized by G_{hc})
K_d	diffuse clearness index
K_b	beam clearness index
K_{bc}	beam clear sky index (B_n normalized by B_{nc})
T_L	Linke turbidity coefficient
T_{Lam2}	Linke turbidity coefficient at air mass = 2
aod	atmospheric aerosol optical depth
w	atmospheric water vapor content or column
δ_{cda}	aerosol optical depth of a clean and dry atmosphere
δ_w	water vapor atmospheric optical depth
T_a	ambiant temperature at 2m
RH	relative humidity at 2m
h	solar elevation angle
AM	atmospheric air mass
n	cloud index
ρ	planetary albedo
ρ_g	overcast sky planetary albedo
ρ_c	clear sky planetary albedo
mbd	mean bias difference
rmsd	root mean square difference
sd	standard deviation
bsd	bias standard deviation (standard deviation of the bias)
R	correlation coefficient
KSI%	second order Kolmogorov-Smirnov test

irradiation from one year to the other in the model uncertainty. To conduct a significant interannual variability analysis, a long period of data is needed. These long time series have to be as continuous as possible and with no missing data. As the majority of the ground measurements time series are not complete and as it is not possible the fill the gaps, a strategy has to be developed to circumvent the problem.

The following corrections are applied on the data: to obtain a yearly total, the data are taken month by month and added. For each month, the missing share of ground measurements is evaluated in term of a number of missing data percentage. When the gaps' length represents less than 5% of the month, a linear extrapolation is applied on the monthly values based on the normalized number of hourly values aggregated in the considered month. When more than 5% of the data are missing, the monthly value is replaced by the average of all the corresponding months of the considered time series. The missing share statistics are given in Table II.

In Lerwick, the 10% missing data for the beam component occur mainly in 2011. For the site of Madrid too many data are missing for the beam component, so that the interannual variability analysis is not significant.

Due to these corrections, the results given in the interannual variability bar charts do not correspond exactly to the hourly validation results. As the hourly comparison is restricted to validated values, some differences may also occur depending on the length of the comparison period. Nevertheless, the results are significant when considered as a general overview the tendency of a model to reproduce the data.

8. Validation results

8.1 Hourly, daily and monthly validation

The total amount of points included in the comparison and the corresponding irradiance and irradiation averages are the following:

- 700'000 hourly values $G_h = 317$ $B_n = 322$ $D_h = 129$ [W/m²]
- 60'000 daily values $G_h = 3.73$ $B_n = 3.78$ $D_h = 1.51$ [Wh/m².day]
- 2'000 monthly values $G_h = 108$ $B_n = 109$ $D_h = 44$ [Wh/m².month]

The number of ground or satellite derived values differ from one site to the other, and the covered periods are not of the same length for all the sites (see Table II).

Table III Results of the hourly, daily and monthly validation. The standard deviation calculated on the mean bias differences over all the 18 sites.

	HelioClim-3v4						HelioClim-3v5					
	Gh		Bn		Dh		Gh		Bn		Dh	
	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd	mbd	sd
hourly [Wh/m2h]	317		322		129		319		323		129	
	0	65	18	155	-12	58	4	64	28	150	-16	55
	0%	21%	6%	48%	-10%	45%	1%	20%	9%	46%	-12%	43%
Daily [kWh/m2]	3.73		3.78		1.51		3.73		3.78		1.51	
	0.00	0.45	0.22	1.24	-0.15	0.47	0.04	0.42	0.33	1.08	-0.18	0.44
	0%	12%	6%	33%	-10%	31%	1%	11%	9%	29%	-12%	29%
Monthly [kWh/m2]	85.7		80.2		41.0		88.4		82.7		42.2	
	8.2	8.8	23.8	21.3	-2.4	5.1	2.8	6.5	10.3	14.2	-2.4	3.7
	0%	6%	6%	16%	-10%	15%	1%	5%	9%	13%	-12%	15%
bias sd	4.4%		13.1%		16.2%		3.4%		13.7%		16.2%	

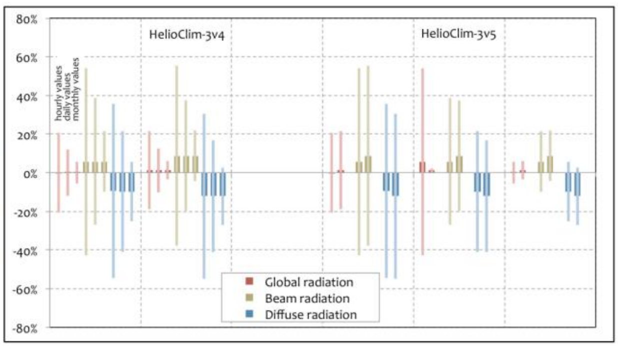

Figure 17 Corresponding graphical representration of the results.

Table III and Figure 17 give the main results of the validation (the complete results, site by site, for the two versions of HelioClim-3, component by component, in hourly, daily and monthly, absolute and relative values are given in the annex, Tables a-I, a-II and a-III). A general observation is that the hourly global irradiance is retrieved with a zero average bias and a standard deviation around 20% (65 [W/m^2]), the beam component around 47% (150 [W/m^2]) with a +6% to +9% bias, and the diffuse around 45% (56 [W/m^2]) with a -10% bias. If the overall bias for the global irradiance is zero, it can be highly variable from one site to the other (-8% to +9%) . This is highlighted by the standard deviation of the mean bias deviation *bsd*; it stays around 3.5% for the global component. For the beam component (and a fortiori for the diffuse irradiance), the bias varies from site to site, especially for northern sites (i.e. Lerwick).

8.1.1 Model-measurements difference distribution

In a general way, for the global component and both versions, the bias distribution around the 1:1 axis follows a un- or slightly skewed normal distribution, so that the standard deviation indicator is significant (see Figures 11 & 12, a-1g to a-4g and a-10g to a-13g in the annex). This is not the case for the normal beam irradiance, where bimodal (i.e. Nantes), skewed or not normal distributions can occur depending on the site. No common rule can be drawn from the Figures a-10b to a-13b in the annex, the shape of the distribution depends on the clear sky model used and the specificities of the input parameters. For some sites with sunny conditions like Almeria, Carpentras, Tamanrasset or Sede Boqer, the dispersion of the hourly bias is so high that the distribution cannot be considered as normal. In this case, the standard deviation has to be considered with precaution. Concerning the diffuse component, even if the values on the model/measurements graphs are not aligned on the 1:1 axis, the frequency of occurrence distribution is not too far from a normal distribution; this makes the standard deviation representative of the uncertainties (see Figures a-1d to a-4d and a-10d to a-13d in the annex)

8.1.2 Improvement from HelioClim-3 version 4 to version 5

The improvement between HelioClim-3 version 4 and version 5 is the use of a new clear sky model. In version 4, the used clear sky is evaluated with the ESRA model, developed by Rigollier and Geiger (Rigollier et al. 2000, Geiger et al. 2002). Validation of this model (Ineichen 2016) shows clearly an underestimation for both global an beam components. This is illustrated on Figure 18 (upper graphs) where the clearness index is represented versus the solar elevation angle for both components. The measurements are plotted in yellow dots, and the model in blue. The upper limit, representative of clear conditions, is never reached by the modelled values, especially for the beam component (see Figures a-1b to a-4b in the annex). The consequence on the irradiance modelled values is that the highest values are never reached. In HelioClim-3 v5, an adaptation of the clear sky model is done using the McClear model (Lefèvre 2013) with MACC-II aerosol sub-daily data (Kaiser et al. 2002). The improvement is illustrated on Figure 18 lower graphs, where the same parameters than for version 4 are represented. For the new version, the clear sky measurements are reached by the modelled values, except for low solar elevation angle values where a slight underestimation is visible (see Figures a-9g and a-9b in the annex).

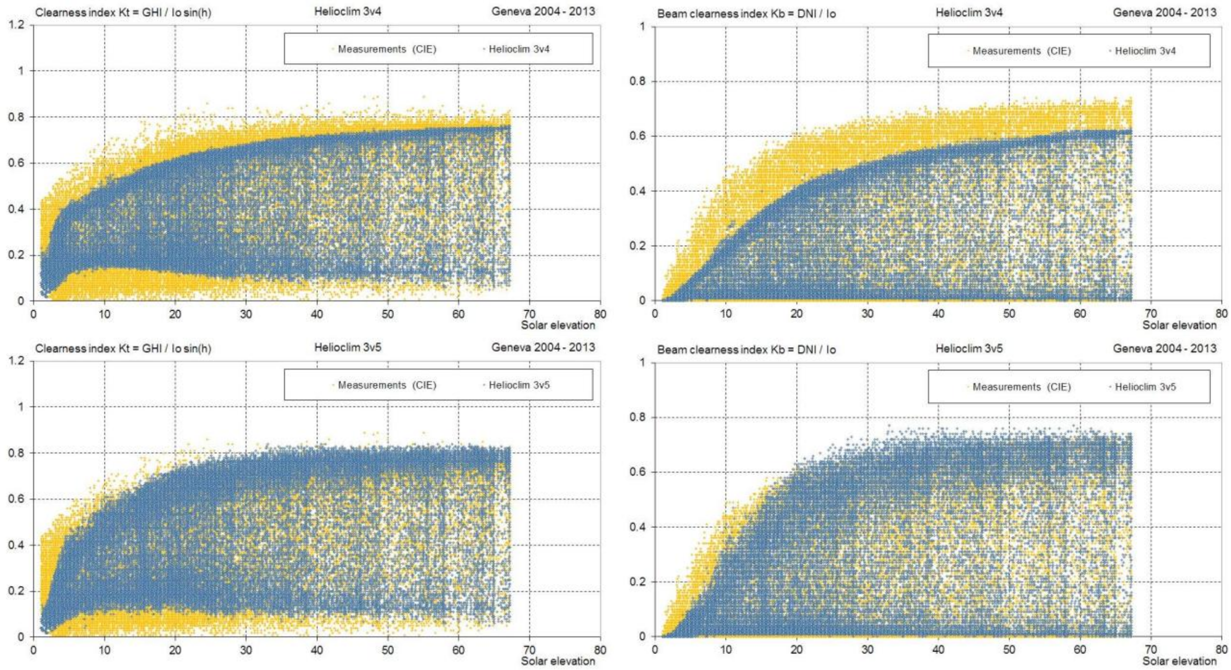

Figure 18 Global and beam clearness index (*K_t and K_b*) plotted versus the solar elevation angle for the two versions of helioclim-3.

8.1.3 Time resolution of the input parameters

When representing the clearness index versus the solar elevation angle, the time resolution effect of the *aod* and *w* input to the model can be pointed out. In version HelioClim-3 v4, monthly climatic values are used to evaluate the clear sky, whereas sub-daily values obtained from the MACC-II project are used in HelioClim-3 v5. This is illustrated on Figure 19 where aggregates of points are visible only on the left graph. This effect can be seen on the graphs for all the sites (see Figures a-9n in the annex), more particularly on sites where *aod* and *w* are highly variable (i.e. Lerwick and Nantes).

