The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF)

Validation Report

Down-welling Surface Shortwave Flux (DSSF)

PRODUCTS: LSA-07 (MDSSF), LSA-08 (EDSSF), LSA-09 (DIDSSF)

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Version 2.0	15/01/2008	Version prepared for ORR-A EPS
Version 2.5	19/10/2010	Daily cumulative estimates.
Version 2.6	10/07/2011	Now includes a comparison of daily DSSF (DIDSSF) with in situ observations.

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Executive Summary

The down-welling surface short-wave radiation flux (DSSF) refers to the radiative energy in the wavelength interval [0.3µm, 4.0µm] reaching the Earth's surface per time and surface unit. The DSSF product for SEVIRI sensor is operational within the LSA SAF since the beginning of the CDOP, available to users in near-real time (via EUMETCast) or offline (via ftp). A similar algorithm was adapted to AVHRR onboard MetOp and is being integrated into the EPS chain.

This document presents the most recent validation results obtained for the LSA SAF DSSF series of product. In the case of DSSF_SEVIRI, these are based on the comparison with ECMWF and ground observations, most of which available from the BSRN database, plus some African stations located within the AMMA study area.

For clear sky conditions the bias calculated on the basis of the whole data period for the six European stations Carpentras, Roissy, Evora, Toravere, Payerne, and Camborne individually exhibits values of +3 Wm^{-2}, +14 Wm^{-2}, +15 Wm^{-2}, +2 Wm^{-2}, +11 Wm^{-2}, and +13 Wm^{-2}, respectively, which corresponds to relative biases of up to 4%. When considering the statistics calculated for individual months more important biases with positive and negative sign can be observed which tend to cancel out over the whole period. Except for Toravere during wintertime (and for very few months for Roissy and Camborne) the monthly bias values remain better than ±10% in all and better than ±5% in the majority of cases.

For cloudy sky conditions the bias calculated with the whole data period for the six stations individually exhibits values of +4 Wm^{-2}, +4 Wm^{-2}, -3 Wm^{-2}, +2 Wm^{-2}, -7 Wm^{-2}, and -3 Wm^{-2}, respectively. In the worst case this corresponds to a relative bias of -3%. In the majority of cases the monthly values remain within ±15%, although there are some months, which are much further off. When considering all data points irrespective of the method applied, biases of +2 Wm^{-2}, +5 Wm^{-2}, +7 Wm^{-2}, +1 Wm^{-2}, -2 Wm^{-2}, and 0 Wm^{-2}, respectively, are obtained for the individual stations. The bias values for the monthly statistics are within ±5% in the majority of cases.

The results point towards a systematic overestimation of DSSF in clear sky conditions, likely due to underestimate of the aerosol load. This appeared clearly for the three African stations. A high dispersion of LSA SAF versus in situ measurements is observed in cloudy cases. The inter-comparison for DLSF clearly indicates that there is room for improvement of the current algorithms, so that systematic errors in both clear and cloudy sky conditions could be reduced.

The daily DSSF product (DIDSSF) shows for June 2009 over France very comparable results with ECMWF SSRD fields in both geographic patterns and magnitude, clear and cloudy cases inclusive. For whole year 2010, results of comparison against well-distributed BSRN stations generally fall within the users specification at the exception of cloudy situations due to misclassification and and misrepresentation of the in situ data at the pixel scale.

Finally, DSSF_AVHRR – prototyping algorithm considered PDU orbits. However, required AL_AVHRR is still not available, which prevents from a scientific validation so far. Nevertheless, it can be anticipated that discrepancies between the respective cloud masks will require first a thorough work of analysis.

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Introduction

The down-welling surface short-wave radiation flux (DSSF) refers to the radiative energy in the wavelength interval [0.3µm, 4.0µm] reaching the Earth's surface per time and surface unit. The DSLF product for SEVIRI sensor is operational within the LSA SAF since the beginning of the CDOP, available to users in near-real time (via EUMETCast) or offline (via ftp). A similar algorithm was adapted to AVHRR onboard MetOp and is being integrated into the EPS chain.

Both SEVIRI and AVHRR products use quite different parameterizations applicable either to clear or cloudy pixels. It essentially depends on the solar zenith angle, on cloud coverage, and to a lesser extent on atmospheric absorption and surface albedo. The method for the retrieval of DSSF that is implemented in the LSA SAF system largely follows previous developments achieved at Météo-France in the framework of the OSI SAF (Frouin et al., 1989; Brisson et al., 1999; Ocean & Sea-Ice , 2005). The main differences of the LSA SAF product are the spatial and temporal resolution, the source of ancillary input data, and the use of three short-wave SEVIRI channels (0.6µm, 0.8µm, and 1.6µm).

The pre-requisites to the DSSF algorithm include cloud information - Cloud Mask, Cloud Type, and Effective Cloudiness (provided by NWC SAF software, processed at IM), and Total Precipitable Water (ECMWF forecasts). An automatic Quality Control (QC) is performed on DSSF data and the quality information is provided on a pixel basis. The DSSF QC contains general information about input data quality and information about DSSF confidence level.

User requests regarding DSSF are summarised in Table 1; further details may be found in the most recent version of the Product Requirements Table (PRT).

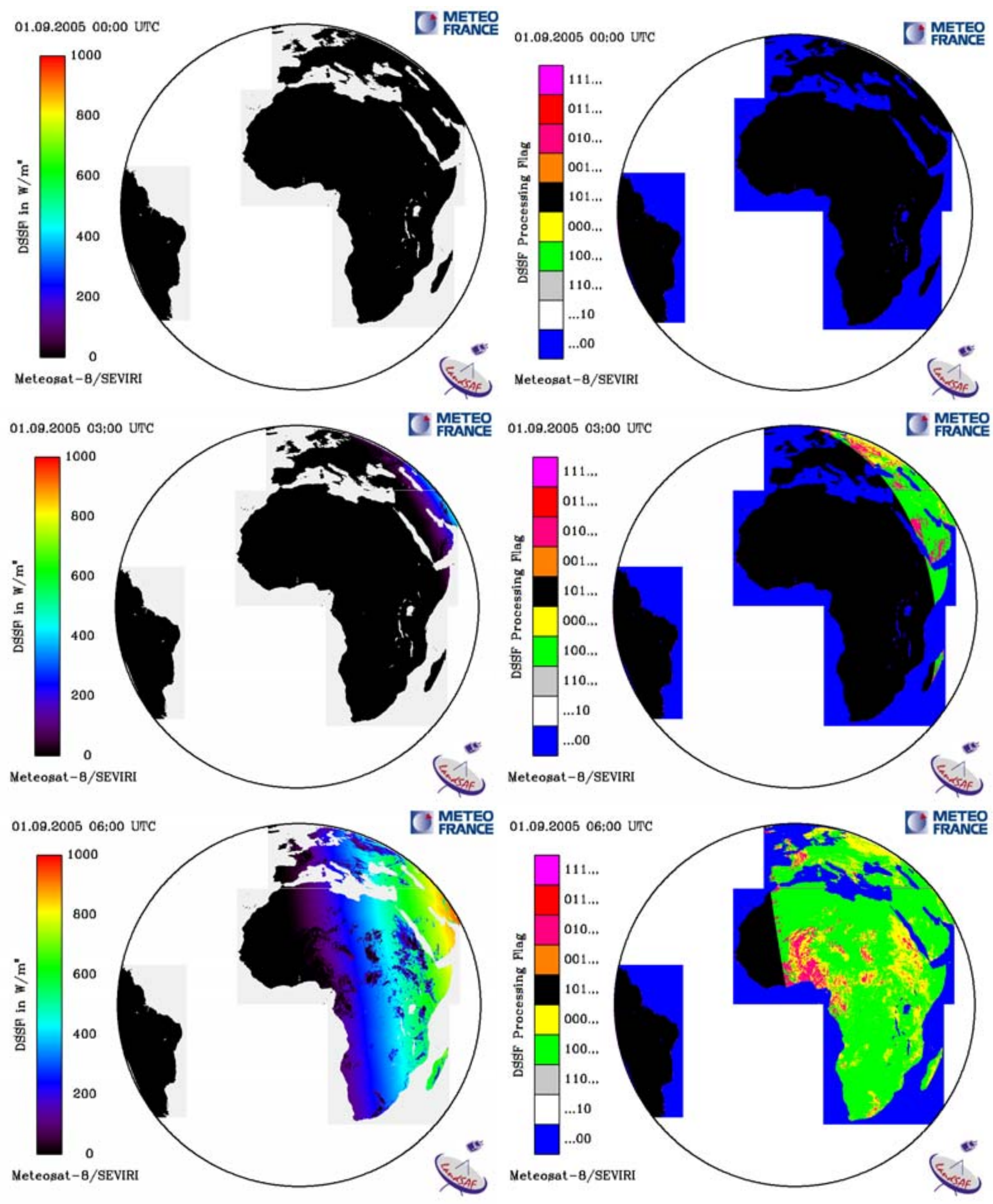
Table 1 Product Requirements for DSSF, in terms of area coverage, resolution and accuracy.

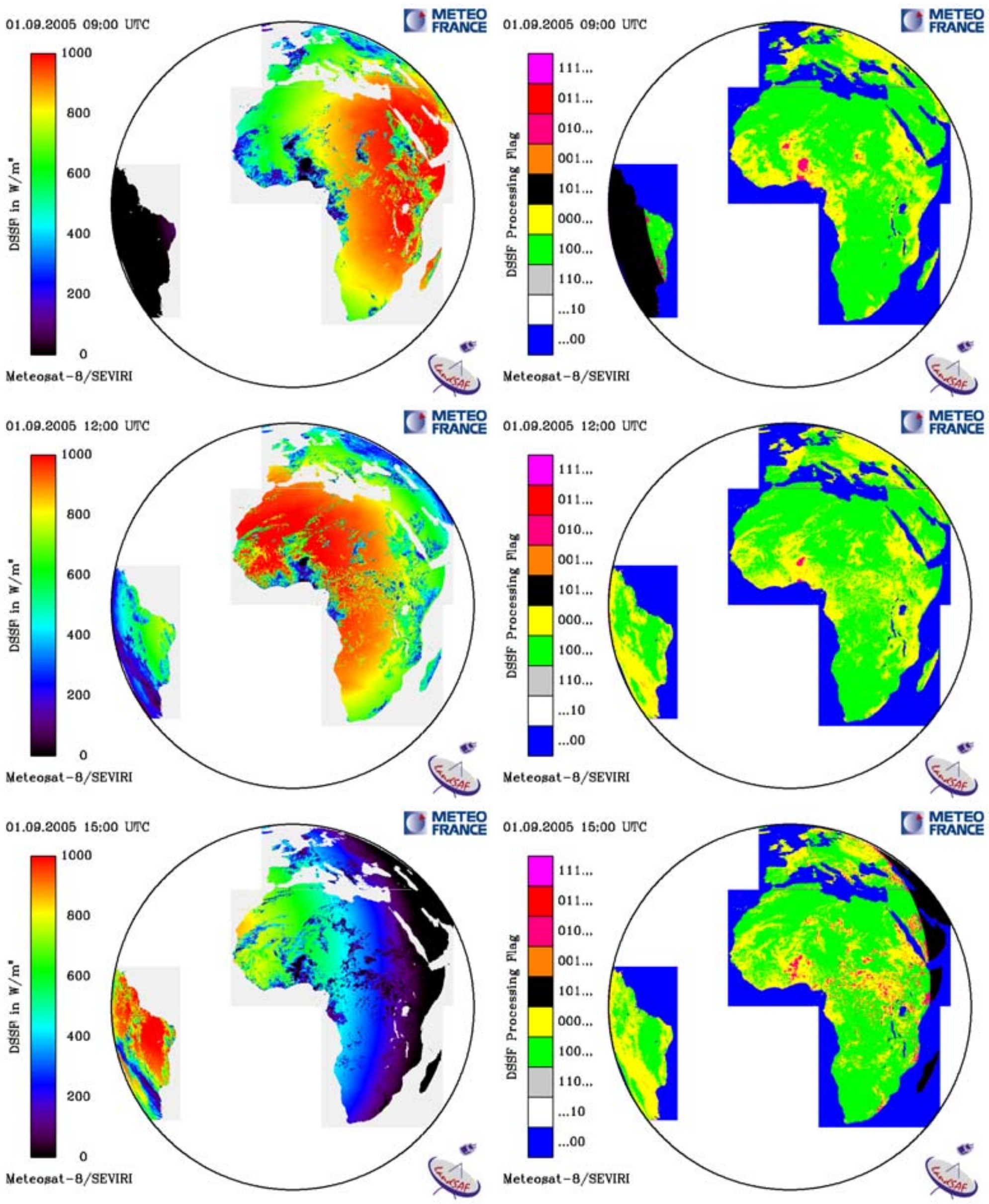
DSSF Product	Coverage	Resolution		Accuracy		
		Temporal	Spatial	Threshold	Target	Optimal
MDSSF (LSA-07) DSSF_SEVIRI	MSG disk	30 min	MSG pixel resolution	20%	DSSF>200 W/m2: 10% DSSF<200 W/m2: 20W/m2	5%
EDSSF (LSA-08) DSSF_AVHRR	Europe & High Latitudes	1/2 day	0.01° x 0.01°	20%	DSSF>200 W/m2: 10% DSSF<200 W/m2: 20W/m2	5%
DIDSSF (LSA-09) DSSF_DAILY	MSG disk	1 day	MSG pixel resolution	20%	DSSF>200 W/m2: 10% DSSF<200 W/m2: 20W/m2	5%

This document presents the most recent validation results obtained for the LSA SAF DSSF products. The reliability of DSSF_SEVIRI is verified based on the comparison with ground observations, most of which available from the BSRN database.

Down-welling Surface Short-wave Radiation Flux

1.1 DSSF Product Images




01.09.2005 09:00 UTC
01.09.2005 12:00 UTC
01.09.2005 15:00 UTC
DSSF in W/m²
1000
800
600
400
200
0
DSSF Processing Flag
111...
011...
010...
001...
101...
000...
100...
110...
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METEO FRANCE
Meteosat-8/SEVIRI

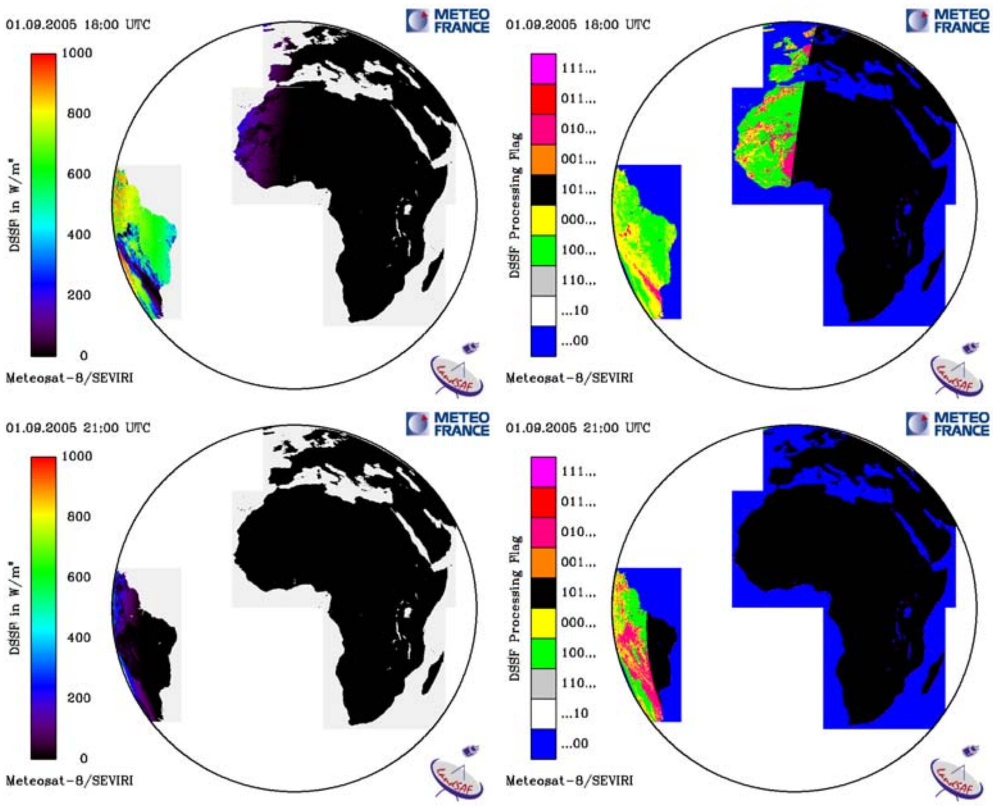


Figure 1: Three-hourly series of (instantaneous) DSSF estimates (left) and the corresponding quality flag information (right) for the 1st of September 2005.

Figure 1 shows a series of re-composed full disk images of the DSSF product and the accompanying quality (or processing) flag. The respective colour codes used for the image and for several of the following figures are listed in the table.

Table 2: Legend for the DSSF quality flag information shown in Figure 1 (right panels).