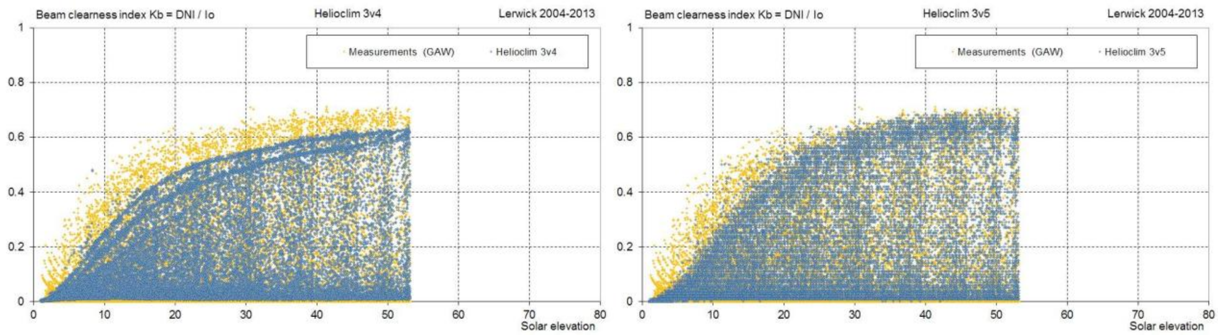

Figure 19 Beam clearness index K_b plotted versus the solar elevation angle for the two versions of helioclim-3 for the site of Lerwick.

8.1.4 Sky condition effect

The observation of the bias versus the modified clearness index K_t' (or the sky type, see Figures a-5g and a-5b in the annex) shows the same general tendency for all the models and both components: a slight overestimation for cloudy conditions and an underestimation for clear skies. The highest effect is a beam component overestimation for intermediate conditions. This is illustrated on Figure 20. For clear conditions, the dispersion is due to an approximate knowledge of turbidity. In the case of intermediate cloud cover, the model does not identify with enough precision the type and thickness of the clouds (see Figures a-5g and a-5b in the annex).

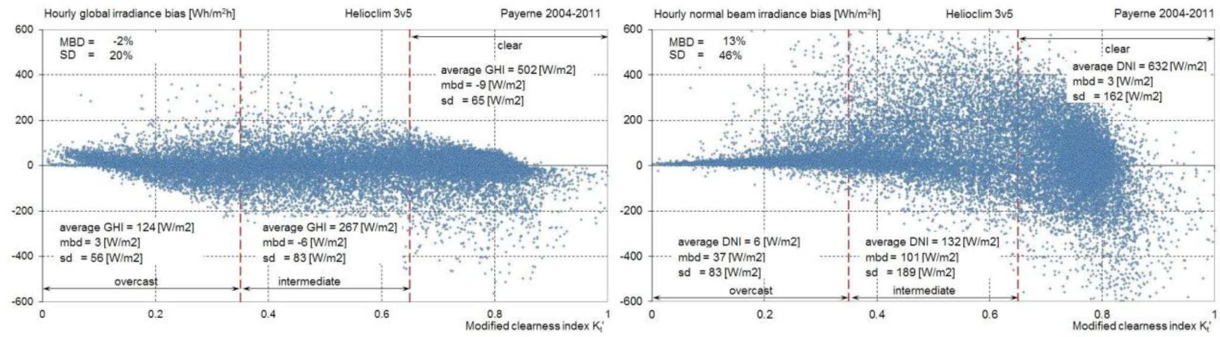

Figure 20 Model bias versus the clearness K_t (or sky conditions) for the global and beam components.

8.1.5 *Snow effect*

For the site of Davos, the snow cover during the winter period has a significant effect on the modeled irradiance. Indeed, if no particular attention is payed in winter, the high reflectance of the snow cover can change the determination of the ground albedo, and during the process, can be interpreted as cloudy conditions. The result is an overestimation of the irradiance for cloudy condition conditions due to the underestimation of the ground albedo. Moreover, the variability of the snow cover induces a higher dispersion of the irradiance, especially for the beam component. The effects are visible on Figure 21 where the model bias is represented versus the modified clearness index, or sky conditions, for the global and the normal beam components.

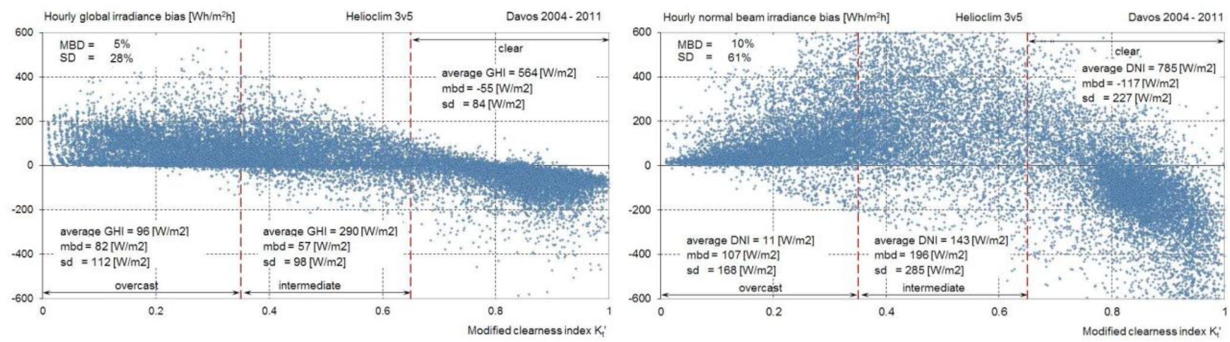

Figure 21 Model bias versus the clearness K_t (or sky conditions) for the global and beam components and the site of Davos.

8.1.6 *Latitude effect*

Due to the angle of view of the ground surface by the satellite, the size of the image pixel increases with the latitude of the site. This means that the reflectance of the ground includes also a higher variety of ground albedo values, and cloud types and altitudes. The small view angle of the satellite with respect to the ground increases the parallax effect on the cloud position (Schutgens 2009, Marie-Joseph 2013). The result on the modeled irradiance is a higher dispersion (standard deviation) for both components as illustrated on Figure 22 where the standard deviation of the modeled values are represented against the latitude of the station.

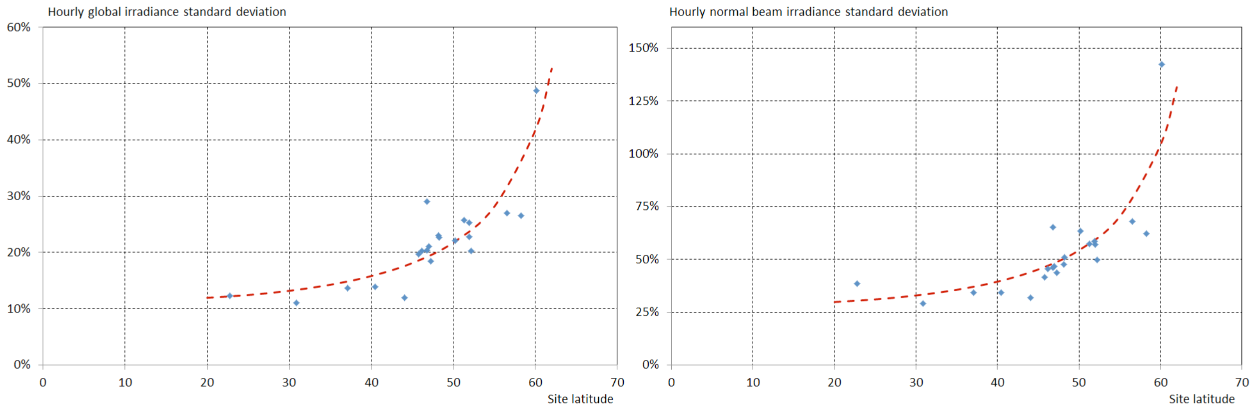

Figure 22 HelioClim-3 relative standard deviation versus the latitude of the station for the global and the normal beam irradiance.

8.1.7 Aerosol effect

The graphs on Figure 23 represent the hourly bias of the beam component versus the aerosol optical depth. A clear dependance can be pointed out for all the sites (see Figures a-6b in the annex), the model shows a negative bias for clean atmosphere condition, and going more or less to an overestimation for higher turbidity. The effect is less market for the version 5 of HelioClim-3. For the global component, as it is less sensitive to the aerosol load, the effect is smaller, even negligible.

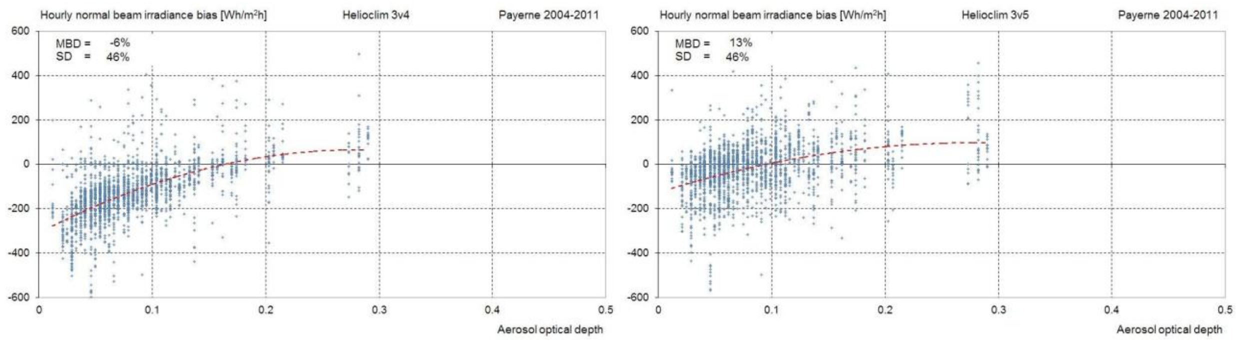

Figure 23 Model bias versus the clearness K_t (or sky conditions) for the beam component and the two version of HC-3.

When representing the daily model-measurements bias versus the day of the year, the general tendency is a summer/winter pattern for the beam component as it is illustrated on Figure 24 left. This effect is certainly correlated with the atmospheric turbidity ; it follows the aerosol load seasonal dependency. The right graph on Figure 24 represents the monthly bias surrounded by ± one standard deviation: the monthly modeled average and the measurements average are represented (for all the sites, see Figures a-7n and a-8n in the annex).

Figure 25 is a graphical illustration of the monthly validation. On the left graph, the monthly values of the two version of HelioClim-3 model, and on the right graph, all the average models are shown; the measurements are in red, the dashed red lines represent ± one standard deviation around the monthly value. Figures a-21n in the annex give a graphical representation for all the sites and models. For the global component, 96% of the monthly HelioClim-3 v5 modeled values are situated between the two dashed lines, 92% for version 4; for the normal beam component, 88% of the monthly HelioClim-3 v5 modeled values are situated between the two dashed lines, 84% for version 4. From these graphs, it

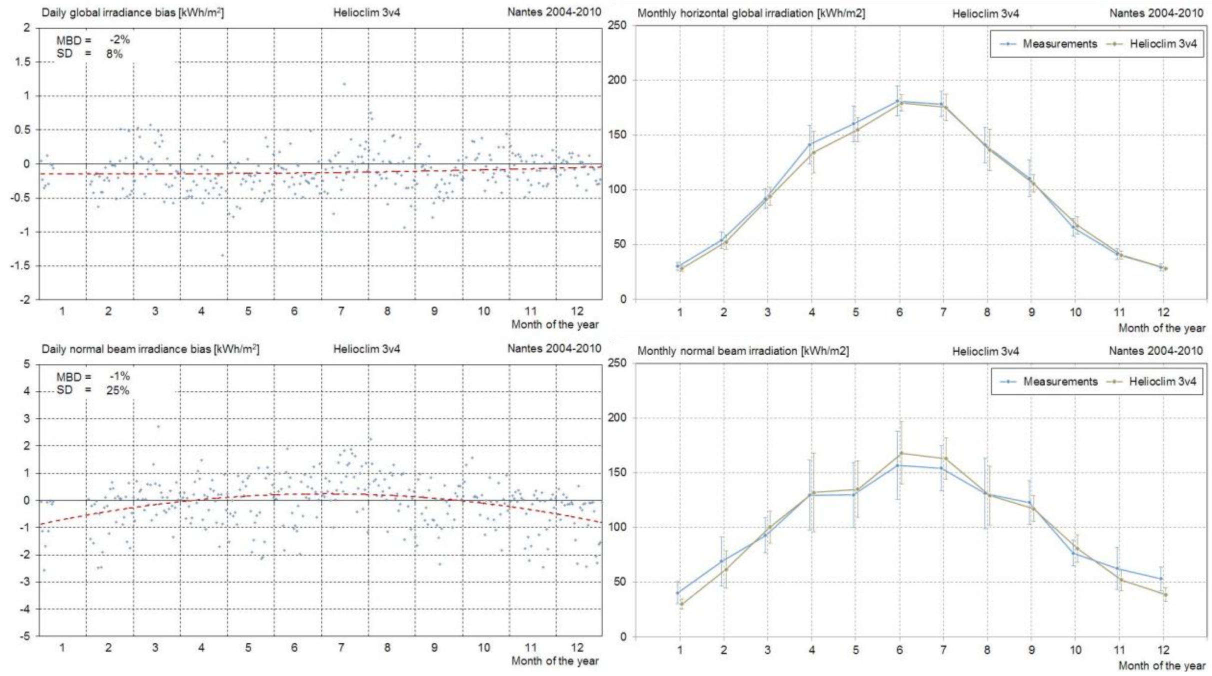

Figure 24 Left graphs: Model-measurements difference for daily normal beam irradiation values versus the day of the year. Right graphs: Monthly averaged values surrounded by ± one standard deviation for the modeled and the measured values of the global irradiation.

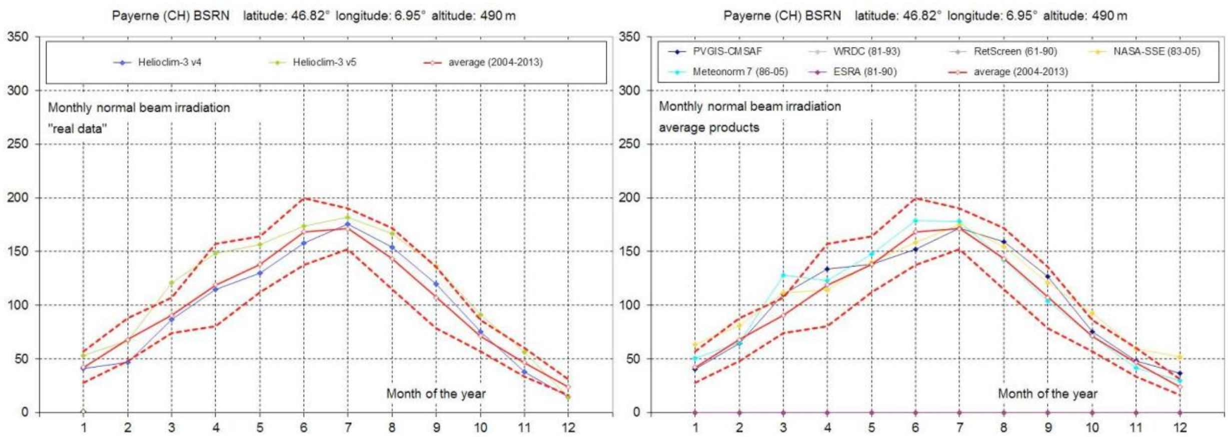

Figure 25 Comparison of the monthly values for all the models. In red, the measurements, the red dashed lines represent ± one standard deviation.

arises that the only site where all the average modelled monthly values are apart from one standard deviation around the average monthly measured values is Sede Boqer (see annex).

8.2 Frequency distribution

The correspondence between the frequency distribution of the modeled values and the measurements is as important as a low bias and standard deviation. It is the guaranteeing of a realist representation of the solar resource by the satellite models.

The general observation is that the two versions of the models, for all the sites, present a coherent frequency distribution representation of the global irradiance level (with the exception of Davos for the snow periods, Figures a-12g and a-13g). When considering the global clearness index frequency distribution, for all non-arid climate sites, a peak of overestimation can be seen for K_t values around 0.15. The peak is slightly smoothed on version 5 values, but still present. For the beam component, the general pattern is an overestimation for very low beam or clearness index values, and an underestimation for intermediate values. For both components, as stated in section 8.1.2, the high irradiance and clearness index values are better modeled with version 5. These two effects are illustrated on Figure 26 for the site of Kassel. The Figures for all the sites are given in the annex, Figures a-14n to a-19n.

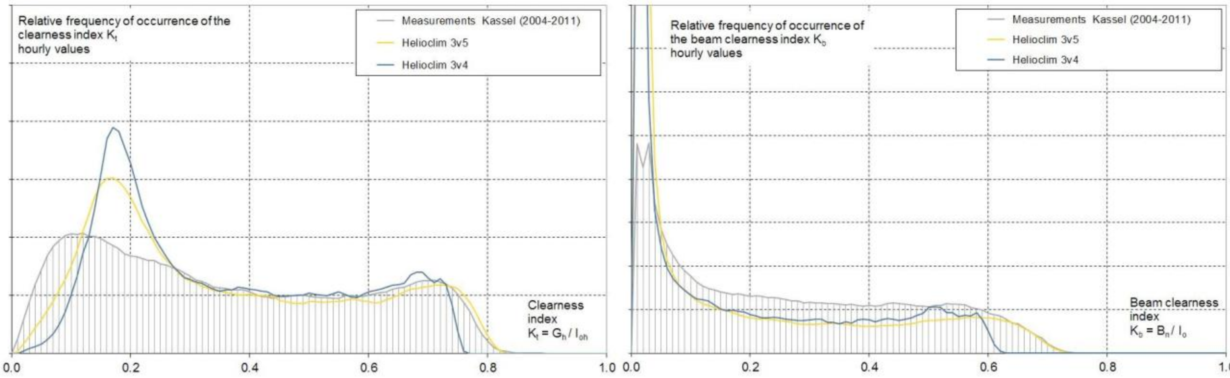

Figure 26 Frequency distribution of occurrence versus the clearness index for the site of Kassel.

8.3 Interannual variability

Beside the visual analysis of Figure a-20g and a-20b, it is interesting to compare the bias of the models with the interannual variability expressed by the standard deviation around the annual irradiation average for both the global and the beam components. The comparison results are given in Table IV. The blue columns represent the annual average for each site and the corresponding standard deviation over the reference period 2004-2010. The results are expressed as mean bias differences; if the *mbd* is less than one standard deviation *sd*, the cell background is represented in green. These *mbd* are highly variable from site to site and from model to model, even if the combined results for all sites are relatively good. On the last lines, the absolute bias and the standard deviation of the bias *bsd* is given for all models. These values express the spatial «smoothness» of the model.

From Table IV, the following points can be underlined for the global component:

- if version 4 has a lower overall mean bias, the absolute bias and the standard deviation of the bias are lower for version 5,
- considering the site by site results, half of the sites present a bias within ± one standard deviation of the interannual variability, 23% within ± two standard deviations, and 14% with a higher bias. The results are slightly better for version 5

and for the beam component:

- the average bias over all sites is relatively high, but as stated in previous sections, the clearness index distribution is better represented by version 5, especially for high values,
- version 4 gives slightly better results for all the annual indicators,
- the worst results arise for high latitude sites (size of the pixels view angles), and for dry climate sites (albedo determination difficulties, aerosol and clear sky model uncertainties),

- considering the site by site results, around half of the sites have a bias within ± one standard deviation of the interannual variability. The site to site and version to version comparison of the bias shows a high variability.

Table IV Results of the yearly validation and interannual variability analysis.

Sites	Yearly total [kWh/m2] 2004-2010	standard deviation 2004-2010	PVGIS-CM SAF	WRDC (1981-1993)	RetScreen (1961-1990)	NASA-SSE (1983-2005)	MN 7 (1980-2000)	ESRA (1981-1990)	Satellight (1996-2000)	Helioclim-3 v4	Helioclim-3 v5	Yearly total [kWh/m2] 2004-2010	standard deviation 2004-2010	PVGIS-CM SAF	NASA-SSE (1983-2005)	MN 7 (1980-2000)	Satellight (1996-2000)	Helioclim-3 v4	Helioclim-3 v5
			Global irradiation, annual mean bias difference											Beam irradiation, annual mean bias difference					
Almeria	1850	2.5%	3.2%		-8.1%	-8.1%	-3.0%		4.9%	4.8%	2.0%	2126	5.5%	7.5%	-3.8%	-11.1%	15.1%	11.8%	3.6%
Bratislava	1197	3.5%	1.4%	-0.7%	-0.6%	-2.7%	-0.1%	2.5%	-5.2%	-0.2%	1.6%	1191	7.4%	-1.3%	-4.0%	-7.5%	-11.9%	0.6%	6.9%
Cabauw	1085	2.3%	1.1%		-5.2%	-5.2%	-0.7%			-4.0%	-2.4%	908	4.7%	5.5%	2.7%	5.9%		12.7%	17.4%
Camborne	1121	3.6%	3.5%		1.5%	1.5%	-2.0%			-0.4%	1.2%	875	5.2%	20.9%	29.3%	15.8%		25.5%	31.4%
Carpentras	1587	2.1%	3.5%	-4.8%	-15.0%	-6.0%	-2.8%	-5.4%	0.4%	2.3%	2.3%	1884	4.1%	5.7%	0.4%	-10.1%	4.9%	2.9%	4.4%
Davos	1383	1.3%	-18.5%		-2.7%	-7.9%	2.1%	-2.9%	-17.5%	9.7%	5.6%	1420	8.4%	-38.5%	-8.0%	18.1%	-26.2%	25.8%	16.6%
Geneva	1282	2.3%	3.8%	-6.3%	0.1%	0.1%	-4.9%	-5.5%	-0.6%	-0.3%	5.7%	1274	3.3%	0.7%	4.3%	-9.8%	-0.9%	1.5%	19.6%
Kassel	1048	2.7%	0.6%		-5.6%	-5.6%	-5.8%	-6.6%	-5.9%	-4.7%	-1.4%	874	6.4%	-0.4%	1.0%	-7.9%	-5.1%	6.8%	17.0%
Lerwick	810	4.7%	-2.9%	-4.3%	9.2%	9.1%	-3.5%	-4.4%	-2.5%	3.4%	5.3%	580	13.3%	15.2%	55.5%	18.2%	0.8%	38.8%	46.4%
Lindenberg	1110	2.7%	0.5%	-2.9%	-2.9%	-8.9%	-3.0%	-11.5%	-3.6%	-3.5%	-3.8%	1026	9.6%	-1.0%	-8.1%	1.4%	-0.4%	2.9%	4.3%
Madrid	1697	4.9%	4.2%		-5.2%	-5.2%	-3.1%	-2.5%	1.7%	3.4%	5.2%	1798	5.2%	16.1%	10.0%	-0.8%	14.1%	16.3%	20.9%
Nantes	1271	3.4%	5.3%	-5.6%	-3.8%	-7.1%	-2.6%	-1.3%	-3.2%	-2.6%	-0.9%	1307	6.7%	2.7%	-12.1%	-9.6%	-8.8%	-3.5%	0.4%
Payerne	1278	2.2%	2.9%	-8.4%	-2.5%	0.4%	-1.8%	-8.3%	-2.8%	-5.6%	0.1%	1191	4.4%	5.5%	11.1%	5.9%	2.0%	-3.1%	14.8%
Sede Boqer	2114	1.2%	0.3%	0.5%	-6.7%	-3.9%	-4.0%			-7.1%	-5.7%	2382	3.6%		4.6%	-5.4%		-16.0%	-12.5%
Tamanrasset	2345	1.8%	-3.4%	0.8%	2.6%	-8.1%	0.9%			2.1%	2.3%	2355	4.0%		6.1%	18.1%		18.5%	19.1%
Toravere	981	3.8%	-0.7%		3.1%	3.1%	-0.1%		4.6%	2.4%	0.7%	1028	8.8%	-12.0%	8.4%	2.4%	7.2%	4.9%	2.2%
Valentia	1021	4.6%	8.6%	-3.9%	-4.8%	8.0%	-5.3%	-4.7%	-4.2%	-0.8%	0.7%	992	13.4%	2.9%	10.7%	-21.5%	-21.3%	-4.7%	0.4%
Vaulx-en-Velin	1304	4.4%	2.7%	-7.8%	-4.0%	-3.0%	-6.3%	-3.3%	0.4%	-0.5%	2.8%	1359	5.3%	-2.1%	-2.1%		-0.5%	-1.4%	8.0%
Wien	1175	2.7%	3.5%	-6.8%	-6.0%	-0.8%	1.0%	-7.0%	-1.4%	-2.1%	0.1%	1112	8.0%	-1.1%	2.9%	-3.1%	-2.5%	0.8%	8.7%
Zilani	1024	3.3%	-6.5%	-3.2%	2.5%	2.5%	-2.6%		6.0%	7.7%	1.6%	1000	9.1%	-13.0%	13.4%	-0.1%	20.5%	21.2%	5.7%
All sites	1334	2.8%	0.6%	-3.6%	-3.2%	-3.3%	-2.3%	-4.6%	-1.7%	0.2%	1.1%	1334	6.2%	0.9%	4.8%	0.0%	-0.2%	7.4%	10.7%
All sites absolute bias			3.8%	4.0%	4.8%	5.0%	2.8%	4.9%	4.0%	3.5%	2.7%			8.5%	7.9%	9.1%	9.5%	10.8%	12.1%
Standard deviation of mbe			5.5%	4.6%	6.3%	6.2%	3.3%	5.5%	5.9%	4.6%	3.6%			13.7%	9.9%	12.0%	13.2%	14.9%	15.2%