Bit 5-7	Binary Code	Colour Code	Description
	000	Yellow	Cloudy Sky Method
	001	Orange	Cloudy Sky Method, A_{TOA} below lower limit
	010	Light Red	Cloudy Sky Method, A_{TOA} above upper limit
	011	Red	Algorithm Failed
	100	Green	Clear Sky Method
	101	Black	Night
	110	Grey	Beyond specified View Angle Limit
	111	Magenta	Not Processed (Cloud Mask undefined)

1.2 Validation with Ground Measurements

The table below includes the list of ground stations and corresponding image pixel locations for which recent in-situ measurements were available to us. The Land-SAF product contains instantaneous estimates corresponding to the respective acquisition time of each line of the MSG image. There is a time difference of approximately 11 minutes for the European sites and 8 minutes for the African sites with respect to the slot time, which needs to be taken into account in the validation exercise. For the ground stations of Carpentras, Toravere, Payerne, Camborne, and Banizoumbou the in-situ data were available with a high temporal resolution in the order of minutes. In this case the in-situ data were averaged over intervals of 15 minutes centred on the exact acquisition times of the respective satellite measurements as a function of the site coordinates. For the other sites the accessible data had already been averaged over certain time intervals (Evora: 10 minutes; Roissy: until 8/2005 15 minutes, afterwards 6 minutes, Agoufou: 15 minutes). In this case we linearly interpolated the data points and re-sampled them corresponding to the exact satellite acquisition times.

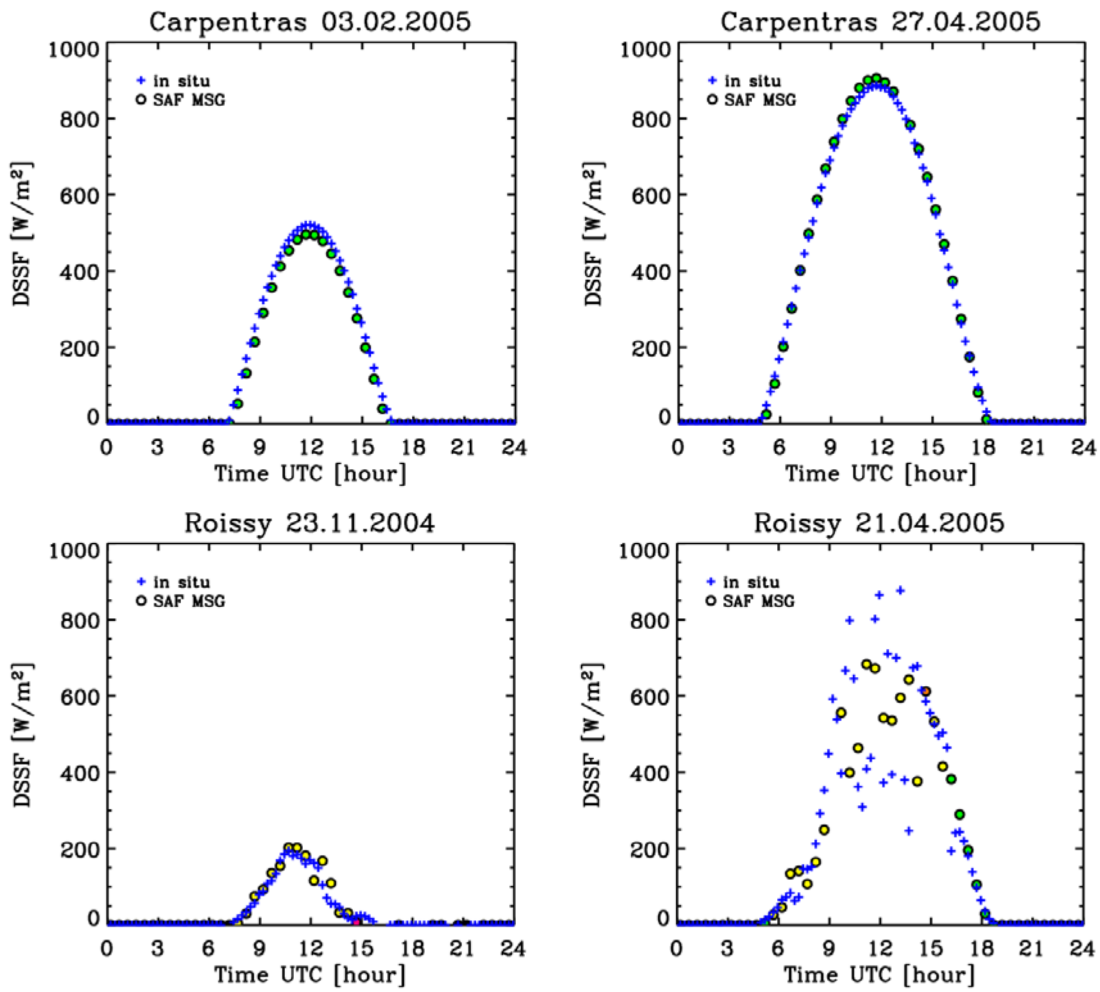
Table 3: List of DSSF in-situ validation stations.

Site	Latitude	Longitude	Column	Line	Zone	Source
Carpentras	44.083	5.059	436	414	Euro	MF/BSRN
Roissy	49.015	2.535	366	311	Euro	MF/CNRM
Evora	38.539	-8.000	085	546	Euro	LSA-SAF
Toravere	58.26	26.47	764	174	Euro	BSRN
Payerne	46.81	6.95	475	356	Euro	BSRN
Camborne	50.22	-5.32	189	289	Euro	BSRN
Agoufou	15.343	-1.481	565	603	NAfr	AMMA
Banizoumbou	13.522	2.632	712	667	NAfr	AMMA (ARM)

1.2.1 Product Time Series

Figure 2 contains a qualitative comparison of the satellite estimates for the down-welling short-wave radiation flux with the corresponding in-situ measurements in the form of time series for selected days. The examples shown for clear days at Carpentras demonstrate that the method works quite well here and that small over- or underestimations may occur. For Roissy the figure shows a favourable and a less favourable example under cloudy conditions. In the latter case (April 21) the discrepancies between the satellite estimates and the in-situ data cannot entirely be attributed to deficiencies of the retrieval method. The example also illustrates the limitation of the validation approach when the conditions are highly variable (in space and time). At least part of the dispersion is a consequence of comparing a local measurement with an estimate for a rather extended image pixel. In this sense the quantitative numbers derived for the standard deviation in the following sections can be considered as an upper limit for the dispersion of the estimates.

The figure also includes favourable examples for clear days at Évora with rather different aerosol concentrations (cf. Section 1.3.1) and the results for Toravere (Estonia) and Agoufou (Mali) support the confidence in the product estimates for high latitudes and the North African continental window. In the Sections 1.3.1 and 1.3.2 potential explanations are given for the significant biases (with opposite sign) which can be observed in the clear sky examples for the latter two sites.



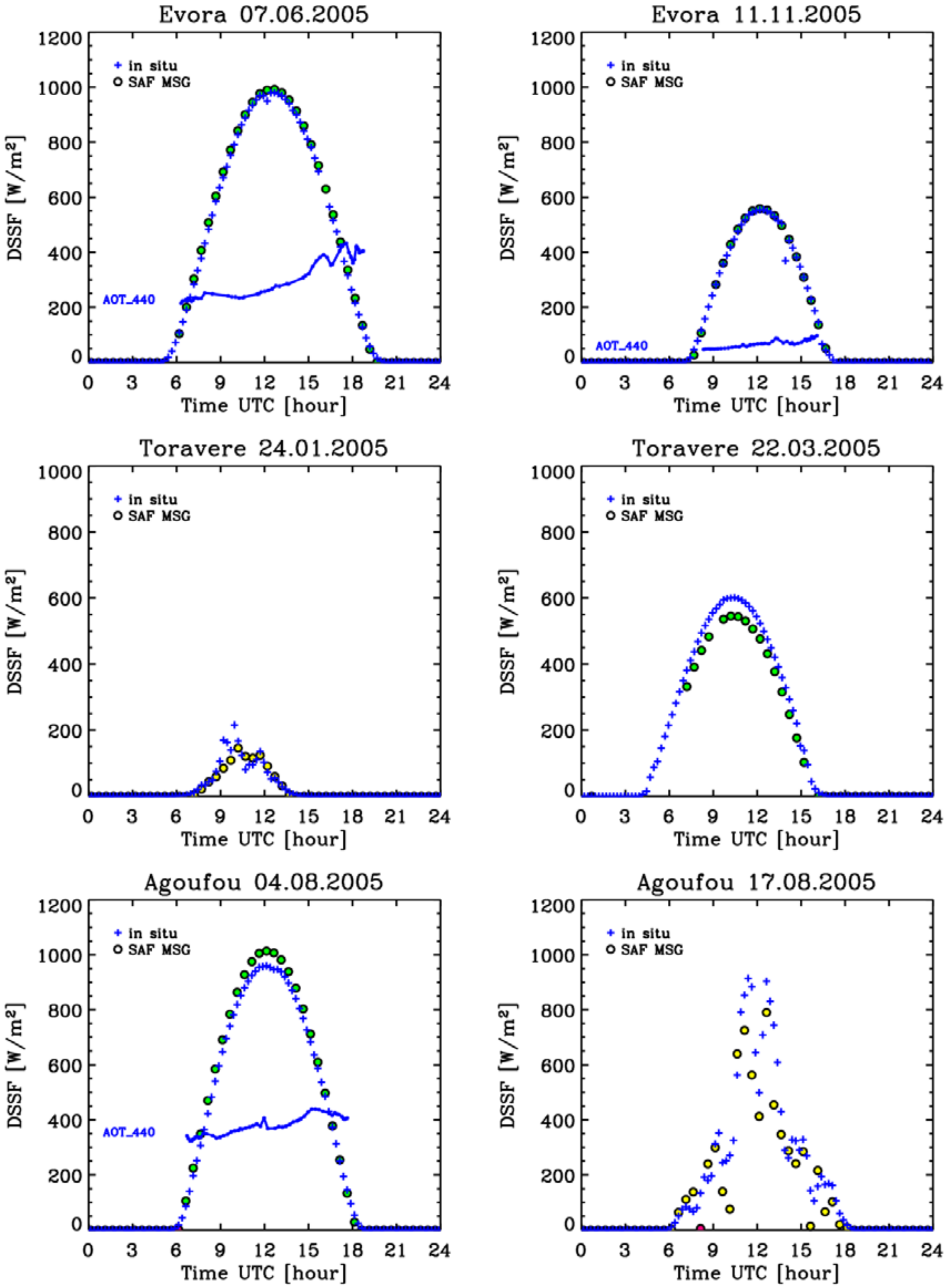
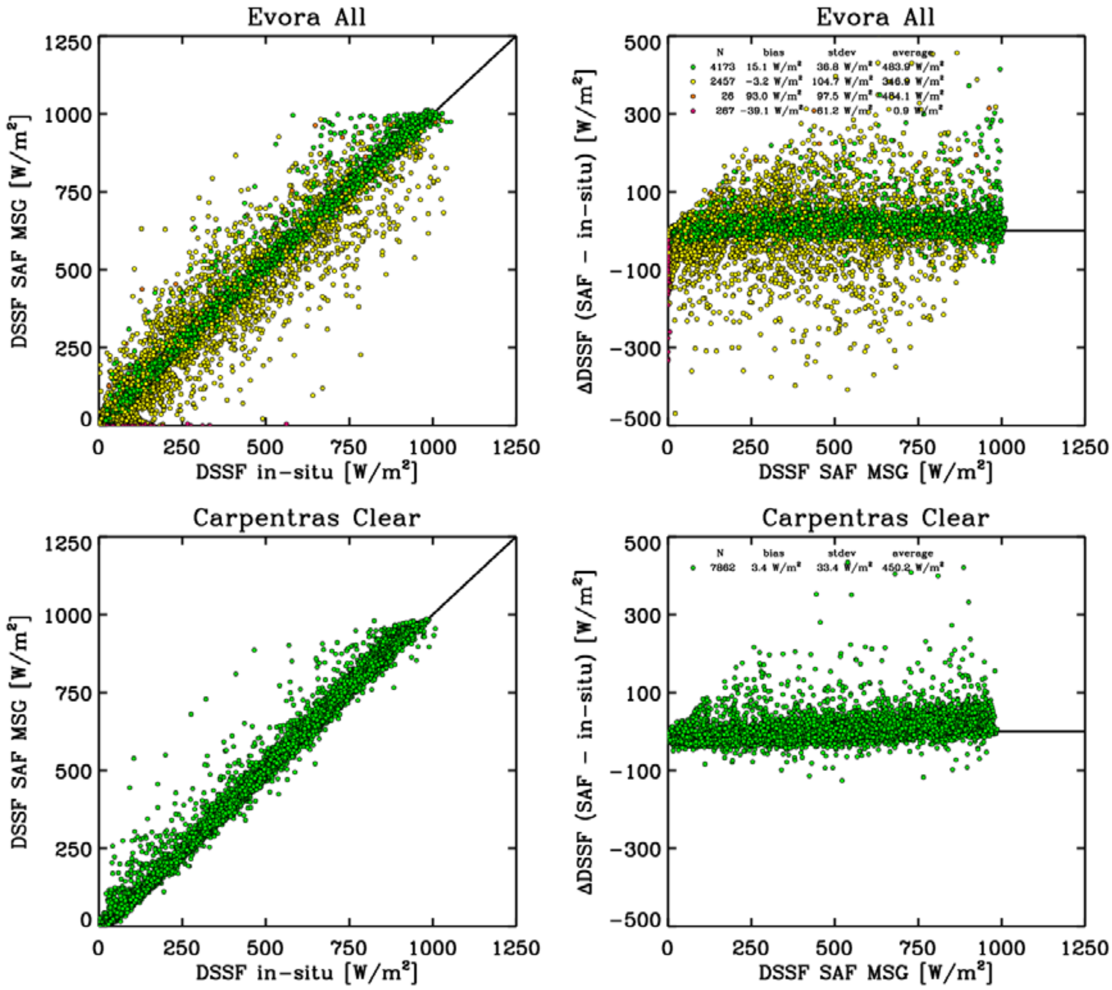


Figure 2: Examples for daily time series of DSSF estimates and in-situ measurements at the ground validation stations. The colours of the dots correspond to the cases listed in the table of Section 1.1. For Évora and Agoufou measurements of the aerosol optical thickness (at 440nm) obtained from Aeronet are also included in the graphs. (The numerical values given on the y-axis need to be divided by 1000 to get the correct optical thickness.)

1.2.2 Scatter Plots and Quantitative Results

The figures of this section depict scatter plots of the Land-SAF DSSF estimates against the in-situ measurements. The graphs of Figure 3 separately include all data points processed with the clear sky method for Carpentras and with the cloudy sky method for Roissy. As expected the dispersion of the distribution is much smaller for the “clear” than for the “cloudy” data points. The biases are relatively small in both cases and there is no significant evidence for a dependence of the bias on the level of the DSSF estimate. A few outliers can be perceived in the scatter plot for clear sky. However, their number is quite small compared to the large amount of data points included in the graph. The outliers may be caused by geo-location uncertainties or by small clouds which obstructed the direct solar radiation but could not be detected on the pixel scale.



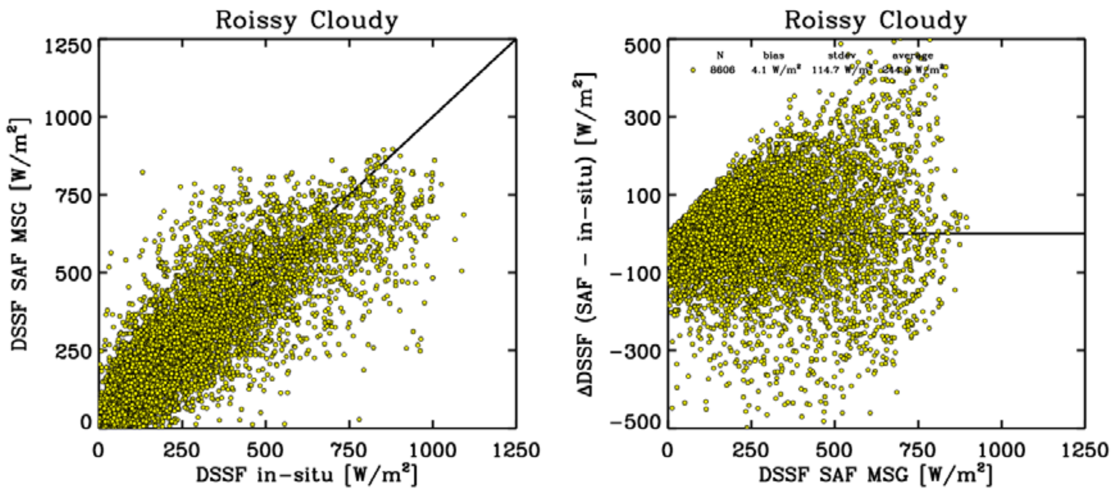


Figure 3: Scatter plots between the satellite estimates and the ground measurements. The top plots include all data points for Carpentras for which the clear sky method was applied over the whole available validation period. The bottom plots include all "cloudy" data points for Roissy.

For the sites of Évora, Toravere, and Banizoumbou Figure 4 shows scatter plots of the same type as in the previous figure. In addition to the "clear" and "normal cloudy" data points the graphs here also include the "pathological cases" in which a limiting condition is violated in the physical parameterisation of the cloudy sky method (see the table in Section 1.1). The number of data points for which this problem occurred is relatively small. For Évora and Toravere the distributions of the validation data points show qualitatively the same behaviour as discussed before. For Banizoumbou a positive bias can be perceived for the clear sky data points.

For validation purposes we calculated daily averages of the Land-SAF DSSF product for the pixels corresponding to the validation sites. This is helpful for comparing the quantitative validation statistics to those of other products which are not available as instantaneous estimates or with equivalent temporal frequency. The daily values are determined by averaging all available (day-time) Land-SAF DSSF estimates for a given day. For comparison only the in-situ measurements corresponding to the product time slots actually used for the determination of the "daily DSSF product" are then also averaged to obtain the corresponding "daily averaged in-situ measurement". [Note that this prescription is useful only for our validation purposes, but not appropriate for generating a daily averaged DSSF product meant to be distributed and utilised. For this purpose the problems of temporal reference for the average and the treatment of missing data would have to be considered much more carefully.] Figure 5 shows the scatter plots obtained for Évora and Toravere with the daily averaged DSSF quantities. As expected the dispersion is much smaller than for the instantaneous radiation estimates.