MBD within one standard deviation	MBD within two standard deviations	MBD higher than two standard deviations

9. Conclusions

The first conclusion is that the quality control is a key point in any model validation. Even if the data are highly qualified by the organization in charge of the acquisition, uncertainties can remain in the data and influence the validation. The best case is when independent data such as aerosol optical depth are also available.

The conclusions of the present study are the following:

- for latitude from 20° to 60°, altitude from sea level to 1600 m and various climate, the hourly global irradiance is retrieved with a negligible bias and an average standard deviation around 20% for both versions of HelioClim-3 scheme. For the beam irradiance, the bias is around 6% to 9%, and the standard deviation around 47%,
- as expected, the main improvement from version 4 to version 5 comes from the clear sky model and the knowledge of the aerosol optical depth, better results are obtained with daily (our sub daily) turbidity instead of monthly climatic values,
- the intermediate sky conditions are more difficult to model: the type and altitude of the clouds are not easy to determine precisely,
- the snow cover has to be taken into account, especially in the alps region,
- a general pattern with the atmospheric aerosol load is visible for all sites. Even if the pattern is present for the two versions of HelioClim-3, it is less marked for the latest version. Some seasonal effects can be related to the aerosol variability during the year,

- the standard deviation is increasing with the latitude, i.e. the size of the pixels and the angle of view of the satellite,
- a peak of discrepancy in the frequency distribution is present for all the non-arid sites around K_t = 0.15 for both versions. On the other hand, version 5 presents a much better representation of high clearness index values,
- even if the overall results for the beam component are slightly worst for the HelioClim-3 v5, the frequency distribution are improved.

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Global irradiance	Hourly values									
	HelioClim-3v4					HelioClim-3v5				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	416	34772	0.981	5%	14%	416	34769	0.983	2%	13%
Bratislava 2004 - 2007	255	18120	0.971	0%	23%	257	17958	0.971	2%	24%
Cabauw 2004 - 2013	253	36243	0.967	-4%	23%	253	36209	0.969	-3%	22%
Camborne 2004 - 2013	254	32920	0.971	0%	22%	254	32911	0.972	2%	22%
Carpentras 2004 - 2013	401	36075	0.985	0%	12%	400	36101	0.986	1%	11%
Davos 2004 - 2011	339	23924	0.933	9%	29%	339	23927	0.938	5%	28%
Geneva 2004 - 2013	286	44421	0.975	-1%	20%	286	44389	0.976	6%	21%
Kassel 2004 - 2011	236	34177	0.964	-5%	26%	237	34162	0.966	-1%	25%
Kishinev 2004-2013	296	43100	0.971	2%	21%	297	43082	0.972	1%	21%
Lerwick 2004-2013	200	31517	0.864	3%	49%	200	31510	0.867	5%	49%
Lindenberg 2004-2010	298	10527	0.964	-5%	20%	299	10509	0.965	-4%	20%
Madrid 2004-2013	401	34445	0.982	3%	14%	404	34197	0.983	5%	14%
Nantes 2004-2010	272	26956	0.978	-2%	18%	276	26519	0.978	-1%	18%
Payerne 2004-2011	341	26119	0.962	-8%	20%	341	26093	0.964	-2%	20%
Sede Boqer 2004-2012	538	30366	0.979	-7%	11%	538	30366	0.982	-5%	10%
Skukuza 2004-2007	423	10865	0.899	8%	32%	423	10863	0.899	3%	31%
Tamanrasset 2004-2013	562	35657	0.978	0%	12%	562	35651	0.982	1%	11%
Toravere 2004 - 2013	255	37016	0.952	0%	26%	255	36989	0.957	-1%	25%
Valentia 2004-2013	219	45517	0.966	0%	25%	224	44399	0.967	2%	25%
Vaulx-en-Velin 2004-2013	291	42612	0.974	1%	20%	294	42025	0.975	5%	20%
Wien 2004-2013	266	41926	0.969	-4%	23%	266	41879	0.969	-1%	23%
Zilani 2004-2009	262	21260	0.952	9%	27%	263	21198	0.955	3%	25%
All sites	317	31753		0.0%	21%	319	31624		1.2%	20%
All sites absolute bias				3.1%					2.7%	
Standard dev. of the bias				4.4%					3.4%	

Beam irradiance	Hourly values									
	HelioClim-3v4					HelioClim-3v5				
	Bn	nb	R	mbd	sd	Bn	nb	R	mbd	sd
Almeria 2004 - 2011	473	34772	0.886	12%	34%	473	34769	0.904	4%	32%
Bratislava 2004 - 2007	265	18120	0.895	-4%	48%	267	17958	0.903	2%	48%
Cabauw 2004 - 2013	217	36243	0.887	17%	57%	217	36209	0.901	14%	56%
Camborne 2004 - 2013	204	32920	0.886	23%	63%	204	32911	0.895	30%	64%
Carpentras 2004 - 2013	484	36075	0.882	1%	32%	483	36101	0.897	3%	30%
Davos 2004 - 2011	366	23924	0.789	17%	65%	366	23927	0.820	10%	61%
Geneva 2004 - 2013	285	44421	0.915	2%	46%	285	44389	0.919	20%	47%
Kassel 2004 - 2011	197	34177	0.909	7%	57%	197	34162	0.916	17%	58%
Kishinev 2004-2013	306	43100	0.897	7%	47%	306	43082	0.907	5%	45%
Lerwick 2004-2013	136	31517	0.660	46%	142%	136	31510	0.669	54%	148%
Lindenberg 2004-2010	284	10527	0.874	2%	50%	285	10509	0.879	2%	49%
Madrid 2004-2013	447	34445	0.895	6%	34%	450	34197	0.914	12%	31%
Nantes 2004-2010	270	26956	0.910	-1%	44%	273	26519	0.916	4%	43%
Payerne 2004-2011	329	26119	0.882	-6%	46%	329	26093	0.892	13%	46%
Sede Boqer 2004-2012	622	30366	0.772	-17%	29%	622	30366	0.808	-14%	28%
Skukuza 2004-2007	415	10865	0.670	19%	63%	415	10863	0.692	8%	60%
Tamanrasset 2004-2013	578	35657	0.749	13%	38%	579	35651	0.822	15%	33%
Toravere 2004 - 2013	268	37016	0.842	3%	62%	268	36989	0.865	0%	58%
Valentia 2004-2013	206	45517	0.887	-2%	59%	211	44399	0.899	4%	57%
Vaulx-en-Velin 2004-2013	300	42612	0.914	2%	42%	303	42025	0.918	12%	43%
Wien 2004-2013	245	41926	0.900	2%	51%	245	41879	0.907	11%	52%
Zilani 2004-2009	245	21260	0.846	27%	68%	246	21198	0.863	12%	62%
All sites	322	31753		6%	48%	323	31624		9%	46%
All sites absolute bias				9.4%					11.1%	
Standard dev. of the bias				13.1%					13.7%	

Diffuse irradiance	Hourly values									
	HelioClim-3v4					HelioClim-3v5				
	Dh	nb	R	mbd	sd	Dh	nb	R	mbd	sd
Almeria 2004 - 2011	128	34772	0.800	-11%	49%	128	34769	0.841	-7%	44%
Bratislava 2004 - 2007	113	18120	0.888	-4%	38%	114	17958	0.896	-7%	37%
Cabauw 2004 - 2013	138	36243	0.907	-22%	41%	138	36209	0.914	-19%	36%
Camborne 2004 - 2013	141	32920	0.897	-18%	41%	141	32911	0.894	-21%	41%
Carpentras 2004 - 2013	123	36075	0.851	-6%	44%	123	36101	0.857	-9%	43%
Davos 2004 - 2011	134	23924	0.748	-3%	59%	134	23927	0.779	0%	56%
Geneva 2004 - 2013	121	44421	0.871	-6%	45%	121	44389	0.879	-14%	44%
Kassel 2004 - 2011	118	34177	0.900	-7%	38%	118	34162	0.909	-11%	37%
Kishinev 2004-2013	121	43100	0.862	-7%	42%	121	43082	0.870	-8%	40%
Lerwick 2004-2013	133	31517	0.824	-19%	49%	133	31510	0.814	-21%	50%
Lindenberg 2004-2010	147	10527	0.895	-14%	33%	147	10509	0.893	-15%	33%
Madrid 2004-2013	117	34445	0.815	4%	48%	117	34197	0.842	-3%	45%
Nantes 2004-2010	130	26956	0.924	-9%	32%	132	26519	0.923	-12%	32%
Payerne 2004-2011	151	26119	0.863	-14%	37%	151	26093	0.885	-21%	35%
Sede Boqer 2004-2012	137	30366	0.638	10%	52%	137	30366	0.692	3%	49%
Skukuza 2004-2007	163	10865	0.766	-18%	47%	163	10863	0.815	-13%	42%
Tamanrasset 2004-2013	170	35657	0.680	-32%	62%	170	35651	0.796	-35%	56%
Toravere 2004 - 2013	115	37016	0.859	-4%	39%	115	36989	0.871	-5%	37%
Valentia 2004-2013	114	45517	0.920	-4%	33%	117	44399	0.919	-7%	33%
Vaulx-en-Velin 2004-2013	118	42612	0.879	0%	38%	119	42025	0.884	-6%	37%
Wien 2004-2013	127	41926	0.867	-12%	41%	127	41879	0.875	-16%	40%
Zilani 2004-2009	125	21260	0.825	-8%	42%	125	21198	0.862	-6%	37%
All sites	129	31753		-10%	45%	129	31624		-12%	43%
All sites absolute bias				10.9%					12.5%	
Standard dev. of the bias				14.5%					16.2%	