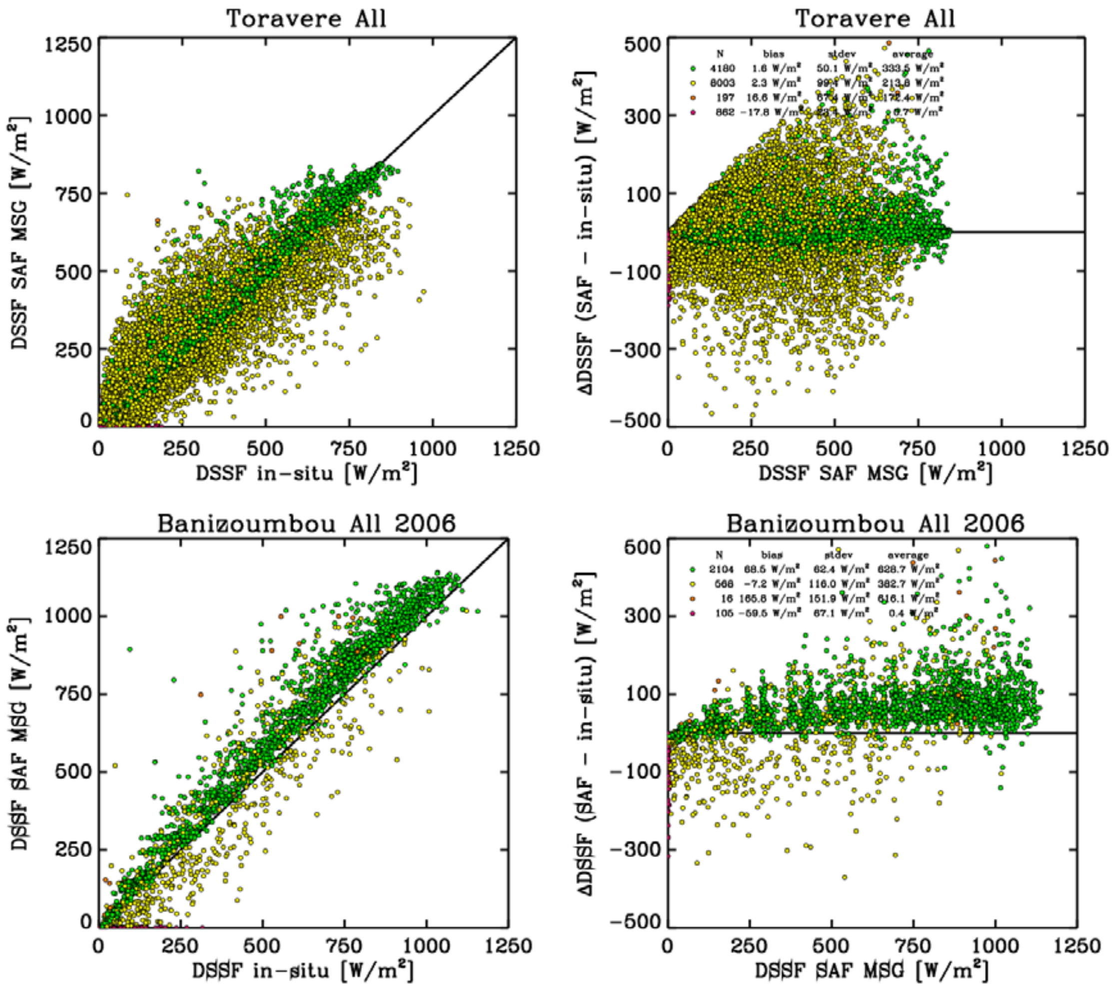


Figure 4: Scatter plots between the satellite estimates and the ground measurements. The graphs include all available data points for Évora (top), Toravere (middle), and Banizoumbou (bottom). The colour code for the points is as specified in the table of Section 1.1.

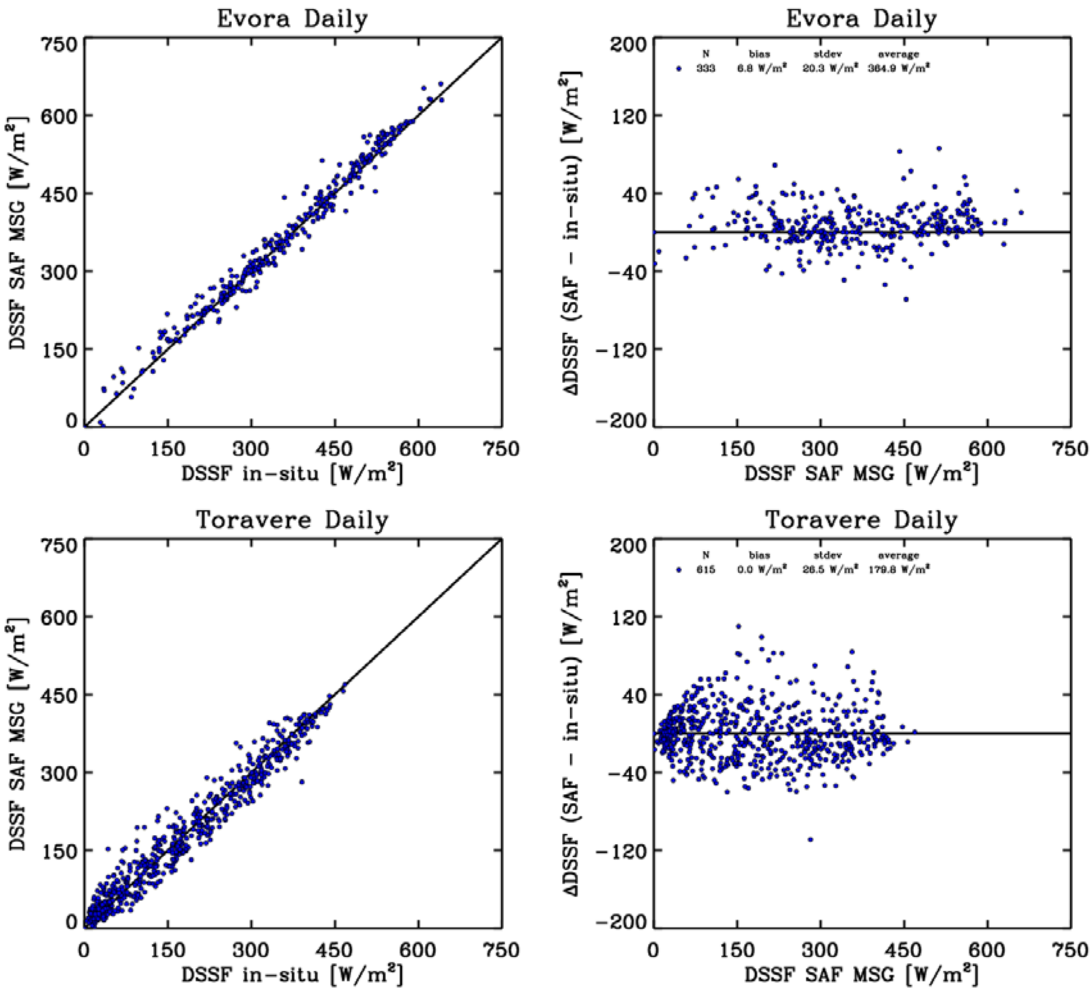


Figure 5: Scatter plots between the daily averages of the satellite estimates and the daily averages of the ground measurements. The shown range of values is different than in the previous figures. (Note that the daily averaged DSSF estimate is not available as a Land-SAF product for the time being. It is only calculated for the image pixels corresponding to the locations of the validation sites.)

For expressing the validation results in a quantitative way we calculate the bias - defined as the average of the difference between the satellite estimates and the in-situ measurements - and the standard deviation of that difference. Both quantities can be considered taking into account all available data points or with a restriction of the analysis to suitably defined sub-samples of the data in order to examine specific dependencies.

The numerical values of the statistical quantities are included (in rather small characters) in the scatter plots, but the figures and tables of the next section may be more convenient.

1.2.3 Time Series of Statistics (European Sites)

The temporal evolution of the statistical quantities over the whole available validation period is shown from Figure 6 to Figure 12 for the European stations of Carpentras, Roissy, Évora, Toravere, Payerne, and Camborne as well as for all six stations combined. For calculating the bias and the standard deviation, monthly sub-samples of the validation data points are considered to illustrate a possible temporal evolution of the product quality. The position of the symbols in the graphs indicates the bias, and the length of the bars (from the centre to each end) corresponds to the standard deviation as defined above. (These are not “error bars” representing the uncertainty in the determination of the bias.)

From the top to the bottom the panels show the results for the data points processed with the clear sky method, for the cloudy sky method, for all processed day-time data points combined irrespective of the method applied, and for the daily averaged DSSF “product” which was calculated for validation purposes only as described in the previous section. The top left plot for clear sky also includes the bias values (but not the standard deviation) for morning and afternoon data points separately. In each case the plot on the left gives the result in absolute units, and the plot on the right in relative units with respect to the average DSSF value in the respective sub-sample of the data points.

The numerical values are also provided in the form of tables. The values given in the line “Total Period” were calculated from the distribution of the data points over the whole time period (and not as averages of the monthly statistics). The results will be discussed in Section 0.

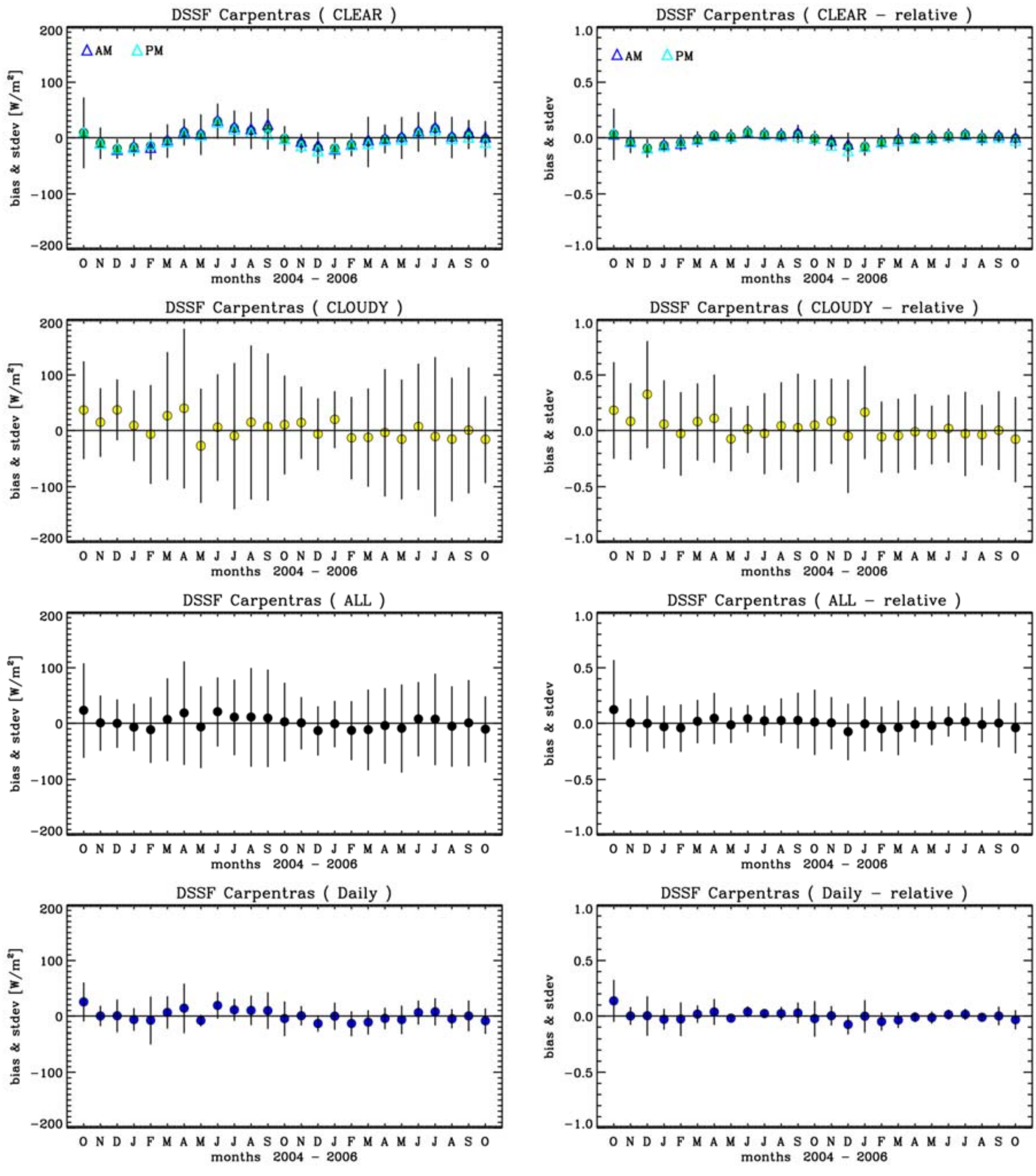


Figure 6: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Carpentras (see the text for details).

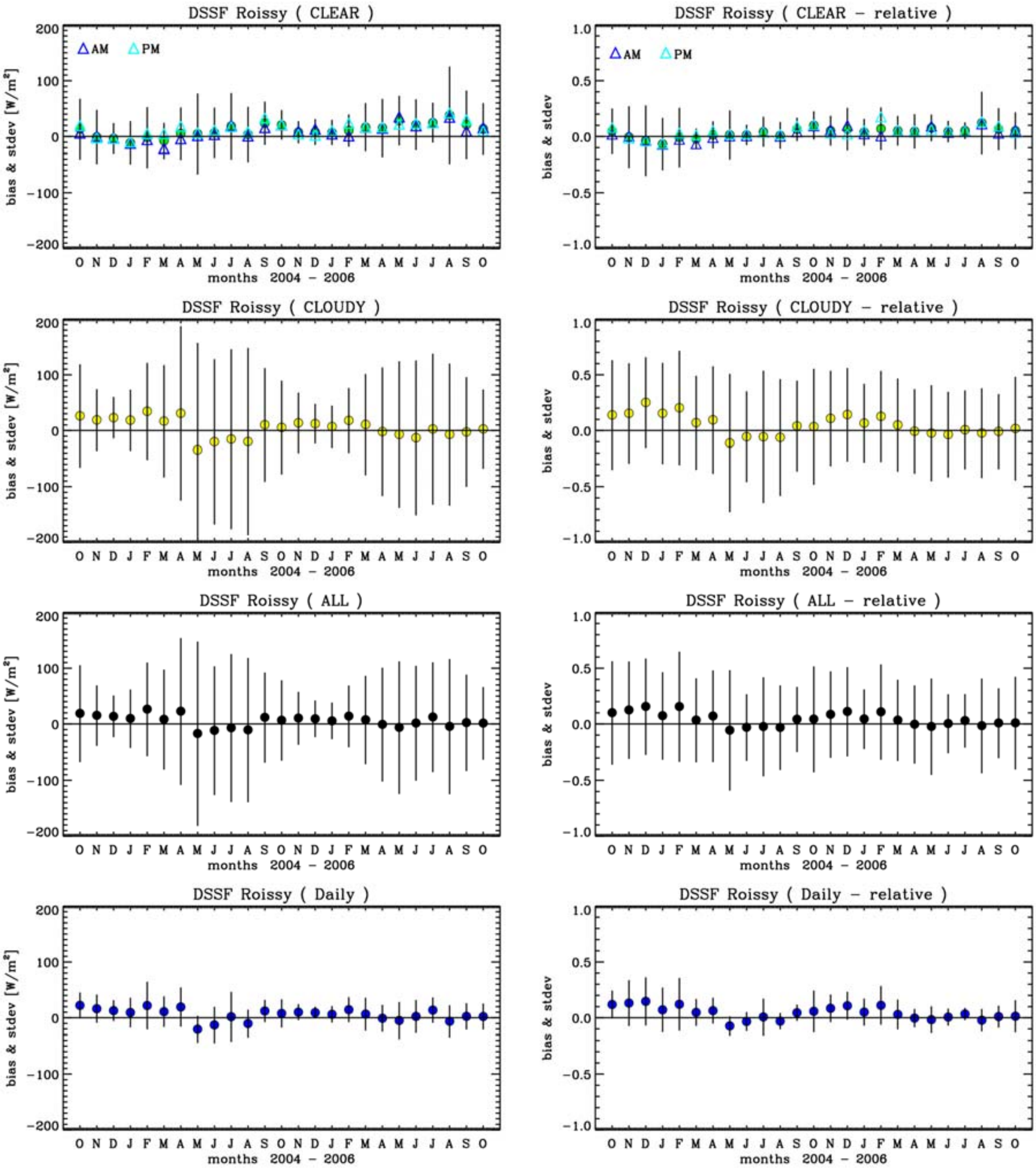


Figure 7: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Roissy.

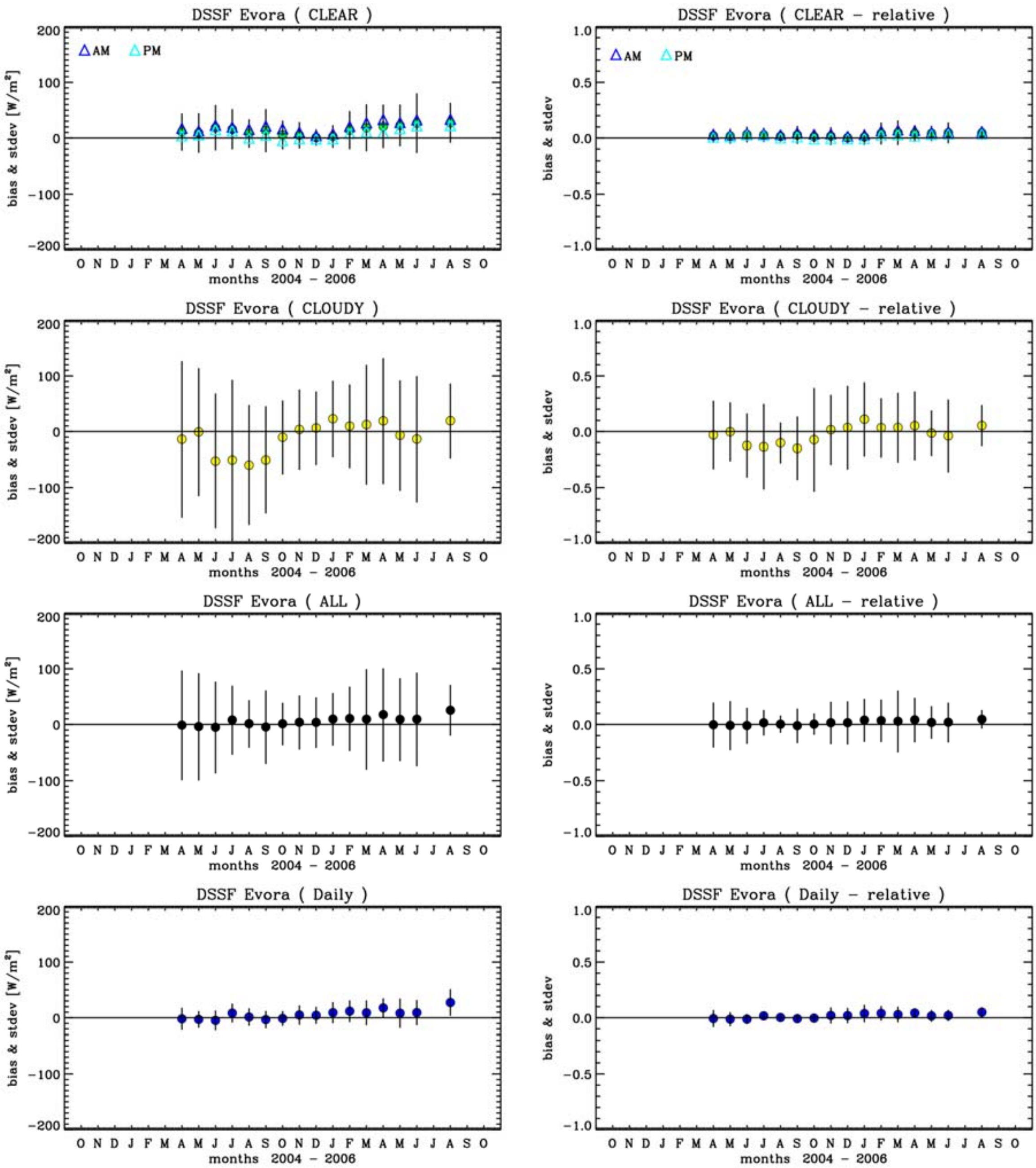


Figure 8: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Évora.

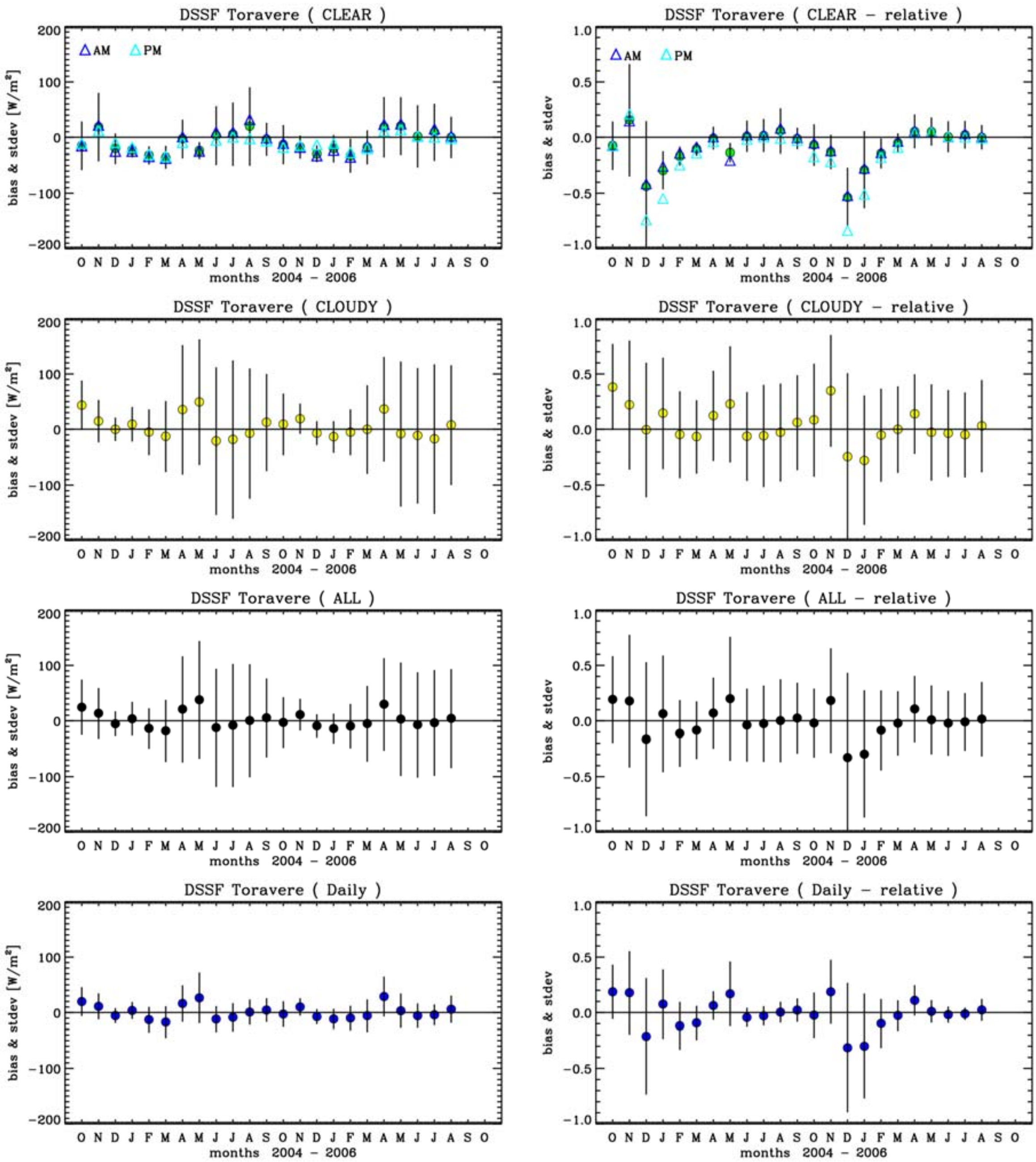


Figure 9: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Toravere.

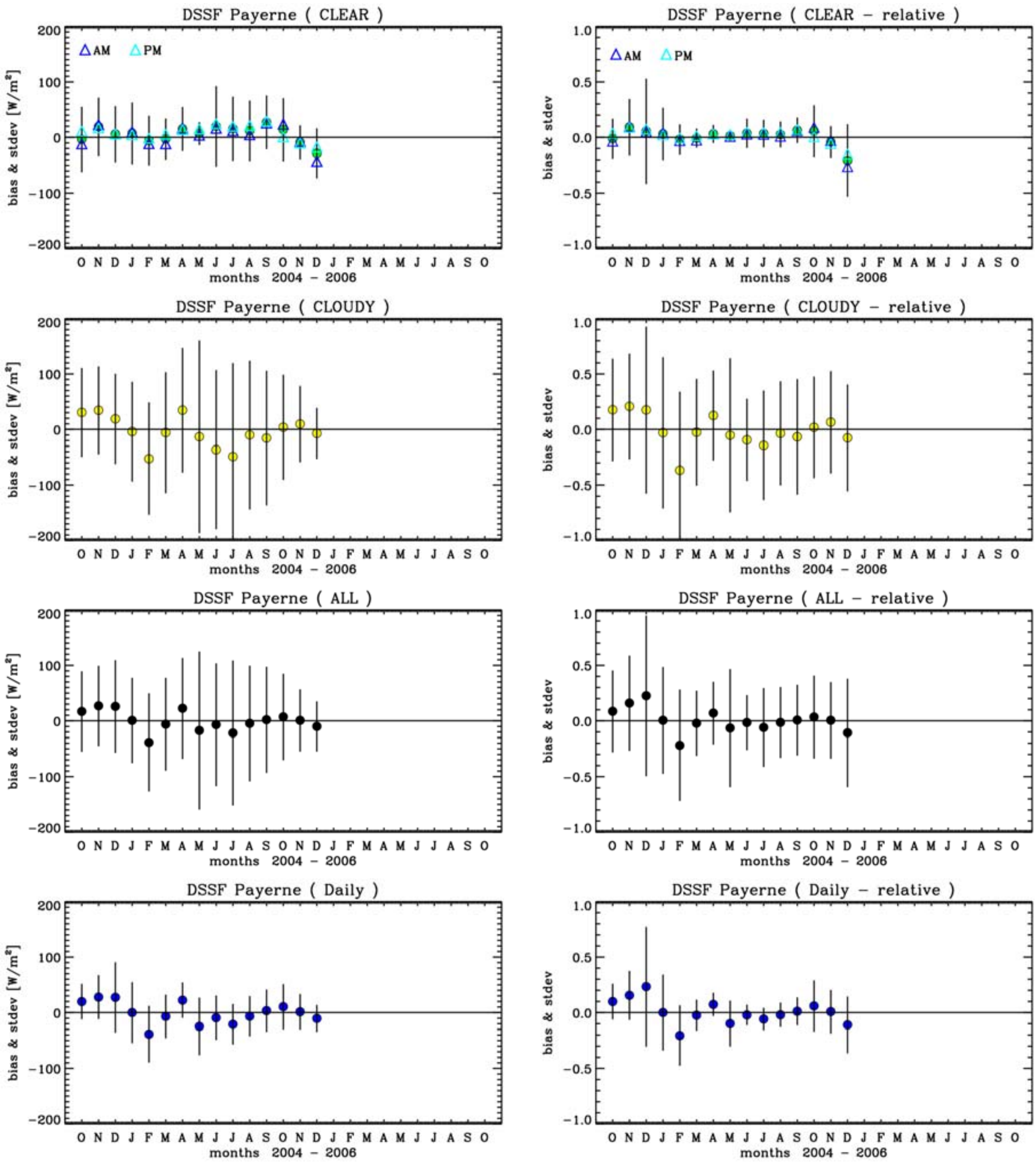


Figure 10: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Payerne.

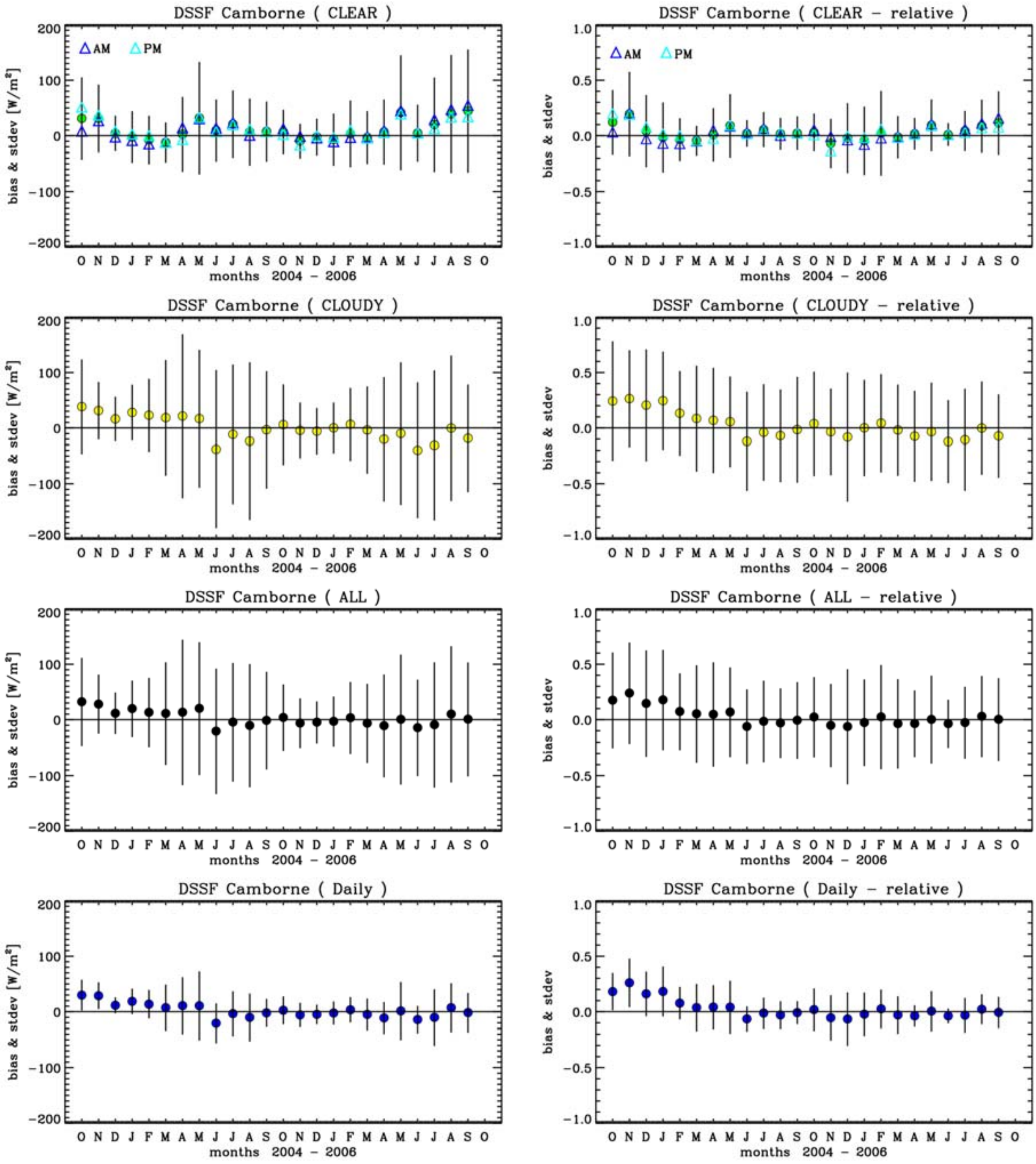


Figure 11: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Camborne.

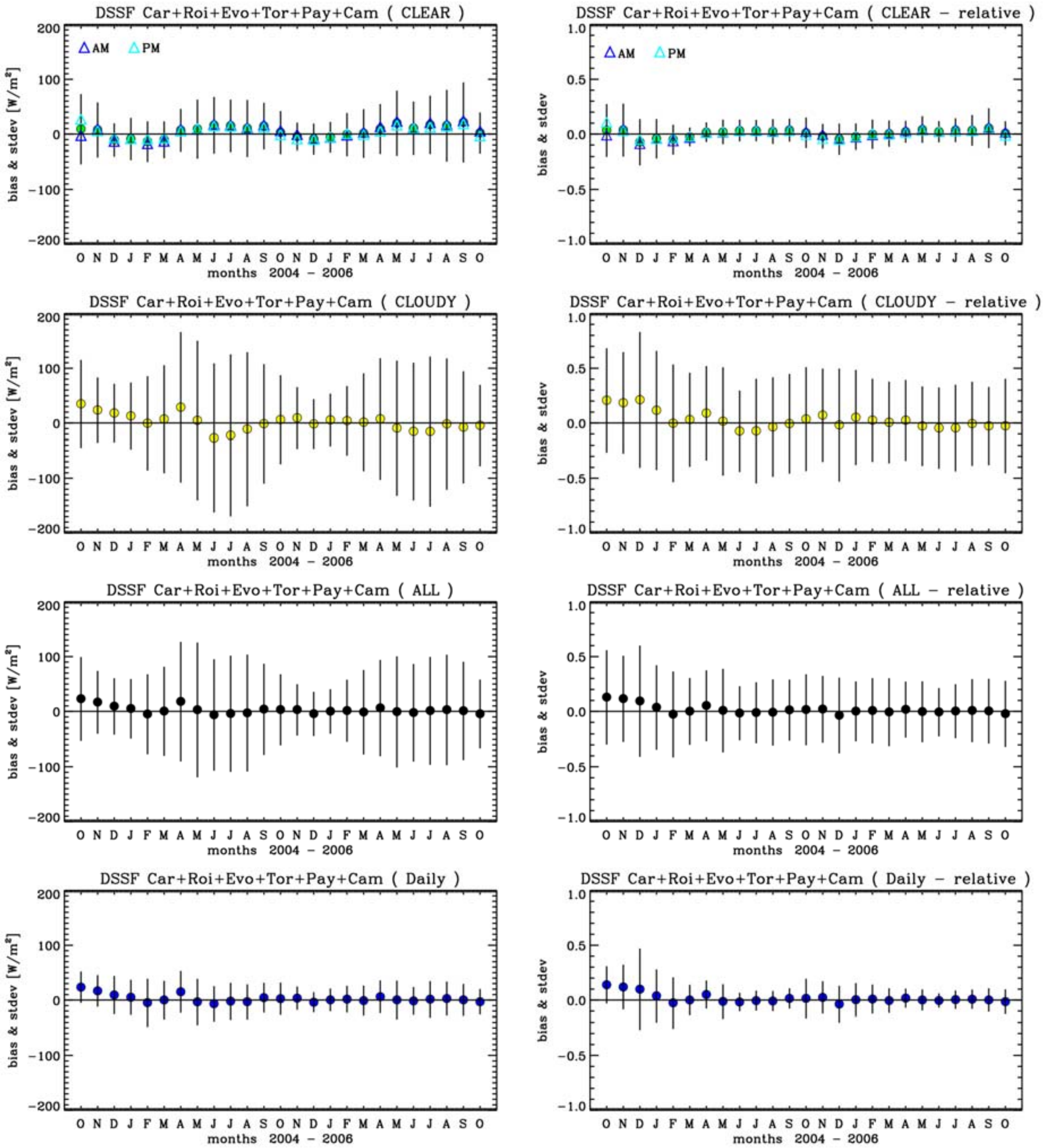


Figure 12: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for the European stations combined (Carpentras, Roissy, Evora, Toravere, Payerne, and Camborne).