Global irradiance	Hourly values									
	HelioClim-3v4					HelioClim-3v5				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	416	34772	0.981	19.5	56.8	416	34769	0.983	7.2	54.3
Bratislava 2004 - 2007	255	18120	0.971	0.7	58.5	257	17958	0.971	6.3	60.4
Cabauw 2004 - 2013	253	36243	0.967	-10.0	57.5	253	36209	0.969	-6.8	55.7
Camborne 2004 - 2013	254	32920	0.971	-0.1	56.0	254	32911	0.972	4.0	55.3
Carpentras 2004 - 2013	401	36075	0.985	1.8	47.9	400	36101	0.986	3.5	45.6
Davos 2004 - 2011	339	23924	0.933	30.0	98.5	339	23927	0.938	18.6	95.7
Geneva 2004 - 2013	286	44421	0.975	-3.0	58.0	286	44389	0.976	16.5	59.2
Kassel 2004 - 2011	236	34177	0.964	-11.1	61.0	237	34162	0.966	-2.9	59.6
Kishinev 2004-2013	296	43100	0.971	5.9	62.5	297	43082	0.972	3.6	61.2
Lerwick 2004-2013	200	31517	0.864	6.8	97.6	200	31510	0.867	10.2	98.4
Lindenberg 2004-2010	298	10527	0.964	-13.9	60.4	299	10509	0.965	-13.4	59.3
Madrid 2004-2013	401	34445	0.982	11.3	55.8	404	34197	0.983	20.1	54.9
Nantes 2004-2010	272	26956	0.978	-6.4	50.0	276	26519	0.978	-2.2	49.6
Payerne 2004-2011	341	26119	0.962	-28.4	69.5	341	26093	0.964	-5.4	69.6
Sede Boqer 2004-2012	538	30366	0.979	-35.2	59.2	538	30366	0.982	-25.4	56.2
Skukuza 2004-2007	423	10865	0.899	31.9	133.7	423	10863	0.899	12.4	131.7
Tamanrasset 2004-2013	562	35657	0.978	-0.5	69.0	562	35651	0.982	3.9	62.7
Toravere 2004 - 2013	255	37016	0.952	0.5	67.5	255	36989	0.957	-3.2	64.1
Valentia 2004-2013	219	45517	0.966	1.0	55.3	224	44399	0.967	4.6	55.9
Vaulx-en-Velin 2004-2013	291	42612	0.974	3.0	57.3	294	42025	0.975	14.9	57.9
Wien 2004-2013	266	41926	0.969	-9.3	60.3	266	41879	0.969	-1.7	60.9
Zilani 2004-2009	262	21260	0.952	22.7	70.8	263	21198	0.955	8.4	66.7
All sites	317	31753		-0.1	65.2	319	31624		3.7	64.1
All sites absolute bias				9.7					8.5	
Standard dev. of the bias				14.1					10.7	

Beam irradiance	Hourly values									
	HelioClim-3v4					HelioClim-3v5				
	Bn	nb	R	mbd	sd	Bn	nb	R	mbd	sd
Almeria 2004 - 2011	473	34772	0.886	55.1	162.7	473	34769	0.904	16.6	150.3
Bratislava 2004 - 2007	265	18120	0.895	-10.4	126.0	267	17958	0.903	4.9	128.5
Cabauw 2004 - 2013	217	36243	0.887	36.9	123.8	217	36209	0.901	30.3	121.2
Camborne 2004 - 2013	204	32920	0.886	47.6	129.1	204	32911	0.895	60.3	130.3
Carpentras 2004 - 2013	484	36075	0.882	4.5	153.8	483	36101	0.897	12.8	145.7
Davos 2004 - 2011	366	23924	0.789	63.8	238.8	366	23927	0.820	36.2	223.4
Geneva 2004 - 2013	285	44421	0.915	4.6	129.8	285	44389	0.919	58.3	134.9
Kassel 2004 - 2011	197	34177	0.909	14.2	112.8	197	34162	0.916	34.0	114.0
Kishinev 2004-2013	306	43100	0.897	20.1	142.8	306	43082	0.907	15.1	137.4
Lerwick 2004-2013	136	31517	0.660	61.8	193.0	136	31510	0.669	72.5	200.7
Lindenberg 2004-2010	284	10527	0.874	4.6	141.8	285	10509	0.879	5.4	140.6
Madrid 2004-2013	447	34445	0.895	28.4	152.7	450	34197	0.914	55.0	140.4
Nantes 2004-2010	270	26956	0.910	-1.9	117.8	273	26519	0.916	10.9	118.3
Payerne 2004-2011	329	26119	0.882	-19.4	151.6	329	26093	0.892	42.6	152.4
Sede Boqer 2004-2012	622	30366	0.772	-108.5	180.9	622	30366	0.808	-86.2	174.0
Skukuza 2004-2007	415	10865	0.670	77.3	260.2	415	10863	0.692	31.1	250.9
Tamanrasset 2004-2013	578	35657	0.749	76.6	222.7	579	35651	0.822	89.6	193.0
Toravere 2004 - 2013	268	37016	0.842	7.8	166.9	268	36989	0.865	-0.2	154.8
Valentia 2004-2013	206	45517	0.887	-4.1	121.1	211	44399	0.899	7.5	121.5
Vaulx-en-Velin 2004-2013	300	42612	0.914	6.1	124.9	303	42025	0.918	37.3	129.1
Wien 2004-2013	245	41926	0.900	5.5	125.4	245	41879	0.907	26.6	127.3
Zilani 2004-2009	245	21260	0.846	66.5	167.0	246	21198	0.863	30.5	151.5
All sites	322	31753		18.0	155.4	323	31624		28.3	150.1
All sites absolute bias				30.1					35.8	
Standard dev. of the bias				42.2					44.1	

Diffuse irradiance	Hourly values									
	HelioClim-3v4					HelioClim-3v5				
	Dh	nb	R	mbd	sd	Dh	nb	R	mbd	sd
Almeria 2004 - 2011	128	34772	0.800	-13.7	62.2	128	34769	0.841	-8.7	56.7
Bratislava 2004 - 2007	113	18120	0.888	-4.8	43.2	114	17958	0.896	-8.5	41.8
Cabauw 2004 - 2013	138	36243	0.907	-30.4	57.0	138	36209	0.914	-26.2	50.3
Camborne 2004 - 2013	141	32920	0.897	-25.1	57.3	141	32911	0.894	-29.2	57.6
Carpentras 2004 - 2013	123	36075	0.851	-7.4	54.1	123	36101	0.857	-10.8	52.2
Davos 2004 - 2011	134	23924	0.748	-4.0	79.1	134	23927	0.779	0.1	75.1
Geneva 2004 - 2013	121	44421	0.871	-6.8	53.9	121	44389	0.879	-17.0	53.6
Kassel 2004 - 2011	118	34177	0.900	-8.4	44.3	118	34162	0.909	-12.8	43.1
Kishinev 2004-2013	121	43100	0.862	-8.1	50.4	121	43082	0.870	-9.7	48.6
Lerwick 2004-2013	133	31517	0.824	-25.3	65.1	133	31510	0.814	-28.5	66.1
Lindenberg 2004-2010	147	10527	0.895	-21.0	48.7	147	10509	0.893	-22.5	48.3
Madrid 2004-2013	117	34445	0.815	4.4	56.0	117	34197	0.842	-3.3	52.7
Nantes 2004-2010	130	26956	0.924	-12.3	41.6	132	26519	0.923	-16.4	41.5
Payerne 2004-2011	151	26119	0.863	-20.9	56.1	151	26093	0.885	-32.3	53.5
Sede Boqer 2004-2012	137	30366	0.638	13.4	71.1	137	30366	0.692	4.7	67.3
Skukuza 2004-2007	163	10865	0.766	-28.6	76.1	163	10863	0.815	-21.9	68.7
Tamanrasset 2004-2013	170	35657	0.680	-54.3	105.0	170	35651	0.796	-59.1	94.8
Toravere 2004 - 2013	115	37016	0.859	-5.0	44.6	115	36989	0.871	-5.7	42.6
Valentia 2004-2013	114	45517	0.920	-4.8	38.3	117	44399	0.919	-8.7	38.5
Vaulx-en-Velin 2004-2013	118	42612	0.879	0.5	44.6	119	42025	0.884	-7.0	44.2
Wien 2004-2013	127	41926	0.867	-15.2	51.9	127	41879	0.875	-20.0	51.1
Zilani 2004-2009	125	21260	0.825	-10.5	52.1	125	21198	0.862	-7.1	46.8
All sites	129	31753		-12.3	58.1	129	31624		-15.8	55.3
All sites absolute bias				14.0					16.2	
Standard dev. of the bias				18.7					20.9	

Table a-I Site by site, for the two helioclim-3 versions, hourly global, normal beam and diffuse irradiance validation results expressed in relative and absolute values. The absolute values are given in [Wh/m²h].

For all sites, the overall values, the absolute mean bias and the standard deviation of the bias are given.