Table 4: Numerical values for bias and standard deviation for Carpentras (Absolute Values in W/m^2).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	50	9.34	63.29	210	37.03	87.50	309	23.42	84.64	17	25.47	35.06
11	2004	201	-9.42	27.87	145	14.88	61.29	383	0.81	49.11	24	0.21	18.39
12	2004	192	-19.50	17.26	104	37.19	54.74	332	-0.13	42.97	22	0.53	29.42
1	2005	267	-16.67	15.41	125	9.10	63.10	436	-6.80	41.86	26	-6.20	20.43
2	2005	252	-14.65	23.79	180	-6.49	88.37	463	-11.47	58.68	26	-7.49	42.43
3	2005	321	-5.38	29.59	145	26.70	114.36	500	6.97	73.92	27	6.47	28.97
4	2005	320	10.12	24.06	225	39.98	143.17	606	18.74	92.62	26	14.15	44.13
5	2005	120	6.13	36.06	67	-26.89	102.22	208	-6.49	73.14	9	-7.96	10.48
6	2005	497	29.84	31.71	230	5.91	95.41	776	20.88	61.46	29	19.07	24.03
7	2005	597	17.55	31.59	163	-9.50	130.96	787	11.17	67.46	31	11.20	19.76
8	2005	470	13.01	33.32	285	14.91	137.97	792	11.34	88.28	31	10.25	26.75
9	2005	341	15.69	36.79	240	6.81	131.86	625	9.36	87.15	28	9.81	32.91
10	2005	129	-1.34	22.43	171	10.53	88.27	337	2.73	70.16	26	-4.43	30.66
11	2005	235	-9.81	16.87	208	14.37	64.37	464	0.84	46.53	28	0.64	17.49
12	2005	276	-17.52	27.66	149	-6.17	64.13	456	-13.17	43.84	28	-13.39	14.92
1	2006	228	-18.69	18.64	210	20.07	50.66	472	-0.84	41.14	28	-0.22	24.55
2	2006	240	-11.97	20.20	236	-13.07	73.58	504	-12.67	52.57	25	-13.26	21.86
3	2006	197	-7.11	44.82	327	-12.17	87.79	578	-11.36	72.23	27	-10.86	21.44
4	2006	492	-2.24	25.73	217	-3.55	113.98	753	-4.02	67.52	29	-4.18	19.42
5	2006	353	0.13	37.11	319	-15.52	107.19	719	-8.91	78.73	27	-6.34	25.06
6	2006	620	10.49	35.64	209	7.28	113.03	869	7.89	66.42	30	6.28	21.57
7	2006	583	16.82	30.20	201	-10.76	142.79	835	7.47	81.73	31	7.73	24.58
8	2006	495	0.97	36.69	261	-15.46	110.60	781	-5.17	71.83	31	-4.91	17.17
9	2006	191	5.91	26.19	162	0.66	112.72	381	0.75	76.96	20	0.32	27.68
10	2006	195	-1.82	31.97	194	-15.93	77.55	414	-10.51	58.88	26	-8.52	22.40
Total Period		7862	3.35	33.43	4983	3.65	104.22	13780	2.18	70.11	652	1.11	27.25

Table 5: Numerical values for bias and standard deviation for Carpentras (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	50	0.03	0.23	210	0.18	0.43	309	0.12	0.45	17	0.14	0.19
11	2004	201	-0.03	0.10	145	0.08	0.34	383	0.00	0.22	24	0.00	0.08
12	2004	192	-0.09	0.08	104	0.33	0.48	332	-0.00	0.25	22	0.00	0.17
1	2005	267	-0.07	0.06	125	0.06	0.39	436	-0.03	0.19	26	-0.03	0.09
2	2005	252	-0.05	0.07	180	-0.03	0.37	463	-0.04	0.21	26	-0.03	0.15
3	2005	321	-0.01	0.07	145	0.08	0.34	500	0.02	0.19	27	0.02	0.08
4	2005	320	0.02	0.05	225	0.11	0.39	606	0.05	0.23	26	0.04	0.12
5	2005	120	0.01	0.07	67	-0.07	0.28	208	-0.01	0.16	9	-0.02	0.02
6	2005	497	0.05	0.06	230	0.01	0.21	776	0.04	0.12	29	0.04	0.05
7	2005	597	0.03	0.06	163	-0.03	0.36	787	0.02	0.14	31	0.02	0.04
8	2005	470	0.02	0.06	285	0.04	0.39	792	0.03	0.20	31	0.02	0.06
9	2005	341	0.03	0.08	240	0.03	0.49	625	0.03	0.25	28	0.03	0.09
10	2005	129	-0.00	0.07	171	0.05	0.41	337	0.01	0.29	26	-0.02	0.16
11	2005	235	-0.04	0.07	208	0.09	0.38	464	0.00	0.23	28	0.00	0.09
12	2005	276	-0.08	0.13	149	-0.05	0.51	456	-0.08	0.25	28	-0.08	0.08
1	2006	228	-0.08	0.08	210	0.16	0.42	472	-0.00	0.24	28	-0.00	0.15
2	2006	240	-0.04	0.06	236	-0.06	0.32	504	-0.05	0.20	25	-0.05	0.08
3	2006	197	-0.02	0.10	327	-0.05	0.33	578	-0.04	0.24	27	-0.04	0.07
4	2006	492	-0.00	0.05	217	-0.01	0.34	753	-0.01	0.15	29	-0.01	0.04
5	2006	353	0.00	0.07	319	-0.04	0.26	719	-0.02	0.17	27	-0.01	0.05
6	2006	620	0.02	0.06	209	0.02	0.30	869	0.02	0.14	30	0.01	0.04
7	2006	583	0.03	0.05	201	-0.03	0.38	835	0.02	0.17	31	0.02	0.05
8	2006	495	0.00	0.07	261	-0.04	0.27	781	-0.01	0.16	31	-0.01	0.04
9	2006	191	0.01	0.06	162	0.00	0.35	381	0.00	0.21	20	0.00	0.08
10	2006	195	-0.01	0.09	194	-0.08	0.38	414	-0.04	0.22	26	-0.03	0.09
Total Period		7862	0.01	0.07	4983	0.01	0.36	13780	0.01	0.19	652	0.00	0.08

Table 6: Numerical values for bias and standard deviation for Roissy (Absolute Values in W/m^2).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	53	13.25	54.17	191	26.31	92.51	299	18.96	86.22	17	22.22	23.23
11	2004	48	-0.73	48.34	273	18.98	55.33	359	15.52	53.59	24	16.17	25.24
12	2004	62	-3.18	27.17	214	23.04	37.15	311	13.72	37.45	22	12.77	18.71
1	2005	107	-10.99	38.58	239	18.61	54.59	401	9.91	51.81	26	9.42	26.38
2	2005	71	-1.76	54.26	339	34.54	86.69	468	26.60	83.39	27	21.85	42.63
3	2005	75	-7.74	32.20	355	16.82	100.40	495	8.40	89.08	27	10.88	27.41
4	2005	136	5.31	46.75	398	30.96	156.07	616	22.93	131.07	26	19.28	35.00
5	2005	44	4.86	72.15	137	-34.24	191.28	214	-17.00	164.69	9	-20.44	23.88
6	2005	309	6.94	44.85	405	-19.98	147.99	776	-11.54	114.80	29	-12.80	32.44
7	2005	201	18.65	59.16	415	-15.17	161.05	677	-6.81	132.02	29	1.92	44.51
8	2005	323	3.77	49.42	436	-19.58	167.59	798	-10.54	128.84	31	-10.30	24.80
9	2005	239	23.56	38.72	326	10.27	101.68	614	11.90	80.24	28	12.15	19.87
10	2005	65	20.84	26.46	221	5.64	83.89	330	6.68	71.52	26	7.82	25.31
11	2005	97	7.67	19.87	309	13.80	54.03	441	10.55	46.95	29	9.97	14.51
12	2005	76	7.94	23.20	297	12.17	35.59	426	9.26	32.89	28	9.17	10.69
1	2006	133	7.21	22.51	269	7.10	37.63	438	5.64	32.82	28	6.11	14.70
2	2006	53	10.49	28.86	418	18.11	57.99	527	14.09	54.84	28	14.40	22.42
3	2006	137	16.63	43.18	405	10.84	90.44	611	7.55	78.58	29	6.46	29.44
4	2006	155	15.42	51.77	508	-1.93	114.94	711	-0.69	101.51	28	-0.93	24.01
5	2006	87	28.41	44.44	584	-6.89	130.97	777	-6.12	118.35	29	-4.78	33.05
6	2006	382	21.17	45.53	406	-12.89	138.33	847	1.65	102.42	29	2.35	29.32
7	2006	425	24.72	35.65	341	2.69	135.02	812	12.61	97.92	29	13.66	22.66
8	2006	99	38.24	87.08	579	-6.94	127.05	752	-4.29	120.70	30	-6.17	28.46
9	2006	100	21.26	61.00	223	-2.38	98.08	356	2.51	85.86	20	2.51	23.60
10	2006	72	13.95	45.99	318	2.76	70.78	439	1.59	64.63	28	2.19	23.20
Total Period		3549	13.84	46.87	8606	4.11	114.70	13495	4.59	97.43	656	6.00	28.37

Table 7: Numerical values for bias and standard deviation for Roissy (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	53	0.05	0.20	191	0.14	0.49	299	0.10	0.46	17	0.12	0.12
11	2004	48	-0.00	0.28	273	0.15	0.45	359	0.13	0.43	24	0.13	0.21
12	2004	62	-0.04	0.31	214	0.25	0.41	311	0.16	0.43	22	0.15	0.22
1	2005	107	-0.07	0.23	239	0.15	0.45	401	0.07	0.39	26	0.07	0.20
2	2005	71	-0.01	0.26	339	0.20	0.51	468	0.16	0.49	27	0.12	0.24
3	2005	75	-0.02	0.09	355	0.07	0.42	495	0.04	0.37	27	0.05	0.12
4	2005	136	0.01	0.12	398	0.10	0.48	616	0.07	0.41	26	0.06	0.12
5	2005	44	0.01	0.22	137	-0.11	0.62	214	-0.06	0.54	9	-0.07	0.09
6	2005	309	0.01	0.09	405	-0.05	0.41	776	-0.03	0.30	29	-0.03	0.08
7	2005	201	0.04	0.13	415	-0.06	0.59	677	-0.02	0.44	29	0.01	0.16
8	2005	323	0.01	0.12	436	-0.06	0.52	798	-0.03	0.38	31	-0.03	0.07
9	2005	239	0.06	0.10	326	0.04	0.41	614	0.04	0.29	28	0.04	0.07
10	2005	65	0.10	0.13	221	0.03	0.52	330	0.04	0.47	26	0.06	0.19
11	2005	97	0.05	0.13	309	0.11	0.43	441	0.09	0.39	29	0.08	0.12
12	2005	76	0.07	0.19	297	0.14	0.42	426	0.11	0.40	28	0.11	0.13
1	2006	133	0.04	0.12	269	0.07	0.35	438	0.05	0.26	28	0.05	0.12
2	2006	53	0.07	0.19	418	0.13	0.41	527	0.11	0.42	28	0.11	0.17
3	2006	137	0.05	0.13	405	0.05	0.42	611	0.03	0.36	29	0.03	0.13
4	2006	155	0.05	0.15	508	-0.01	0.38	711	-0.00	0.35	28	-0.00	0.08
5	2006	87	0.08	0.12	584	-0.02	0.43	777	-0.02	0.43	29	-0.02	0.12
6	2006	382	0.04	0.10	406	-0.04	0.38	847	0.00	0.26	29	0.01	0.08
7	2006	425	0.05	0.07	341	0.01	0.35	812	0.03	0.24	29	0.03	0.06
8	2006	99	0.12	0.28	579	-0.02	0.40	752	-0.01	0.42	30	-0.02	0.10
9	2006	100	0.07	0.19	223	-0.01	0.34	356	0.01	0.31	20	0.01	0.10
10	2006	72	0.05	0.17	318	0.02	0.46	439	0.01	0.41	28	0.01	0.14
Total Period		3549	0.04	0.13	8606	0.02	0.47	13495	0.02	0.38	656	0.03	0.12

Table 8: Numerical values for bias and standard deviation for Évora (Absolute Values in W/m²).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004												
11	2004												
12	2004												
1	2005												
2	2005												
3	2005												
4	2005	135	10.66	33.48	113	-13.83	140.31	252	-1.21	97.86	12	-1.95	19.84
5	2005	83	8.97	35.51	94	-0.74	114.49	193	-3.67	95.76	9	-2.99	14.96
6	2005	455	18.35	40.76	211	-52.46	120.75	688	-4.99	81.97	29	-4.84	17.71
7	2005	636	15.68	36.03	79	-50.46	143.16	725	8.08	61.47	31	8.33	16.87
8	2005	132	8.05	25.68	10	-59.67	107.36	146	1.37	42.07	6	1.28	15.79
9	2005	323	13.33	38.73	118	-50.38	95.86	452	-4.55	65.58	22	-3.37	15.60
10	2005	103	5.43	25.91	29	-10.34	65.98	141	1.25	37.66	8	-1.35	13.32
11	2005	231	4.94	23.66	144	3.69	71.78	397	3.96	47.96	24	4.93	17.34
12	2005	225	0.87	14.56	119	6.31	65.56	359	3.76	44.93	22	4.30	15.33
1	2006	272	2.66	20.32	185	22.85	68.33	477	9.71	46.74	28	9.08	19.00
2	2006	260	15.41	39.38	240	10.39	77.15	521	11.75	59.85	28	12.58	19.64
3	2006	175	18.34	42.39	357	12.39	107.27	585	9.46	89.81	30	8.94	22.32
4	2006	324	20.81	38.98	317	19.12	112.81	676	17.67	83.18	29	17.59	17.17
5	2006	387	22.59	37.46	269	-6.78	98.76	687	9.14	73.92	29	8.10	26.26
6	2006	232	26.61	53.63	128	-13.50	113.02	377	9.53	83.47	15	9.16	22.49
7	2006												
8	2006	200	27.26	36.02	44	19.26	66.92	247	25.48	45.57	11	27.32	24.04
9	2006												
10	2006												
Total Period		4173	15.05	36.84	2457	-3.15	104.71	6923	6.80	71.22	333	6.79	20.26

Table 9: Numerical values for bias and standard deviation for Évora (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004												
11	2004												
12	2004												
1	2005												
2	2005												
3	2005												
4	2005	135	0.02	0.06	113	-0.03	0.31	252	-0.00	0.20	12	-0.01	0.08
5	2005	83	0.02	0.07	94	-0.00	0.26	193	-0.01	0.22	9	-0.01	0.06
6	2005	455	0.03	0.07	211	-0.12	0.29	688	-0.01	0.16	29	-0.01	0.04
7	2005	636	0.03	0.06	79	-0.13	0.38	725	0.01	0.11	31	0.02	0.03
8	2005	132	0.01	0.05	10	-0.10	0.18	146	0.00	0.08	6	0.00	0.03
9	2005	323	0.03	0.08	118	-0.15	0.28	452	-0.01	0.15	22	-0.01	0.04
10	2005	103	0.01	0.05	29	-0.07	0.46	141	0.00	0.10	8	-0.00	0.04
11	2005	231	0.02	0.08	144	0.02	0.31	397	0.02	0.19	24	0.02	0.07
12	2005	225	0.00	0.05	119	0.04	0.37	359	0.02	0.19	22	0.02	0.07
1	2006	272	0.01	0.07	185	0.11	0.33	477	0.04	0.19	28	0.04	0.08
2	2006	260	0.04	0.11	240	0.04	0.27	521	0.04	0.20	28	0.04	0.07
3	2006	175	0.05	0.11	357	0.04	0.31	585	0.03	0.28	30	0.03	0.07
4	2006	324	0.04	0.08	317	0.05	0.31	676	0.04	0.20	29	0.04	0.04
5	2006	387	0.04	0.07	269	-0.01	0.20	687	0.02	0.15	29	0.02	0.05
6	2006	232	0.05	0.09	128	-0.04	0.33	377	0.02	0.18	15	0.02	0.05
7	2006												
8	2006	200	0.05	0.06	44	0.05	0.18	247	0.05	0.08	11	0.05	0.04
9	2006												
10	2006												
Total Period		4173	0.03	0.08	2457	-0.01	0.30	6923	0.02	0.17	333	0.02	0.06

Table 10: Numerical values for bias and standard deviation for Toravere (Absolute Values in W/m^2).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	69	-14.70	43.41	182	43.55	44.37	282	24.52	49.65	17	19.83	25.97
11	2004	88	18.88	61.21	187	14.55	38.22	315	13.60	45.47	24	11.14	23.36
12	2004	48	-20.35	27.12	148	-0.15	21.13	247	-5.32	22.43	22	-5.48	13.53
1	2005	23	-22.41	12.87	261	9.07	31.16	347	3.71	30.34	26	3.70	15.16
2	2005	114	-32.18	15.90	276	-4.95	40.81	430	-13.58	36.09	27	-12.70	22.92
3	2005	109	-35.50	20.07	347	-12.69	63.58	487	-18.02	55.74	27	-17.15	28.44
4	2005	234	-2.59	34.36	361	35.48	116.50	645	21.01	95.51	26	16.28	32.91
5	2005	6	-23.60	14.76	191	49.39	113.06	232	37.91	105.87	9	26.41	45.61
6	2005	318	3.45	52.61	507	-20.93	132.91	888	-12.17	106.09	30	-11.73	23.24
7	2005	375	6.06	56.76	469	-18.16	142.62	895	-8.04	110.47	31	-8.52	25.17
8	2005	264	20.01	70.33	535	-7.30	117.13	858	0.53	101.48	31	0.84	22.78
9	2005	210	-3.17	29.25	390	12.63	87.33	643	5.53	70.84	28	4.50	21.41
10	2005	166	-12.81	34.89	132	9.16	55.18	312	-2.92	45.37	26	-2.70	23.23
11	2005	59	-17.33	20.33	294	18.98	27.33	395	11.08	28.57	28	10.14	15.66
12	2005	35	-29.26	14.56	249	-6.95	21.47	344	-8.95	20.76	28	-7.33	13.58
1	2006	42	-20.28	24.26	290	-13.39	28.21	365	-13.86	26.67	28	-11.52	18.05
2	2006	73	-31.90	29.91	379	-5.81	40.60	485	-9.92	39.43	28	-10.19	21.71
3	2006	153	-17.57	30.34	387	-0.08	79.67	603	-5.05	67.94	29	-5.61	29.25
4	2006	232	18.67	54.14	530	36.67	94.14	805	29.93	83.24	29	28.76	36.00
5	2006	368	20.74	51.57	459	-8.13	130.48	872	3.08	101.87	29	3.21	30.92
6	2006	420	2.13	55.81	503	-11.21	121.93	996	-6.96	94.60	30	-5.75	22.03
7	2006	523	9.32	51.13	383	-17.21	134.73	952	-3.48	95.06	31	-4.10	18.64
8	2006	251	0.19	36.80	543	7.91	107.65	844	4.35	88.87	31	5.86	24.40
9	2006												
10	2006												
Total Period		4180	1.58	50.07	8003	2.26	99.38	13242	0.95	83.01	615	0.03	26.53

Table 11: Numerical values for bias and standard deviation for Toravere (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	69	-0.07	0.22	182	0.38	0.39	282	0.19	0.39	17	0.19	0.24
11	2004	88	0.16	0.50	187	0.22	0.58	315	0.18	0.60	24	0.18	0.38
12	2004	48	-0.44	0.59	148	-0.00	0.61	247	-0.16	0.69	22	-0.21	0.52
1	2005	23	-0.29	0.17	261	0.15	0.50	347	0.06	0.52	26	0.08	0.31
2	2005	114	-0.17	0.08	276	-0.05	0.39	430	-0.11	0.30	27	-0.12	0.21
3	2005	109	-0.10	0.06	347	-0.07	0.33	487	-0.08	0.26	27	-0.09	0.15
4	2005	234	-0.01	0.10	361	0.12	0.41	645	0.07	0.32	26	0.06	0.13
5	2005	6	-0.14	0.08	191	0.23	0.52	232	0.20	0.56	9	0.17	0.29
6	2005	318	0.01	0.14	507	-0.06	0.40	888	-0.04	0.33	30	-0.04	0.09
7	2005	375	0.02	0.15	469	-0.06	0.46	895	-0.02	0.34	31	-0.03	0.09
8	2005	264	0.06	0.20	535	-0.03	0.44	858	0.00	0.37	31	0.00	0.09
9	2005	210	-0.01	0.10	390	0.06	0.43	643	0.02	0.32	28	0.02	0.11
10	2005	166	-0.07	0.19	132	0.08	0.51	312	-0.02	0.31	26	-0.02	0.20
11	2005	59	-0.13	0.15	294	0.35	0.50	395	0.18	0.47	28	0.19	0.29
12	2005	35	-0.54	0.27	249	-0.24	0.75	344	-0.33	0.76	28	-0.31	0.58
1	2006	42	-0.29	0.35	290	-0.28	0.58	365	-0.30	0.57	28	-0.30	0.47
2	2006	73	-0.14	0.13	379	-0.06	0.41	485	-0.09	0.36	28	-0.10	0.22
3	2006	153	-0.05	0.08	387	-0.00	0.39	603	-0.02	0.29	29	-0.03	0.14
4	2006	232	0.05	0.15	530	0.14	0.36	805	0.11	0.30	29	0.11	0.14
5	2006	368	0.05	0.13	459	-0.03	0.43	872	0.01	0.31	29	0.01	0.10
6	2006	420	0.01	0.14	503	-0.04	0.39	996	-0.02	0.29	30	-0.02	0.07
7	2006	523	0.02	0.12	383	-0.05	0.38	952	-0.01	0.26	31	-0.01	0.05
8	2006	251	0.00	0.11	543	0.03	0.41	844	0.02	0.33	31	0.02	0.10
9	2006												
10	2006												
Total Period		4180	0.00	0.15	8003	0.01	0.46	13242	0.00	0.35	615	0.00	0.15

Table 12: Numerical values for bias and standard deviation for Payerne (Absolute Values in W/m^2).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	84	-3.62	58.68	175	30.57	80.08	306	16.85	72.25	17	19.84	31.94
11	2004	110	19.28	52.13	231	34.41	79.09	378	26.96	72.17	24	27.77	39.39
12	2004	47	5.92	50.39	212	18.91	81.19	308	26.04	83.17	22	27.41	63.16
1	2005	146	7.42	55.54	240	-3.87	89.69	423	0.81	76.56	26	0.11	54.71
2	2005	118	-5.66	44.54	310	-52.50	101.13	477	-38.50	87.96	27	-38.59	50.83
3	2005	187	-2.85	36.91	266	-5.66	108.84	499	-6.04	83.29	27	-6.65	38.98
4	2005	196	15.16	39.72	350	34.72	112.28	606	22.58	90.70	26	22.34	31.83
5	2005	44	6.74	20.52	129	-13.10	173.61	207	-17.21	141.99	9	-24.65	51.47
6	2005	405	19.99	72.43	318	-36.32	143.21	773	-6.67	110.28	29	-9.20	39.68
7	2005	348	15.74	57.66	384	-48.72	168.28	796	-21.67	130.28	31	-20.92	36.23
8	2005	305	11.90	54.19	405	-10.00	133.80	792	-4.51	103.92	31	-6.54	36.08
9	2005	270	27.11	48.32	315	-15.56	121.22	626	2.14	95.40	28	3.51	37.98
10	2005	136	14.00	56.74	172	3.91	94.57	333	7.22	77.56	26	10.56	40.72
11	2005	166	-8.72	30.38	249	9.69	68.46	451	0.85	55.66	28	1.44	31.85
12	2005	45	-28.48	44.74	357	-7.26	45.85	438	-9.86	44.93	28	-10.41	24.06
1	2006												
2	2006												
3	2006												
4	2006												
5	2006												
6	2006												
7	2006												
8	2006												
9	2006												
10	2006												
Total Period		2607	11.10	54.62	4113	-7.21	116.87	7413	-1.85	95.74	379	-0.66	44.09

Table 13: Numerical values for bias and standard deviation for Payerne (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	84	-0.01	0.18	175	0.18	0.46	306	0.09	0.37	17	0.10	0.16
11	2004	110	0.09	0.25	231	0.21	0.48	378	0.16	0.43	24	0.16	0.22
12	2004	47	0.06	0.47	212	0.18	0.75	308	0.23	0.72	22	0.23	0.54
1	2005	146	0.03	0.23	240	-0.03	0.68	423	0.01	0.48	26	0.00	0.34
2	2005	118	-0.02	0.13	310	-0.37	0.71	477	-0.22	0.50	27	-0.21	0.27
3	2005	187	-0.01	0.09	266	-0.02	0.48	499	-0.02	0.29	27	-0.02	0.14
4	2005	196	0.03	0.08	350	0.13	0.41	606	0.07	0.28	26	0.07	0.10
5	2005	44	0.01	0.04	129	-0.05	0.69	207	-0.06	0.53	9	-0.10	0.21
6	2005	405	0.04	0.13	318	-0.09	0.37	773	-0.01	0.25	29	-0.02	0.09
7	2005	348	0.03	0.12	384	-0.14	0.49	796	-0.06	0.35	31	-0.06	0.10
8	2005	305	0.03	0.12	405	-0.04	0.47	792	-0.01	0.32	31	-0.02	0.11
9	2005	270	0.06	0.11	315	-0.07	0.52	626	0.01	0.32	28	0.01	0.12
10	2005	136	0.06	0.23	172	0.02	0.46	333	0.03	0.37	26	0.06	0.23
11	2005	166	-0.04	0.14	249	0.07	0.46	451	0.01	0.34	28	0.01	0.20
12	2005	45	-0.21	0.33	357	-0.08	0.48	438	-0.11	0.49	28	-0.11	0.25
1	2006												
2	2006												
3	2006												
4	2006												
5	2006												
6	2006												
7	2006												
8	2006												
9	2006												
10	2006												
Total Period		2607	0.03	0.14	4113	-0.03	0.53	7413	-0.01	0.36	379	-0.00	0.18

Table 14: Numerical values for bias and standard deviation for Camborne (Absolute Values in W/m^2).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	117	31.08	73.93	155	38.44	85.24	300	32.28	79.01	18	29.79	27.69
11	2004	73	31.22	60.66	256	31.24	51.62	364	28.04	53.22	24	28.72	24.10
12	2004	71	4.21	31.68	199	16.27	39.93	307	11.47	37.44	22	11.52	14.36
1	2005	71	-2.18	46.27	288	27.87	50.12	402	19.98	50.27	26	18.56	22.92
2	2005	129	-7.72	43.29	295	22.85	65.60	467	13.23	61.98	27	13.53	25.61
3	2005	84	-12.08	35.94	368	18.56	103.97	500	11.24	92.11	27	7.28	41.54
4	2005	91	2.60	67.14	375	21.47	147.57	560	13.45	130.60	23	10.91	51.31
5	2005	44	31.85	101.01	152	16.86	124.13	216	20.45	119.30	9	10.69	61.93
6	2005	291	9.45	55.61	433	-37.91	142.25	809	-20.62	112.48	29	-20.55	35.73
7	2005	239	20.98	60.51	517	-11.43	125.82	831	-4.31	106.45	31	-3.53	40.17
8	2005	347	6.85	60.07	425	-23.44	142.00	820	-10.38	110.54	31	-10.24	42.92
9	2005	224	7.75	53.94	365	-3.19	105.57	631	-1.33	87.52	28	-2.11	25.21
10	2005	111	7.02	39.64	180	5.95	72.68	328	3.96	59.40	24	2.49	25.14
11	2005	98	-9.68	30.97	307	-4.40	50.08	450	-6.10	44.41	29	-5.84	21.84
12	2005	83	-2.16	32.81	204	-5.79	41.68	326	-4.48	37.40	22	-4.79	17.47
1	2006	98	-6.86	46.67	166	0.08	45.68	282	-2.96	44.67	17	-2.37	20.66
2	2006	80	3.63	59.63	403	6.49	65.72	528	3.47	64.40	28	3.38	22.82
3	2006	88	-3.19	47.47	467	-3.53	78.30	629	-6.32	70.90	30	-4.90	28.38
4	2006	301	6.84	58.33	421	-20.12	111.92	770	-10.77	92.14	29	-11.16	28.67
5	2006	243	41.65	102.96	462	-9.75	128.31	816	0.64	116.69	29	1.43	52.12
6	2006	517	4.84	50.99	316	-39.82	122.18	900	-14.37	86.53	30	-14.07	24.56
7	2006	398	19.91	84.79	399	-31.05	134.98	879	-9.09	112.54	31	-10.24	50.75
8	2006	284	39.17	106.12	453	-0.19	130.75	807	10.13	122.35	31	7.22	44.01
9	2006	133	44.64	110.64	225	-18.41	96.83	399	0.86	102.19	21	-1.61	35.42
10	2006												
Total Period		4215	13.34	69.91	7831	-3.41	108.98	13321	-0.04	94.75	616	1.05	36.00

Table 15: Numerical values for bias and standard deviation for Camborne (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	117	0.12	0.29	155	0.24	0.54	300	0.18	0.43	18	0.18	0.17
11	2004	73	0.20	0.38	256	0.26	0.44	364	0.24	0.45	24	0.26	0.22
12	2004	71	0.04	0.32	199	0.21	0.50	307	0.15	0.48	22	0.16	0.20
1	2005	71	-0.01	0.31	288	0.25	0.44	402	0.18	0.45	26	0.18	0.23
2	2005	129	-0.03	0.19	295	0.13	0.38	467	0.07	0.34	27	0.08	0.15
3	2005	84	-0.04	0.13	368	0.09	0.48	500	0.05	0.44	27	0.04	0.21
4	2005	91	0.01	0.24	375	0.07	0.47	560	0.05	0.47	23	0.04	0.20
5	2005	44	0.09	0.28	152	0.06	0.41	216	0.07	0.40	9	0.04	0.24
6	2005	291	0.02	0.12	433	-0.12	0.45	809	-0.06	0.33	29	-0.06	0.11
7	2005	239	0.05	0.16	517	-0.04	0.43	831	-0.01	0.37	31	-0.01	0.14
8	2005	347	0.02	0.14	425	-0.07	0.42	820	-0.03	0.31	31	-0.03	0.12
9	2005	224	0.02	0.15	365	-0.01	0.48	631	-0.01	0.34	28	-0.01	0.10
10	2005	111	0.03	0.17	180	0.04	0.47	328	0.02	0.36	24	0.02	0.19
11	2005	98	-0.07	0.22	307	-0.03	0.39	450	-0.05	0.37	29	-0.05	0.20
12	2005	83	-0.02	0.31	204	-0.08	0.58	326	-0.06	0.52	22	-0.07	0.24
1	2006	98	-0.05	0.31	166	0.00	0.43	282	-0.03	0.39	17	-0.02	0.19
2	2006	80	0.02	0.38	403	0.04	0.44	528	0.03	0.47	28	0.03	0.17
3	2006	88	-0.01	0.19	467	-0.02	0.41	629	-0.04	0.40	30	-0.03	0.17
4	2006	301	0.02	0.14	421	-0.07	0.41	770	-0.03	0.30	29	-0.04	0.10
5	2006	243	0.09	0.23	462	-0.03	0.44	816	0.00	0.39	29	0.00	0.18
6	2006	517	0.01	0.10	316	-0.12	0.37	900	-0.04	0.22	30	-0.04	0.07
7	2006	398	0.04	0.18	399	-0.11	0.46	879	-0.03	0.32	31	-0.03	0.16
8	2006	284	0.09	0.24	453	-0.00	0.42	807	0.03	0.36	31	0.02	0.13
9	2006	133	0.11	0.28	225	-0.07	0.37	399	0.00	0.37	21	-0.01	0.14
10	2006												
Total Period		4215	0.04	0.19	7831	-0.01	0.47	13321	-0.00	0.37	616	0.00	0.16

Table 16: Numerical values for bias and standard deviation for all European sites (Absolute Values in W/m^2).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	373	9.35	63.65	913	35.09	80.10	1496	23.17	75.91	86	23.50	28.64
11	2004	520	7.95	49.68	1092	23.81	59.31	1799	16.99	56.68	120	16.80	28.66
12	2004	420	-10.33	29.92	877	18.27	53.08	1505	9.60	50.91	110	9.35	34.74
1	2005	614	-8.49	37.99	1153	13.05	60.70	2009	5.31	53.79	130	5.12	31.84
2	2005	684	-13.38	36.50	1400	-0.26	85.59	2305	-4.72	72.40	134	-4.66	43.45
3	2005	776	-9.95	33.10	1481	7.27	98.21	2481	0.59	80.68	135	0.17	34.73
4	2005	1112	7.19	38.65	1822	28.96	137.00	3285	18.25	108.53	139	15.11	38.04
5	2005	341	9.53	53.44	770	4.86	145.23	1270	3.11	122.34	54	-3.16	41.75
6	2005	2275	16.38	51.19	2104	-26.79	135.62	4710	-6.12	101.11	175	-6.70	31.88
7	2005	2396	15.43	47.46	2027	-22.18	147.53	4711	-3.82	105.54	184	-1.96	33.40
8	2005	1841	10.69	51.52	2096	-10.88	140.16	4206	-2.58	106.05	161	-3.03	31.69
9	2005	1607	14.73	42.46	1754	-1.20	108.70	3591	4.22	82.56	162	4.36	27.13
10	2005	710	3.24	38.84	905	6.30	80.66	1781	3.42	64.25	136	2.51	29.15
11	2005	886	-4.33	25.14	1511	9.55	56.05	2598	3.32	46.34	166	3.50	21.15
12	2005	740	-8.81	28.03	1375	-1.50	45.10	2349	-4.07	39.70	156	-4.01	18.21
1	2006	773	-5.31	27.45	1120	5.79	47.82	2034	0.40	40.04	129	0.44	20.66
2	2006	706	-0.49	38.87	1676	4.41	63.04	2565	1.63	56.13	137	1.70	24.21
3	2006	750	1.49	43.99	1943	1.62	88.97	3006	-1.14	76.58	145	-1.01	27.16
4	2006	1504	9.59	45.14	1993	7.67	110.59	3715	6.52	87.43	144	6.06	29.62
5	2006	1438	20.18	58.99	2093	-9.09	123.05	3871	-0.43	100.84	143	0.42	34.91
6	2006	2171	11.13	48.17	1562	-15.15	125.29	3989	-2.01	88.55	134	-1.50	25.35
7	2006	1929	17.16	52.67	1324	-15.28	136.57	3478	1.49	97.88	122	1.57	32.89
8	2006	1329	15.72	64.90	1880	-1.59	119.53	3431	3.17	100.23	134	2.75	30.76
9	2006	424	21.68	72.64	610	-7.48	101.91	1136	1.34	89.17	61	0.37	28.99
10	2006	267	2.43	36.87	512	-4.32	73.90	853	-4.29	62.16	54	-2.97	23.24
Total Period		26586	8.65	48.25	35993	0.21	108.41	68174	2.02	86.50	3251	2.26	31.06

Table 17: Numerical values for bias and standard deviation for all European sites (Relative Values).