Global irradiance	Daily values									
	HelioClim-3v4					HelioClim-3v5				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	5.04	2872	0.993	5%	7%	5.04	2872	0.995	2%	6%
Bratislava 2004 - 2007	3.26	1417	0.994	0%	12%	3.26	1417	0.994	2%	12%
Cabauw 2004 - 2013	2.89	3168	0.990	-4%	12%	2.89	3168	0.991	-3%	11%
Camborne 2004 - 2013	2.99	2793	0.992	0%	11%	2.99	2792	0.993	2%	11%
Carpentras 2004 - 2013	4.47	3229	0.996	1%	6%	4.47	3229	0.996	1%	6%
Davos 2004 - 2011	3.08	2618	0.972	9%	20%	3.08	2618	0.975	5%	19%
Geneva 2004 - 2013	3.52	3609	0.991	-1%	9%	3.52	3609	0.991	6%	10%
Kassel 2004 - 2011	2.83	2855	0.990	-5%	13%	2.83	2855	0.991	-1%	12%
Kishinev 2004-2013	3.56	3591	0.988	2%	11%	3.56	3591	0.989	1%	11%
Lerwick 2004-2013	2.63	2393	0.937	3%	34%	2.63	2393	0.938	5%	34%
Lindenberg 2004-2010	3.29	952	0.995	-5%	10%	3.29	952	0.996	-4%	10%
Madrid 2004-2013	4.47	3083	0.993	3%	8%	4.47	3083	0.994	5%	7%
Nantes 2004-2010	3.48	2106	0.996	-2%	8%	3.47	2106	0.997	-1%	8%
Payerne 2004-2011	3.63	2448	0.991	-8%	11%	3.63	2448	0.992	-2%	11%
Sede Boqer 2004-2012	5.69	2866	0.994	-7%	7%	5.69	2866	0.996	-5%	6%
Skukuza 2004-2007	4.94	932	0.973	8%	22%	4.94	932	0.973	3%	22%
Tamanrasset 2004-2013	6.22	3223	0.982	0%	8%	6.22	3223	0.988	1%	7%
Toravere 2004 - 2013	3.20	2950	0.986	0%	14%	3.20	2950	0.989	-1%	13%
Valentia 2004-2013	2.76	3610	0.987	0%	13%	2.76	3610	0.988	2%	12%
Vaulx-en-Velin 2004-2013	3.45	3589	0.989	1%	10%	3.45	3589	0.990	5%	10%
Wien 2004-2013	3.31	3368	0.990	-4%	11%	3.31	3368	0.989	-1%	11%
Zilani 2004-2009	3.11	1794	0.985	10%	19%	3.12	1784	0.989	3%	15%
All sites	3.73	2704		0.0%	12%	3.73	2704		1.2%	11%
All sites absolute bias				3.1%					2.7%	
Standard dev. of the bias				4.3%					3.3%	

Beam irradiance	Daily values									
	HelioClim-3v4					HelioClim-3v5				
	Bn	nb	R	mbd	sd	Bn	nb	R	mbd	sd
Almeria 2004 - 2011	5.73	2872	0.937	12%	24%	5.73	2872	0.960	4%	20%
Bratislava 2004 - 2007	3.38	1417	0.972	-4%	29%	3.38	1417	0.981	2%	23%
Cabauw 2004 - 2013	2.48	3168	0.946	17%	37%	2.48	3168	0.963	14%	31%
Camborne 2004 - 2013	2.40	2793	0.948	23%	41%	2.40	2792	0.957	30%	38%
Carpentras 2004 - 2013	5.40	3229	0.962	3%	19%	5.40	3229	0.962	3%	19%
Davos 2004 - 2011	3.31	2617	0.885	17%	49%	3.31	2617	0.907	10%	44%
Geneva 2004 - 2013	3.51	3609	0.956	2%	28%	3.51	3609	0.965	20%	25%
Kassel 2004 - 2011	2.36	2855	0.963	7%	34%	2.36	2855	0.970	17%	31%
Kishinev 2004-2013	3.67	3591	0.945	7%	29%	3.67	3591	0.958	5%	26%
Lerwick 2004-2013	1.79	2393	0.788	46%	101%	1.79	2393	0.794	54%	103%
Lindenberg 2004-2010	3.14	952	0.968	2%	33%	3.14	952	0.971	2%	31%
Madrid 2004-2013	4.99	3083	0.943	6%	25%	4.99	3083	0.963	12%	20%
Nantes 2004-2010	3.45	2106	0.972	-1%	25%	3.44	2106	0.980	4%	21%
Payerne 2004-2011	3.51	2448	0.961	-6%	30%	3.51	2448	0.968	13%	27%
Sede Boqer 2004-2012	6.59	2866	0.939	-17%	21%	6.59	2866	0.962	-14%	18%
Skukuza 2004-2007	4.84	932	0.909	19%	45%	4.84	932	0.914	8%	43%
Tamanrasset 2004-2013	6.40	3223	0.818	13%	32%	6.40	3223	0.893	15%	25%
Toravere 2004 - 2013	3.36	2950	0.935	3%	39%	3.36	2950	0.955	0%	32%
Valentia 2004-2013	2.60	3610	0.945	-2%	34%	2.60	3610	0.959	4%	30%
Vaulx-en-Velin 2004-2013	3.56	3589	0.964	2%	26%	3.55	3589	0.972	12%	21%
Wien 2004-2013	3.05	3368	0.957	2%	30%	3.05	3368	0.967	11%	26%
Zilani 2004-2009	2.90	1794	0.939	30%	48%	2.92	1784	0.954	12%	39%
All sites	3.78	2704		6%	33%	3.78	2703		9%	29%
All sites absolute bias				9.5%					11.1%	
Standard dev. of the bias				13.0%					13.5%	

Diffuse irradiance	Daily values									
	HelioClim-3v4					HelioClim-3v5				
	Dh	nb	R	mbd	sd	Dh	nb	R	mbd	sd
Almeria 2004 - 2011	1.55	2872	0.893	-11%	34%	1.55	2872	0.918	-7%	30%
Bratislava 2004 - 2007	1.45	1417	0.969	-4%	26%	1.45	1417	0.975	-7%	24%
Cabauw 2004 - 2013	1.58	3168	0.956	-22%	29%	1.58	3168	0.968	-19%	25%
Camborne 2004 - 2013	1.66	2793	0.961	-18%	26%	1.66	2792	0.962	-21%	26%
Carpentras 2004 - 2013	1.37	3229	0.900	-9%	31%	1.37	3229	0.900	-9%	31%
Davos 2004 - 2011	1.21	2617	0.892	-3%	41%	1.21	2617	0.904	0%	39%
Geneva 2004 - 2013	1.49	3609	0.883	-6%	30%	1.49	3609	0.913	-14%	28%
Kassel 2004 - 2011	1.41	2855	0.959	-7%	25%	1.41	2855	0.969	-11%	24%
Kishinev 2004-2013	1.45	3591	0.904	-7%	28%	1.45	3591	0.915	-8%	26%
Lerwick 2004-2013	1.76	2393	0.943	-19%	31%	1.76	2393	0.941	-21%	32%
Lindenberg 2004-2010	1.62	952	0.982	-14%	23%	1.62	952	0.983	-15%	23%
Madrid 2004-2013	1.30	3083	0.877	4%	36%	1.30	3083	0.907	-3%	32%
Nantes 2004-2010	1.66	2106	0.978	-9%	20%	1.66	2106	0.981	-12%	20%
Payerne 2004-2011	1.61	2448	0.952	-14%	26%	1.61	2448	0.969	-21%	23%
Sede Boqer 2004-2012	1.45	2866	0.800	10%	42%	1.45	2866	0.832	3%	39%
Skukuza 2004-2007	1.90	932	0.957	-18%	30%	1.90	932	0.966	-13%	27%
Tamanrasset 2004-2013	1.88	3223	0.745	-32%	48%	1.88	3223	0.855	-35%	42%
Toravere 2004 - 2013	1.44	2950	0.951	-4%	23%	1.44	2950	0.958	-5%	21%
Valentia 2004-2013	1.44	3610	0.953	-4%	22%	1.44	3610	0.956	-7%	21%
Vaulx-en-Velin 2004-2013	1.40	3589	0.898	0%	27%	1.40	3589	0.921	-6%	25%
Wien 2004-2013	1.58	3368	0.925	-12%	26%	1.58	3368	0.937	-16%	25%
Zilani 2004-2009	1.48	1794	0.959	-8%	29%	1.49	1784	0.971	-6%	24%
All sites	1.51	2704		-10%	31%	1.51	2703		-12%	29%
All sites absolute bias				11.0%					12.5%	
Standard dev. of the bias				14.4%					16.1%	

Global irradiance	Daily values									
	HelioClim-3v4					HelioClim-3v5				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	5.04	2872	0.993	0.24	0.37	5.04	2872	0.995	0.09	0.33
Bratislava 2004 - 2007	3.26	1417	0.994	0.01	0.39	3.26	1417	0.994	0.08	0.39
Cabauw 2004 - 2013	2.89	3168	0.990	-0.11	0.35	2.89	3168	0.991	-0.08	0.33
Camborne 2004 - 2013	2.99	2793	0.992	0.00	0.34	2.99	2792	0.993	0.05	0.33
Carpentras 2004 - 2013	4.47	3229	0.996	0.04	0.25	4.47	3229	0.996	0.04	0.25
Davos 2004 - 2011	3.08	2618	0.972	0.27	0.62	3.08	2618	0.975	0.17	0.57
Geneva 2004 - 2013	3.52	3609	0.991	-0.04	0.33	3.52	3609	0.991	0.20	0.34
Kassel 2004 - 2011	2.83	2855	0.990	-0.13	0.37	2.83	2855	0.991	-0.03	0.35
Kishinev 2004-2013	3.56	3591	0.988	0.07	0.39	3.56	3591	0.989	0.04	0.38
Lerwick 2004-2013	2.63	2393	0.937	0.09	0.90	2.63	2393	0.938	0.13	0.90
Lindenberg 2004-2010	3.29	952	0.995	-0.15	0.34	3.29	952	0.996	-0.15	0.33
Madrid 2004-2013	4.47	3083	0.993	0.13	0.35	4.47	3083	0.994	0.22	0.32
Nantes 2004-2010	3.48	2106	0.996	-0.08	0.29	3.47	2106	0.997	-0.03	0.27
Payerne 2004-2011	3.63	2448	0.991	-0.30	0.39	3.63	2448	0.992	-0.06	0.40
Sede Boqer 2004-2012	5.69	2866	0.994	-0.37	0.38	5.69	2866	0.996	-0.27	0.33
Skukuza 2004-2007	4.94	932	0.973	0.37	1.11	4.94	932	0.973	0.14	1.10
Tamanrasset 2004-2013	6.22	3223	0.982	-0.01	0.51	6.22	3223	0.988	0.04	0.41
Toravere 2004 - 2013	3.20	2950	0.986	0.01	0.45	3.20	2950	0.989	-0.04	0.40
Valentia 2004-2013	2.76	3610	0.987	0.01	0.35	2.76	3610	0.988	0.06	0.34
Vaulx-en-Velin 2004-2013	3.45	3589	0.989	0.04	0.36	3.45	3589	0.990	0.17	0.33
Wien 2004-2013	3.31	3368	0.990	-0.12	0.36	3.31	3368	0.989	-0.02	0.37
Zilani 2004-2009	3.11	1794	0.985	0.30	0.58	3.12	1784	0.989	0.10	0.48
All sites	3.73	2704		0.00	0.45	3.73	2704		0.04	0.42
All sites absolute bias				0.12					0.10	
Standard dev. of the bias				0.16					0.12	