Month:	Year	Clear			Cloudy			All			Daily Averages		
		N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev	N	Bias	Stdev
10	2004	373	0.04	0.24	913	0.21	0.47	1496	0.13	0.43	86	0.14	0.17
11	2004	520	0.04	0.24	1092	0.19	0.46	1799	0.12	0.39	120	0.12	0.20
12	2004	420	-0.07	0.21	877	0.21	0.62	1505	0.10	0.50	110	0.10	0.37
1	2005	614	-0.04	0.18	1153	0.12	0.54	2009	0.04	0.38	130	0.04	0.24
2	2005	684	-0.05	0.13	1400	-0.00	0.53	2305	-0.03	0.39	134	-0.02	0.23
3	2005	776	-0.03	0.09	1481	0.03	0.43	2481	0.00	0.30	135	0.00	0.14
4	2005	1112	0.02	0.09	1822	0.09	0.43	3285	0.05	0.32	139	0.05	0.13
5	2005	341	0.02	0.11	770	0.02	0.49	1270	0.01	0.38	54	-0.01	0.16
6	2005	2275	0.03	0.10	2104	-0.07	0.37	4710	-0.01	0.24	175	-0.02	0.08
7	2005	2396	0.03	0.10	2027	-0.07	0.48	4711	-0.01	0.28	184	-0.01	0.09
8	2005	1841	0.02	0.11	2096	-0.04	0.45	4206	-0.01	0.30	161	-0.01	0.09
9	2005	1607	0.04	0.10	1754	-0.00	0.45	3591	0.01	0.28	162	0.01	0.09
10	2005	710	0.01	0.14	905	0.04	0.47	1781	0.02	0.32	136	0.02	0.18
11	2005	886	-0.02	0.11	1511	0.07	0.42	2598	0.02	0.30	166	0.02	0.15
12	2005	740	-0.04	0.14	1375	-0.02	0.51	2349	-0.04	0.34	156	-0.04	0.17
1	2006	773	-0.02	0.12	1120	0.05	0.43	2034	0.00	0.27	129	0.00	0.15
2	2006	706	-0.00	0.13	1676	0.03	0.38	2565	0.01	0.30	137	0.01	0.13
3	2006	750	0.00	0.12	1943	0.01	0.37	3006	-0.00	0.31	145	-0.00	0.11
4	2006	1504	0.02	0.10	1993	0.03	0.37	3715	0.02	0.25	144	0.02	0.09
5	2006	1438	0.04	0.12	2093	-0.03	0.36	3871	-0.00	0.27	143	0.00	0.10
6	2006	2171	0.02	0.10	1562	-0.04	0.37	3989	-0.00	0.22	134	-0.00	0.06
7	2006	1929	0.04	0.11	1324	-0.04	0.39	3478	0.00	0.24	122	0.00	0.08
8	2006	1329	0.03	0.14	1880	-0.01	0.38	3431	0.01	0.28	134	0.01	0.09
9	2006	424	0.05	0.18	610	-0.03	0.35	1136	0.00	0.29	61	0.00	0.11
10	2006	267	0.01	0.11	512	-0.03	0.43	853	-0.02	0.30	54	-0.01	0.11
Total Period		26586	0.02	0.12	35993	0.00	0.44	68174	0.01	0.30	3251	0.01	0.12

1.2.4 Time Series of Statistics (African Sites)

Figure 14, respectively, show the time series of the validation statistics for Agoufou and Banizoumbou. The graphs contain data points for the period for which both the satellite product as well as the in-situ data was available. The results have not yet been analysed in detail, but in general the performance seems to be not as good as for the European sites. In particular, there is evidence for a positive bias in clear sky situations.

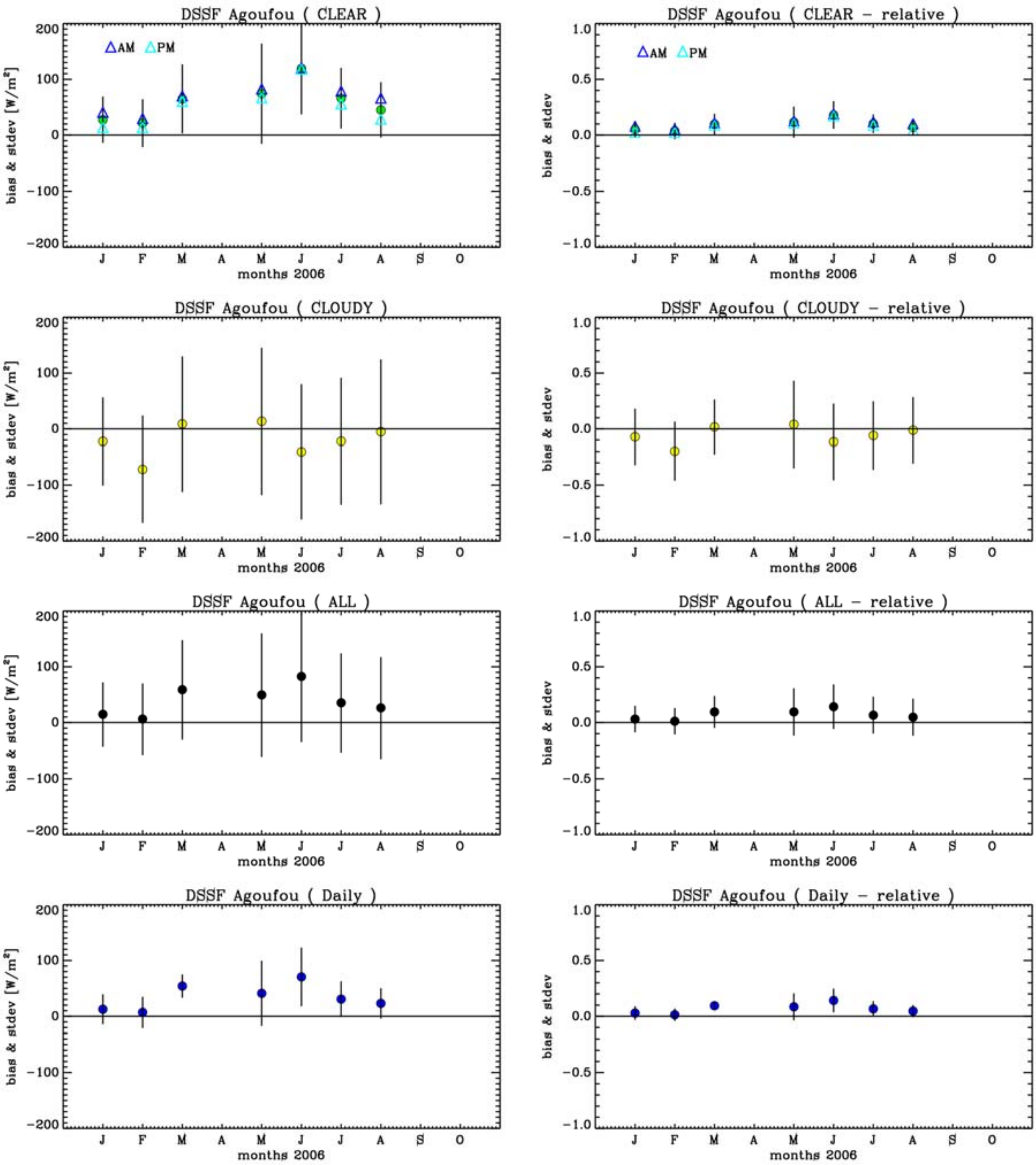


Figure 13: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Agoufou.

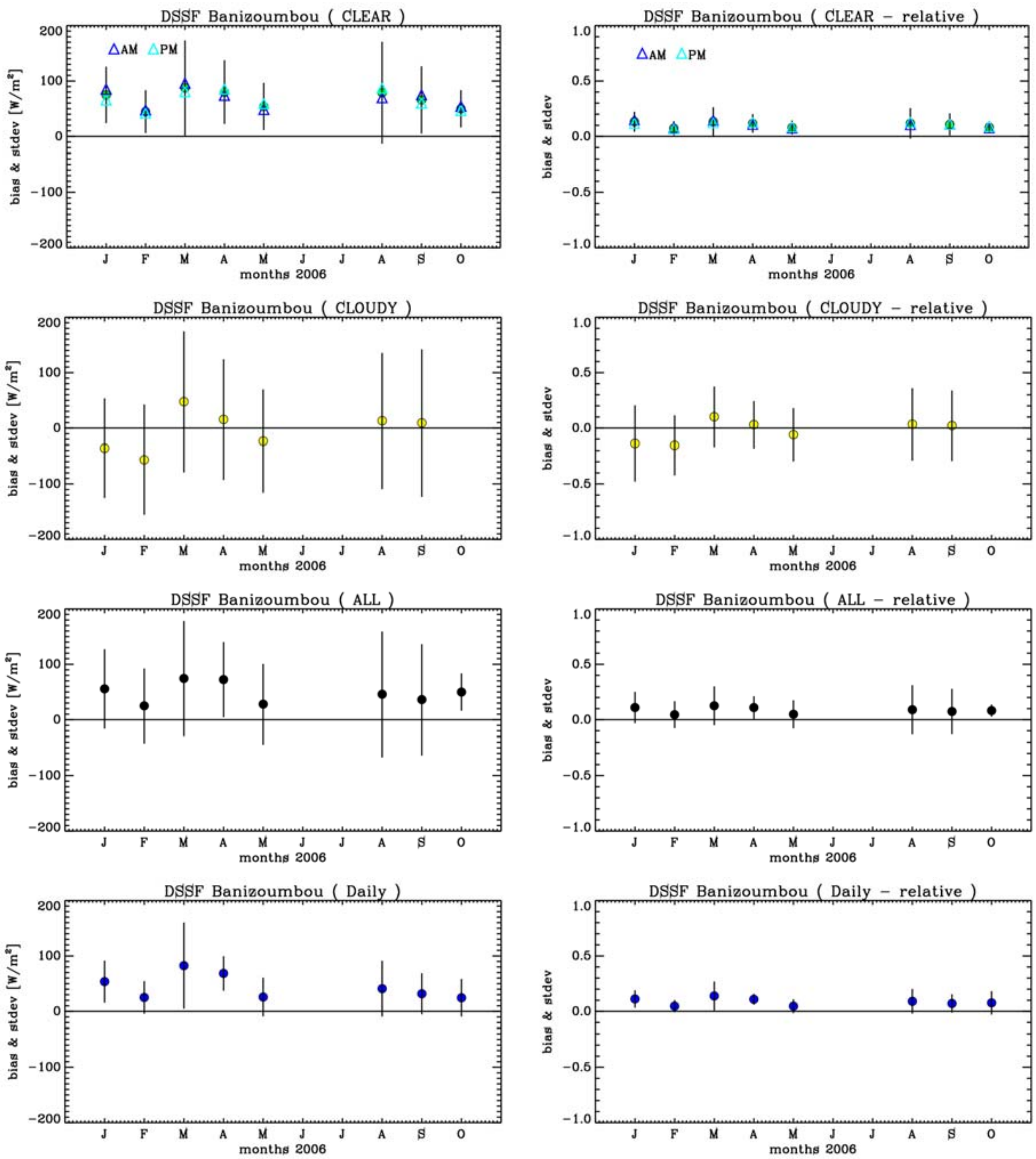


Figure 14: Temporal evolution of bias and standard deviation between the Land-SAF DSSF estimates and ground measurements for Banizoumbou.

1.3 Dependence on Other Physical Variables

1.3.1 Aerosols

For the locations of Carpentras, Évora, Agoufou, and Banizoumbou measurements of the aerosol optical thickness at various wavelengths are provided by the Aeronet initiative. Some examples are shown in the plots of Figure 2 along with the satellite estimates and the ground measurements of the down-welling radiation.

In the presently applied method for retrieving DSSF, the effects of aerosols are included in terms of a simple parameterisation as a function of the visibility (whose value was fixed at 20 km). Aerosols contribute to the reduction of the direct radiation and enhance the amount of diffuse radiation. The effects partly cancel in the total down-welling radiation.

The satisfactory results obtained in the Évora example cases shown in Figure 2 for rather different aerosol concentrations support the validity of the approach. However, for the Agoufou example case (4 August 2005) shown in Figure 2 with even higher aerosol optical thickness values there is a significant underestimation of DSSF. A quantitative analysis taking into account the aerosol information has not yet been carried out.

For a later version of the DSSF algorithm it is planned to parameterise the direct and diffuse contributions separately as a function of the aerosol optical thickness to be read from the same input files as for the atmospheric correction code in the albedo product chain. Replacing the aerosol optical depth (AOD) climatology by AOD product issue from MACC/GEMS would then be beneficial for the albedo and short-wave radiation products at the same time.

1.3.2 Surface Albedo

The down-welling radiation depends on the surface albedo via multiple scattering between the ground and the atmosphere, which is already taken into account in the parameterisations employed for deriving the DSSF estimates. At the beginning a constant albedo value of 0.15 (for land) was used. Since the Land-SAF albedo product is now sufficiently mature, the constant value was replaced by the total short-wave broadband albedo estimate in version 1.11 of the DSSF algorithm, which was implemented in the operational system on 20 February 2006.

Significant differences in the derived estimates are only expected for snow-covered surfaces which exhibit rather large albedo values. For the example case of Toravere on 22 March 2005 shown in Figure 2 there is a significant underestimation of the down-welling radiation. The ground measurements of albedo provided by BSRN for that day depicted in Figure 15 show that the surface was snow covered. A correct specification of surface albedo would have led to DSSF estimates, which are almost as high as the in-situ measurements.

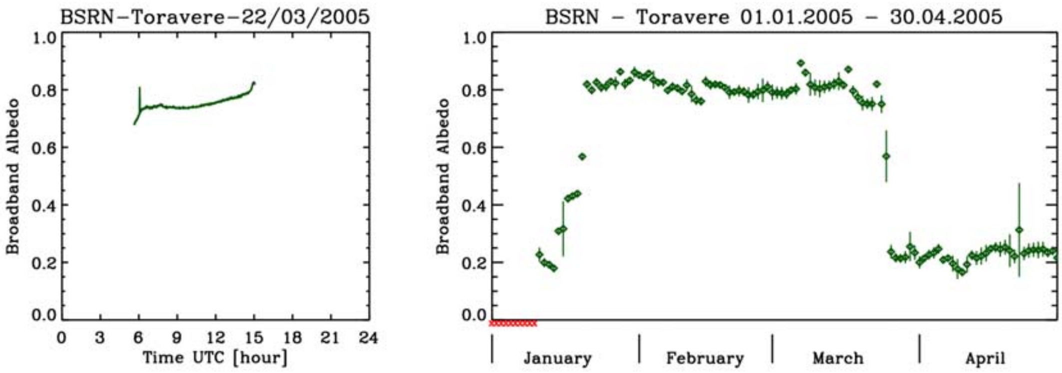


Figure 15: Albedo measurements provided by the BSRN station at Toravere. The plot on the right shows the daily averaged albedo values.

The daily averaged BSRN albedo time series in Figure 15 indicates that snow was present at Toravere from the middle of January to the end of March 2005. This is consistent with the DSSF underestimation, which can be observed in the top left plot of Figure 9 for clear sky situations.

1.4 Comparison with ground measurements and ECMWF analysis

Comparing the product with ground measurements of the down-welling radiation flux has performed validation studies. The presented results are based on the Baseline Surface Radiation Network (BSRN) stations of Carpentras (France) and Toravere (Estonia) for which data concomitant with the product time series were already available. In addition, the in-situ data from ground stations run by the LSA SAF project in Évora (Portugal) and by Météo-France in Roissy (France) have been used. Note that during the validation period from October 2004 to August 2006 successive algorithm versions were running in the operational system.

1.4.1 Diurnal cycle

In general a good agreement between the satellite estimates and the in-situ data can be observed when comparing the daily time series. A few examples are shown in Figure 16. The cases for Carpentras and Évora presented in the figure are typical for clear sky situations. For cloudy sky conditions the day chosen for Toravere represents a favourable example. In the unfavourable case depicted for Roissy with a rather large dispersion, the discrepancies cannot entirely be attributed to deficiencies of the retrieval method. The example also illustrates the limitation of the validation approach when the conditions are highly variable in space and time. At least part of the dispersion is a consequence of comparing a local measurement with an estimate for a rather extended image pixel.