Beam irradiance	Daily values									
	HelioClim-3v4					HelioClim-3v5				
	Bn	nb	R	mbd	sd	Bn	nb	R	mbd	sd
Almeria 2004 - 2011	5.73	2872	0.937	0.67	1.38	5.73	2872	0.960	0.20	1.15
Bratislava 2004 - 2007	3.38	1417	0.972	-0.13	0.97	3.38	1417	0.981	0.06	0.79
Cabauw 2004 - 2013	2.48	3168	0.946	0.42	0.91	2.48	3168	0.963	0.35	0.77
Camborne 2004 - 2013	2.40	2793	0.948	0.56	0.98	2.40	2792	0.957	0.71	0.91
Carpentras 2004 - 2013	5.40	3229	0.962	0.14	1.03	5.40	3229	0.962	0.14	1.03
Davos 2004 - 2011	3.31	2617	0.885	0.58	1.62	3.31	2617	0.907	0.32	1.46
Geneva 2004 - 2013	3.51	3609	0.956	0.06	0.97	3.51	3609	0.965	0.72	0.87
Kassel 2004 - 2011	2.36	2855	0.963	0.17	0.80	2.36	2855	0.970	0.41	0.73
Kishinev 2004-2013	3.67	3591	0.945	0.24	1.08	3.67	3591	0.958	0.18	0.95
Lerwick 2004-2013	1.79	2393	0.788	0.81	1.80	1.79	2393	0.794	0.96	1.84
Lindenberg 2004-2010	3.14	952	0.968	0.05	1.02	3.14	952	0.971	0.06	0.96
Madrid 2004-2013	4.99	3083	0.943	0.31	1.27	4.99	3083	0.963	0.61	0.99
Nantes 2004-2010	3.45	2106	0.972	-0.02	0.87	3.44	2106	0.980	0.14	0.72
Payerne 2004-2011	3.51	2448	0.961	-0.21	1.06	3.51	2448	0.968	0.45	0.95
Sede Boqer 2004-2012	6.59	2866	0.939	-1.15	1.40	6.59	2866	0.962	-0.91	1.17
Skukuza 2004-2007	4.84	932	0.909	0.90	2.19	4.84	932	0.914	0.36	2.08
Tamanrasset 2004-2013	6.40	3223	0.818	0.85	2.07	6.40	3223	0.893	0.99	1.60
Toravere 2004 - 2013	3.36	2950	0.935	0.10	1.29	3.36	2950	0.955	0.00	1.08
Valentia 2004-2013	2.60	3610	0.945	-0.05	0.88	2.60	3610	0.959	0.09	0.79
Vaulx-en-Velin 2004-2013	3.56	3589	0.964	0.07	0.92	3.55	3589	0.972	0.44	0.76
Wien 2004-2013	3.05	3368	0.957	0.07	0.90	3.05	3368	0.967	0.33	0.79
Zilani 2004-2009	2.90	1794	0.939	0.86	1.38	2.92	1784	0.954	0.36	1.13
All sites	3.78	2704		0.22	1.24	3.78	2703		0.33	1.08
All sites absolute bias				0.36					0.42	
Standard dev. of the bias				0.49					0.51	

Diffuse irradiance	Daily values									
	HelioClim-3v4					HelioClim-3v5				
	Dh	nb	R	mbd	sd	Dh	nb	R	mbd	sd
Almeria 2004 - 2011	1.55	2872	0.893	-0.17	0.52	1.55	2872	0.918	-0.11	0.47
Bratislava 2004 - 2007	1.45	1417	0.969	-0.06	0.37	1.45	1417	0.975	-0.11	0.35
Cabauw 2004 - 2013	1.58	3168	0.956	-0.35	0.46	1.58	3168	0.968	-0.30	0.39
Camborne 2004 - 2013	1.66	2793	0.961	-0.30	0.43	1.66	2792	0.962	-0.34	0.44
Carpentras 2004 - 2013	1.37	3229	0.900	-0.12	0.42	1.37	3229	0.900	-0.12	0.42
Davos 2004 - 2011	1.21	2617	0.892	-0.04	0.50	1.21	2617	0.904	0.00	0.47
Geneva 2004 - 2013	1.49	3609	0.883	-0.08	0.44	1.49	3609	0.913	-0.21	0.42
Kassel 2004 - 2011	1.41	2855	0.959	-0.10	0.36	1.41	2855	0.969	-0.15	0.34
Kishinev 2004-2013	1.45	3591	0.904	-0.10	0.40	1.45	3591	0.915	-0.12	0.38
Lerwick 2004-2013	1.76	2393	0.943	-0.33	0.54	1.76	2393	0.941	-0.37	0.55
Lindenberg 2004-2010	1.62	952	0.982	-0.23	0.37	1.62	952	0.983	-0.25	0.37
Madrid 2004-2013	1.30	3083	0.877	0.05	0.47	1.30	3083	0.907	-0.04	0.42
Nantes 2004-2010	1.66	2106	0.978	-0.16	0.34	1.66	2106	0.981	-0.21	0.33
Payerne 2004-2011	1.61	2448	0.952	-0.22	0.42	1.61	2448	0.969	-0.34	0.38
Sede Boqer 2004-2012	1.45	2866	0.800	0.14	0.61	1.45	2866	0.832	0.05	0.56
Skukuza 2004-2007	1.90	932	0.957	-0.33	0.57	1.90	932	0.966	-0.26	0.50
Tamanrasset 2004-2013	1.88	3223	0.745	-0.60	0.90	1.88	3223	0.855	-0.65	0.78
Toravere 2004 - 2013	1.44	2950	0.951	-0.06	0.33	1.44	2950	0.958	-0.07	0.31
Valentia 2004-2013	1.44	3610	0.953	-0.06	0.31	1.44	3610	0.956	-0.11	0.31
Vaulx-en-Velin 2004-2013	1.40	3589	0.898	0.01	0.37	1.40	3589	0.921	-0.08	0.35
Wien 2004-2013	1.58	3368	0.925	-0.19	0.42	1.58	3368	0.937	-0.25	0.40
Zilani 2004-2009	1.48	1794	0.959	-0.12	0.42	1.49	1784	0.971	-0.08	0.36
All sites	1.51	2704		-0.15	0.47	1.51	2703		-0.18	0.44
All sites absolute bias				0.17					0.19	
Standard dev. of the bias				0.22					0.24	

Table a-II Site by site, for the two helioclim-3 versions, daily global, normal beam and diffuse irradiation validation results expressed in relative and absolute values. The absolute values are given in [kWh/m²h day].
For all sites, the overall values, the absolute mean bias and the standard deviation of the bias are given.

Global irradiance	Monthly values									
	HelioClim-3v4					HelioClim-3v5				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	152.3	95	0.999	5%	3%	152.3	95	0.999	2%	2%
Bratislava 2004 - 2007	98.2	47	0.999	0%	5%	98.2	47	0.999	2%	5%
Cabauw 2004 - 2013	85.6	107	0.996	-4%	7%	85.6	107	0.997	-3%	6%
Camborne 2004 - 2013	85.3	98	0.999	0%	4%	85.3	98	0.999	2%	4%
Carpentras 2004 - 2013	123.6	117	0.999	1%	2%	123.6	117	0.999	1%	2%
Davos 2004 - 2011	85.4	95	0.994	9%	11%	85.4	95	0.996	5%	8%
Geneva 2004 - 2013	106.8	119	0.999	-1%	3%	106.8	119	0.999	6%	3%
Kassel 2004 - 2011	85.1	95	0.998	-5%	7%	85.1	95	0.998	-1%	6%
Kishinev 2004-2013	107.4	119	0.997	2%	5%	107.4	119	0.998	1%	4%
Lerwick 2004-2013	65.7	96	0.993	3%	12%	65.7	96	0.994	5%	12%
Lindenberg 2004-2010	89.7	35	0.999	-5%	4%	89.7	35	0.999	-4%	5%
Madrid 2004-2013	125.5	110	0.998	3%	4%	125.5	110	0.998	5%	4%
Nantes 2004-2010	103.1	71	0.999	-2%	3%	103.0	71	1.000	-1%	3%
Payerne 2004-2011	101.1	88	0.997	-8%	6%	101.1	88	0.999	-2%	4%
Sede Boqer 2004-2012	163.3	100	0.997	-7%	4%	163.3	100	0.999	-5%	4%
Skukuza 2004-2007	127.8	36	0.998	8%	6%	127.8	36	0.998	3%	6%
Tamanrasset 2004-2013	187.3	107	0.994	0%	4%	187.3	107	0.996	1%	3%
Toravere 2004 - 2013	86.5	109	0.993	0%	10%	86.5	109	0.995	-1%	8%
Valentia 2004-2013	83.7	119	0.997	0%	6%	83.6	119	0.999	2%	5%
Vaulx-en-Velin 2004-2013	104.0	119	0.996	1%	6%	104.0	119	0.997	5%	4%
Wien 2004-2013	99.5	112	0.998	-4%	4%	99.5	112	0.998	-1%	5%
Zilani 2004-2009	85.7	65	0.997	10%	10%	88.4	63	0.997	3%	7%
All sites	107.7	95		0.0%	6%	107.7	95		1.2%	5%
All sites absolute bias				3.1%					2.7%	
Standard dev. of the bias				4.3%					3.3%	

Beam irradiance	Monthly values									
	HelioClim-3v4					HelioClim-3v5				
	Bn	nb	R	mbd	sd	Bn	nb	R	mbd	sd
Almeria 2004 - 2011	173.3	95	0.986	12%	9%	173.3	95	0.991	4%	7%
Bratislava 2004 - 2007	102.0	47	0.994	-4%	10%	102.0	47	0.996	2%	9%
Cabauw 2004 - 2013	73.5	107	0.983	17%	16%	73.5	107	0.986	14%	14%
Camborne 2004 - 2013	68.4	98	0.984	23%	23%	68.4	98	0.984	30%	22%
Carpentras 2004 - 2013	149.2	117	0.981	3%	8%	149.2	117	0.981	3%	8%
Davos 2004 - 2011	92.1	95	0.923	17%	29%	92.1	95	0.942	10%	22%
Geneva 2004 - 2013	106.4	119	0.990	2%	8%	106.4	119	0.987	20%	9%
Kassel 2004 - 2011	70.9	95	0.992	7%	11%	70.9	95	0.991	17%	12%
Kishinev 2004-2013	110.7	119	0.987	7%	10%	110.7	119	0.981	5%	11%
Lerwick 2004-2013	44.5	96	0.942	46%	53%	44.5	96	0.947	54%	53%
Lindenberg 2004-2010	85.4	35	0.993	2%	14%	85.4	35	0.988	2%	16%
Madrid 2004-2013	139.9	110	0.975	6%	12%	139.9	110	0.983	12%	9%
Nantes 2004-2010	102.4	71	0.992	-1%	10%	102.1	71	0.995	4%	8%
Payerne 2004-2011	97.7	88	0.990	-6%	10%	97.7	88	0.990	13%	12%
Sede Boqer 2004-2012	188.8	100	0.986	-17%	8%	188.8	100	0.989	-14%	8%
Skukuza 2004-2007	125.3	36	0.987	19%	17%	125.3	36	0.990	8%	13%
Tamanrasset 2004-2013	192.8	107	0.867	13%	20%	192.8	107	0.935	15%	14%
Toravere 2004 - 2013	90.9	109	0.966	3%	22%	90.9	109	0.978	0%	16%
Valentia 2004-2013	78.9	119	0.969	-2%	18%	78.8	119	0.982	4%	15%
Vaulx-en-Velin 2004-2013	107.3	119	0.986	2%	10%	107.0	119	0.988	12%	8%
Wien 2004-2013	91.7	112	0.988	2%	10%	91.7	112	0.986	11%	11%
Zilani 2004-2009	80.2	65	0.987	30%	27%	82.7	63	0.987	12%	17%
All sites	109.1	95		5.8%	16%	109.2	95		8.8%	13%
All sites absolute bias				9.6%					11.1%	
Standard dev. of the bias				12.8%					13.5%	

Diffuse irradiance	Monthly values									
	HelioClim-3v4					HelioClim-3v5				
	Dh	nb	R	mbd	sd	Dh	nb	R	mbd	sd
Almeria 2004 - 2011	46.9	95	0.985	-11%	11%	46.9	95	0.987	-7%	10%
Bratislava 2004 - 2007	43.7	47	0.995	-4%	10%	43.7	47	0.996	-7%	11%
Cabauw 2004 - 2013	46.8	107	0.996	-22%	18%	46.8	107	0.997	-19%	16%
Camborne 2004 - 2013	47.4	98	0.997	-18%	14%	47.4	98	0.996	-21%	15%
Carpentras 2004 - 2013	37.9	117	0.964	-9%	12%	37.9	117	0.964	-9%	12%
Davos 2004 - 2011	33.7	95	0.963	-3%	22%	33.7	95	0.964	0%	21%
Geneva 2004 - 2013	45.1	119	0.979	-6%	11%	45.1	119	0.978	-14%	13%
Kassel 2004 - 2011	42.4	95	0.995	-7%	12%	42.4	95	0.995	-11%	14%
Kishinev 2004-2013	43.9	119	0.989	-7%	10%	43.9	119	0.982	-8%	11%
Lerwick 2004-2013	43.8	96	0.996	-19%	16%	43.8	96	0.996	-21%	18%
Lindenberg 2004-2010	44.3	35	0.997	-14%	12%	44.3	35	0.996	-15%	14%
Madrid 2004-2013	36.5	110	0.956	4%	15%	36.5	110	0.964	-3%	13%
Nantes 2004-2010	49.2	71	0.997	-9%	10%	49.2	71	0.997	-12%	10%
Payerne 2004-2011	44.9	88	0.993	-14%	10%	44.9	88	0.991	-21%	13%
Sede Boqer 2004-2012	41.5	100	0.932	10%	19%	41.5	100	0.913	3%	21%
Skukuza 2004-2007	49.1	36	0.993	-18%	16%	49.1	36	0.996	-13%	12%
Tamanrasset 2004-2013	56.7	107	0.853	-32%	30%	56.7	107	0.941	-35%	25%
Toravere 2004 - 2013	39.0	109	0.993	-4%	9%	39.0	109	0.994	-5%	8%
Valentia 2004-2013	43.8	119	0.997	-4%	8%	43.7	119	0.997	-7%	9%
Vaulx-en-Velin 2004-2013	42.2	119	0.978	0%	10%	42.1	119	0.975	-6%	13%
Wien 2004-2013	47.5	112	0.989	-12%	12%	47.5	112	0.988	-16%	14%
Zilani 2004-2009	41.0	65	0.995	-8%	12%	42.2	63	0.997	-6%	9%
All sites	43.7	95		-9.7%	15%	43.8	95		-12.2%	15%
All sites absolute bias				11.0%					12.5%	
Standard dev. of the bias				14.5%					16.1%	

Global irradiance	Monthly values									
	HelioClim-3v4					HelioClim-3v5				
	Gh	nb	R	mbd	sd	Gh	nb	R	mbd	sd
Almeria 2004 - 2011	152.3	95	0.999	7.13	4.17	152.3	95	0.999	2.65	3.29
Bratislava 2004 - 2007	98.2	47	0.999	0.29	4.63	98.2	47	0.999	2.40	4.61
Cabauw 2004 - 2013	85.6	107	0.996	-3.38	6.20	85.6	107	0.997	-2.29	5.45
Camborne 2004 - 2013	85.3	98	0.999	-0.02	3.35	85.3	98	0.999	1.34	3.32
Carpentras 2004 - 2013	123.6	117	0.999	1.08	2.46	123.6	117	0.999	1.08	2.46
Davos 2004 - 2011	85.4	95	0.994	7.57	9.11	85.4	95	0.996	4.69	6.44
Geneva 2004 - 2013	106.8	119	0.999	-1.11	3.19	106.8	119	0.999	6.15	3.27
Kassel 2004 - 2011	85.1	95	0.998	-3.99	6.36	85.1	95	0.998	-1.03	4.77
Kishinev 2004-2013	107.4	119	0.997	2.15	5.00	107.4	119	0.998	1.31	4.64
Lerwick 2004-2013	65.7	96	0.993	2.24	7.93	65.7	96	0.994	3.35	7.72
Lindenberg 2004-2010	89.7	35	0.999	-4.18	3.92	89.7	35	0.999	-4.01	4.22
Madrid 2004-2013	125.5	110	0.998	3.53	4.72	125.5	110	0.998	6.24	4.68
Nantes 2004-2010	103.1	71	0.999	-2.42	3.14	103.0	71	1.000	-0.84	2.66
Payerne 2004-2011	101.1	88	0.997	-8.43	5.79	101.1	88	0.999	-1.61	4.20
Sede Boqer 2004-2012	163.3	100	0.997	-10.68	6.90	163.3	100	0.999	-7.70	5.88
Skukuza 2004-2007	127.8	36	0.998	9.64	8.22	127.8	36	0.998	3.75	8.05
Tamanrasset 2004-2013	187.3	107	0.994	-0.15	8.08	187.3	107	0.996	1.29	6.53
Toravere 2004 - 2013	86.5	109	0.993	0.16	8.37	86.5	109	0.995	-1.10	6.61
Valentia 2004-2013	83.7	119	0.997	0.38	5.19	83.6	119	0.999	1.73	4.20
Vaulx-en-Velin 2004-2013	104.0	119	0.996	1.07	6.25	104.0	119	0.997	5.27	4.43
Wien 2004-2013	99.5	112	0.998	-3.50	4.22	99.5	112	0.998	-0.62	4.75
Zilani 2004-2009	85.7	65	0.997	8.21	8.78	88.4	63	0.997	2.81	6.52
All sites	107.7	95		0.03	5.99	107.7	95		1.26	5.05
All sites absolute bias				3.34					2.86	
Standard dev. of the bias				4.60					3.55	

Beam irradiance	Monthly values									
	HelioClim-3v4					HelioClim-3v5				
	Bn	nb	R	mbd	sd	Bn	nb	R	mbd	sd
Almeria 2004 - 2011	173.3	95	0.986	20.18	14.96	173.3	95	0.991	6.09	12.35
Bratislava 2004 - 2007	102.0	47	0.994	-3.99	10.13	102.0	47	0.996	1.89	9.15
Cabauw 2004 - 2013	73.5	107	0.983	12.49	11.58	73.5	107	0.986	10.24	10.26
Camborne 2004 - 2013	68.4	98	0.984	16.01	15.94	68.4	98	0.984	20.23	15.02
Carpentras 2004 - 2013	149.2	117	0.981	3.94	12.27	149.2	117	0.981	3.94	12.27
Davos 2004 - 2011	92.1	95	0.923	16.07	27.09	92.1	95	0.942	9.11	20.50
Geneva 2004 - 2013	106.4	119	0.990	1.71	8.40	106.4	119	0.987	21.74	9.98
Kassel 2004 - 2011	70.9	95	0.992	5.12	7.48	70.9	95	0.991	12.23	8.58
Kishinev 2004-2013	110.7	119	0.987	7.26	11.30	110.7	119	0.981	5.48	12.16
Lerwick 2004-2013	44.5	96	0.942	20.30	23.66	44.5	96	0.947	23.81	23.48
Lindenberg 2004-2010	85.4	35	0.993	1.38	11.87	85.4	35	0.988	1.61	13.93
Madrid 2004-2013	139.9	110	0.975	8.91	16.37	139.9	110	0.983	17.11	12.65
Nantes 2004-2010	102.4	71	0.992	-0.74	10.15	102.1	71	0.995	4.09	8.39
Payerne 2004-2011	97.7	88	0.990	-5.75	9.94	97.7	88	0.990	12.63	11.24
Sede Boqer 2004-2012	188.8	100	0.986	-32.94	14.93	188.8	100	0.989	-26.17	15.92
Skukuza 2004-2007	125.3	36	0.987	23.32	20.74	125.3	36	0.990	9.40	16.79
Tamanrasset 2004-2013	192.8	107	0.867	25.52	39.24	192.8	107	0.935	29.85	26.75
Toravere 2004 - 2013	90.9	109	0.966	2.64	19.96	90.9	109	0.978	-0.06	14.48
Valentia 2004-2013	78.9	119	0.969	-1.56	14.19	78.8	119	0.982	2.81	11.88
Vaulx-en-Velin 2004-2013	107.3	119	0.986	2.18	10.82	107.0	119	0.988	13.16	8.89
Wien 2004-2013	91.7	112	0.988	2.07	9.26	91.7	112	0.986	9.95	9.83
Zilani 2004-2009	80.2	65	0.987	23.76	21.32	82.7	63	0.987	10.27	14.22
All sites	109.1	95		6.32	17.19	109.2	95		9.56	14.36
All sites absolute bias				10.42					12.11	
Standard dev. of the bias				14.02					14.74	

Diffuse irradiance	Monthly values									
	HelioClim-3v4					HelioClim-3v5				
	Dh	nb	R	mbd	sd	Dh	nb	R	mbd	sd
Almeria 2004 - 2011	46.9	95	0.985	-5.02	5.35	46.9	95	0.987	-3.20	4.74
Bratislava 2004 - 2007	43.7	47	0.995	-1.86	4.44	43.7	47	0.996	-3.24	4.75
Cabauw 2004 - 2013	46.8	107	0.996	-10.29	8.32	46.8	107	0.997	-8.87	7.31
Camborne 2004 - 2013	47.4	98	0.997	-8.43	6.52	47.4	98	0.996	-9.79	7.00
Carpentras 2004 - 2013	37.9	117	0.964	-3.35	4.66	37.9	117	0.964	-3.35	4.66
Davos 2004 - 2011	33.7	95	0.963	-1.02	7.39	33.7	95	0.964	0.03	6.96
Geneva 2004 - 2013	45.1	119	0.979	-2.53	4.81	45.1	119	0.978	-6.36	5.98
Kassel 2004 - 2011	42.4	95	0.995	-3.03	5.13	42.4	95	0.995	-4.60	5.95
Kishinev 2004-2013	43.9	119	0.989	-2.93	4.49	43.9	119	0.982	-3.52	4.85
Lerwick 2004-2013	43.8	96	0.996	-8.30	7.07	43.8	96	0.996	-9.34	7.67
Lindenberg 2004-2010	44.3	35	0.997	-6.33	5.50	44.3	35	0.996	-6.75	6.05
Madrid 2004-2013	36.5	110	0.956	1.36	5.34	36.5	110	0.964	-1.03	4.89
Nantes 2004-2010	49.2	71	0.997	-4.65	4.72	49.2	71	0.997	-6.14	5.04
Payerne 2004-2011	44.9	88	0.993	-6.19	4.68	44.9	88	0.991	-9.58	6.01
Sede Boqer 2004-2012	41.5	100	0.932	4.06	7.77	41.5	100	0.913	1.41	8.83
Skukuza 2004-2007	49.1	36	0.993	-8.62	7.80	49.1	36	0.996	-6.62	5.82
Tamanrasset 2004-2013	56.7	107	0.853	-18.08	17.14	56.7	107	0.941	-19.69	14.02
Toravere 2004 - 2013	39.0	109	0.993	-1.71	3.34	39.0	109	0.994	-1.93	3.09
Valentia 2004-2013	43.8	119	0.997	-1.85	3.50	43.7	119	0.997	-3.23	3.81
Vaulx-en-Velin 2004-2013	42.2	119	0.978	0.17	4.40	42.1	119	0.975	-2.48	5.28
Wien 2004-2013	47.5	112	0.989	-5.70	5.82	47.5	112	0.988	-7.47	6.45
Zilani 2004-2009	41.0	65	0.995	-3.42	5.12	42.2	63	0.997	-2.39	3.74
All sites	43.7	95		-4.25	6.73	43.8	95		-5.33	6.52
All sites absolute bias				4.81					5.47	
Standard dev. of the bias				6.33					7.04	

Table a-III Site by site, for the two helioclim-3 versions, monthly global, normal beam and diffuse irradiation validation results expressed in relative and absolute values. The absolute values are given in [kWh/m²h day].

For all sites, the overall values, the absolute mean bias and the standard deviation of the bias are given.