For a quantitative analysis, the exact acquisition times of the satellite measurements need to be taken into account. For the ground stations of Carpentras and Toravere the in-situ data were available with a high temporal resolution in the order of minutes. In this case the in-situ data were averaged over intervals of 15 minutes centred on the exact acquisition times of the respective satellite measurements as a function of the site coordinates. For the other sites the accessible data had already been averaged over certain time intervals. In this case the data points were linearly interpolated and re-sampled corresponding to the exact reference times of the satellite product.

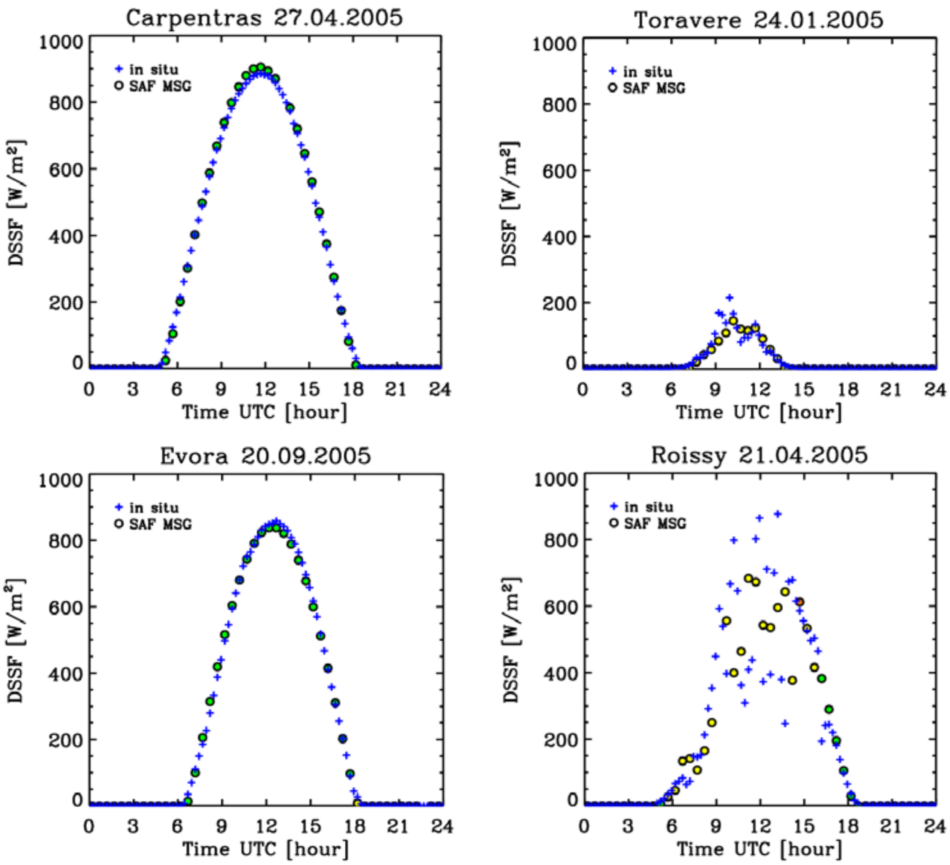


Figure 16: Examples for daily time series of MDSSF estimates and in-situ measurements at the ground validation stations. The colour code of the dots is the same as for the quality flag in Figure 2.

1.5 Scatter Plots

Figure 17 depicts scatter plots of the LSA SAF estimates against the in-situ measurements for the whole validation period. The top left plot includes all data points for Carpentras for which the clear sky method was applied and the top right plot all “cloudy” data points for Roissy. As expected, the dispersion of the distribution is much smaller for the “clear” than for the “cloudy” data points. The biases are relatively small in both cases and there is no significant evidence for a dependence of the bias on the level of the MDSSF estimate. A few outliers can be perceived in the scatter plot for clear sky. However, their number is quite small compared to the large amount of data points included in the graph. The outliers may be caused by small clouds obstructing direct solar radiation and not detectable at the pixel scale.

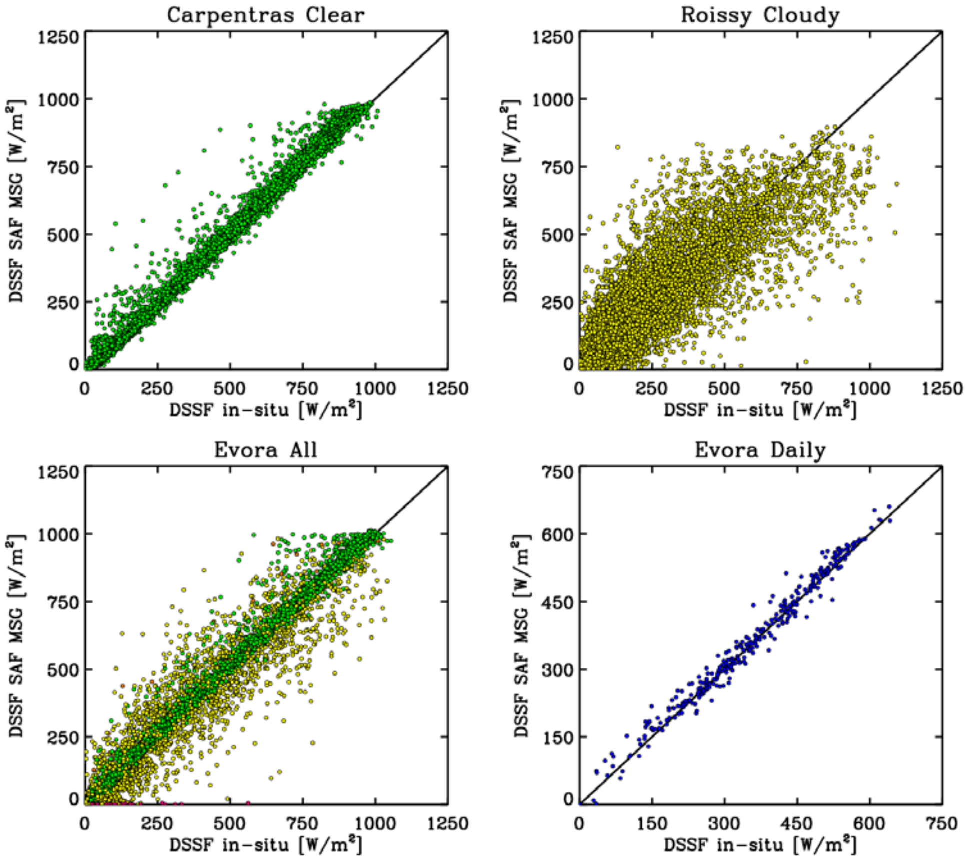


Figure 17: Scatter plots between the satellite estimates and the ground measurements. The colour code of the dots is the same as for the quality flag in the previous figures. The bottom right plot shows the daily averaged estimates as explained in the text. (Note that the shown range of values is different in this case.)

The bottom left plot of Figure 17 includes all available data points for the site of Évora. For validation purposes we also calculated daily averages of the LSA SAF MDSSF product for the pixels corresponding to the validation sites. The resulting data points for Evora are depicted in the bottom right plot of the figure. As expected the dispersion is much smaller than for the instantaneous radiation estimates. This is helpful for comparing the quantitative validation statistics to those of other products, which are not available as instantaneous estimates. The daily values are determined by averaging all available (day-time) LSA SAF MDSSF estimates for a given day. For the sake of comparison only, the in-situ measurements corresponding to the product time slots actually used for the determination of a "daily DSSF product" are then also averaged to obtain the corresponding "daily averaged in-situ measurement". Note that this prescription should be perceived as a proxy and is only useful for present validation purposes, but not appropriate for generating a daily averaged DSSF (DIDSSF). For this purpose the problems of temporal reference for the average and the treatment of missing data would have to be considered much more carefully as it would be further detailed in next Chapter 3.

1.6 Validation Statistics

For quantifying the validation results, the bias – defined as the average of the difference between the LSA SAF estimate and the in-situ measurement – as well as the standard deviation of that difference are considered. The temporal evolution of these statistical quantities for all four stations combined over the whole validation period is shown in Figure 18. The position of the symbols in the graphs indicates the bias, and the length of the bars (from the centre to each end) corresponds to the standard deviation as defined above. Monthly sub-samples of the validation data points are considered in order to illustrate a possible temporal evolution of the product quality. From the top left to the bottom right the panels show the results for the data points processed with the clear sky method, for the cloudy sky method, for all processed day-time data points combined irrespective of the method applied, and for the daily averaged DSSF values which were calculated for validation purposes only as described above. The top left plot for clear sky also includes the bias values (but not the standard deviation) for morning and afternoon data points separately.
Considering the whole validation period and all sites the standard deviation of the instantaneous validation data points is in the order of 40 Wm^{-2} for clear sky and 110 Wm^{-2} for cloudy sky. Combining all (instantaneous) data points the standard deviation amounts to roughly 85 Wm^{-2}. It reduces to 30 Wm^{-2} for the daily averaged values. Taking into account the whole validation data set there is a small positive bias of about 5 Wm^{-2}. However, a slight seasonal trend can be perceived especially for the clear sky case. The standard deviation of the monthly bias values depicted in Figure 18 is about 10 Wm^{-2} to 15 Wm^{-2} for the clear and cloudy cases and in the order of 5 Wm^{-2} for the quantities referring to all data points and the daily average.

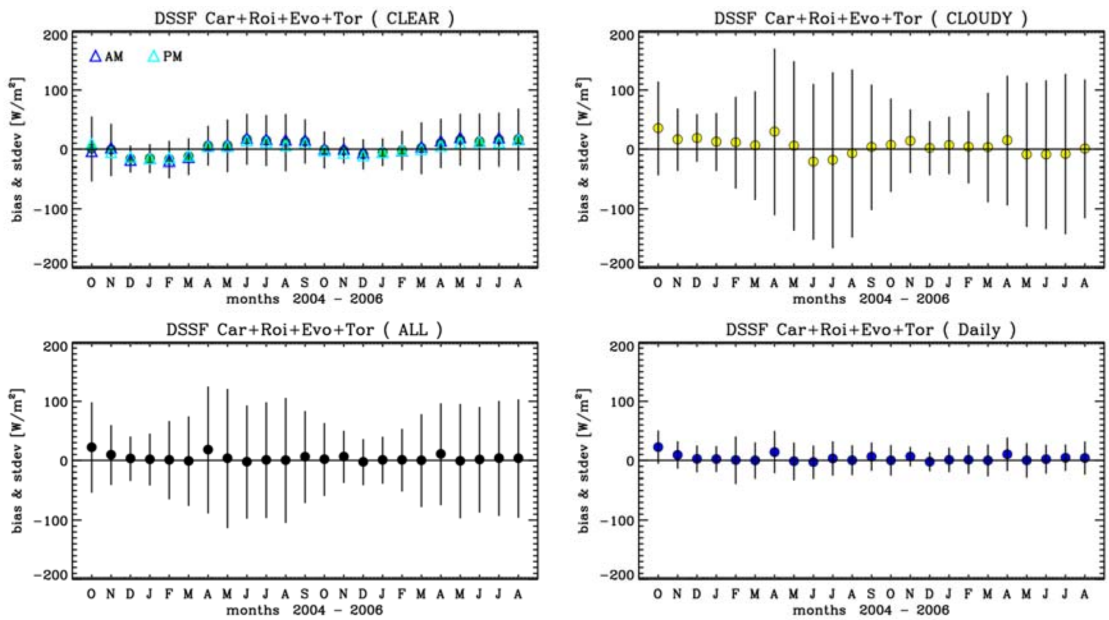


Figure 18: Temporal evolution of bias and standard deviation between the LSA SAF estimates and ground measurements for all validation sites combined (Carpentras, Roissy, Évora, and Toravere) for the period from October 2004 to August 2006.

Daily DSSF (DIDSSF) evaluation

We estimate the daily synthesis (time integrated) (0 - 23:30 UTC) of DSSF values (J / m^2 a scaling factor of 10) as the sum of [0.5*(DSSF_t1 + DSSF_t2)*(t2-t1)], for all pairs of times (t1,t2) with valid data. Hitherto, one on two slots is taken, that is the time sampling is 30 min. The product name is DIDSSF and dimension is normally in J/kg/m². For sake of clear understanding and to be compliant with the unity of the users specification (indicated in W/m²), we divided original field by 86400s (24h*3600s).

3.1 Comparison with ECMWF analysis

Results of comparison appear in the next set of Figures 19-23 between DIDSSF and similar product issued from ECMWF (so-called SSRD) at 0.25° over France. ECMWF model runs at 00:00UTC for a forecast after at 24:00UTC. This later quantity offers a direct mean of comparison with DIDSSF. Results for summer 2009 were preferably investigated because of the large amount of solar radiation obtained during that period of the year.

First important information from all figures is that same geographical patterns and magnitude are observed between DIDSSF and SSRD fields. Besides, most frequent scenario is that ECMWF overestimates slightly daily-integrated radiation in average between 20 and 30 W/m². On the other hand, maximum values are observed for DIDSSF, which tends to indicate the occurrence of clouds to be in excess for ECMWF. This seems to be confirmed by a different spatial distribution of the daily-integrated radiation. Nevertheless, these conclusions - observed bias and spatial discrepancy - seem to vanish somewhat for the studied situations in August and September (see Figure 23). The bias between DIDSSF and SSRD is more evidenced in reporting time series for 2009 in average for France (see Figure 24, top). Best results (correlation, standard deviation) are observed during summer and fall periods. Also is shown the low number of missing (daytime) slots corresponding to the fraction of daytime missing slots over the total number of daytime slots. From it, it is difficult to say that more data would question the present conclusions.

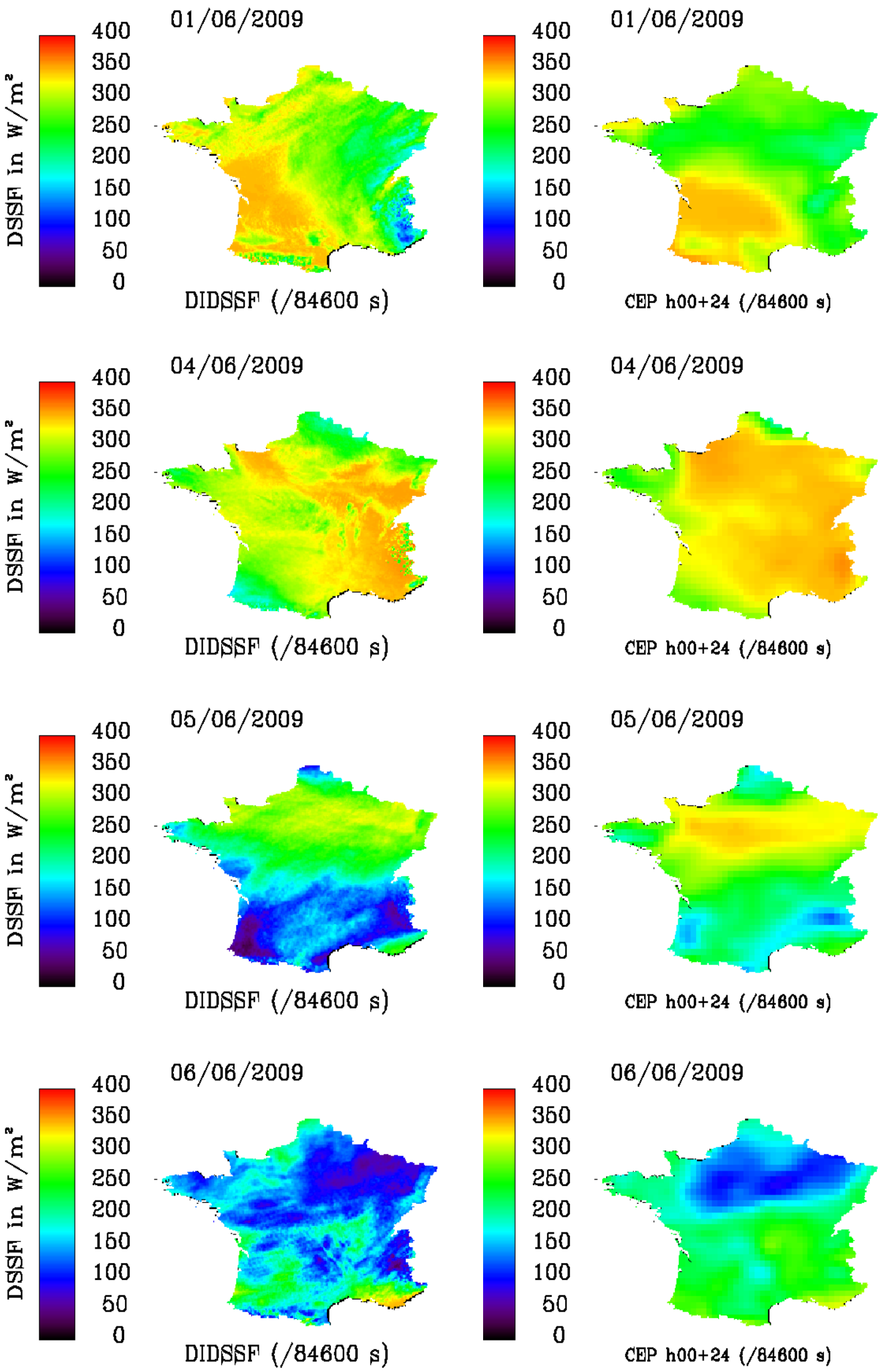


Figure 19: Comparison between daily cumulative DSSF (DIDSSF) (left) and ECMWF forecast product (SSRD) over France at different dates during June 2009.

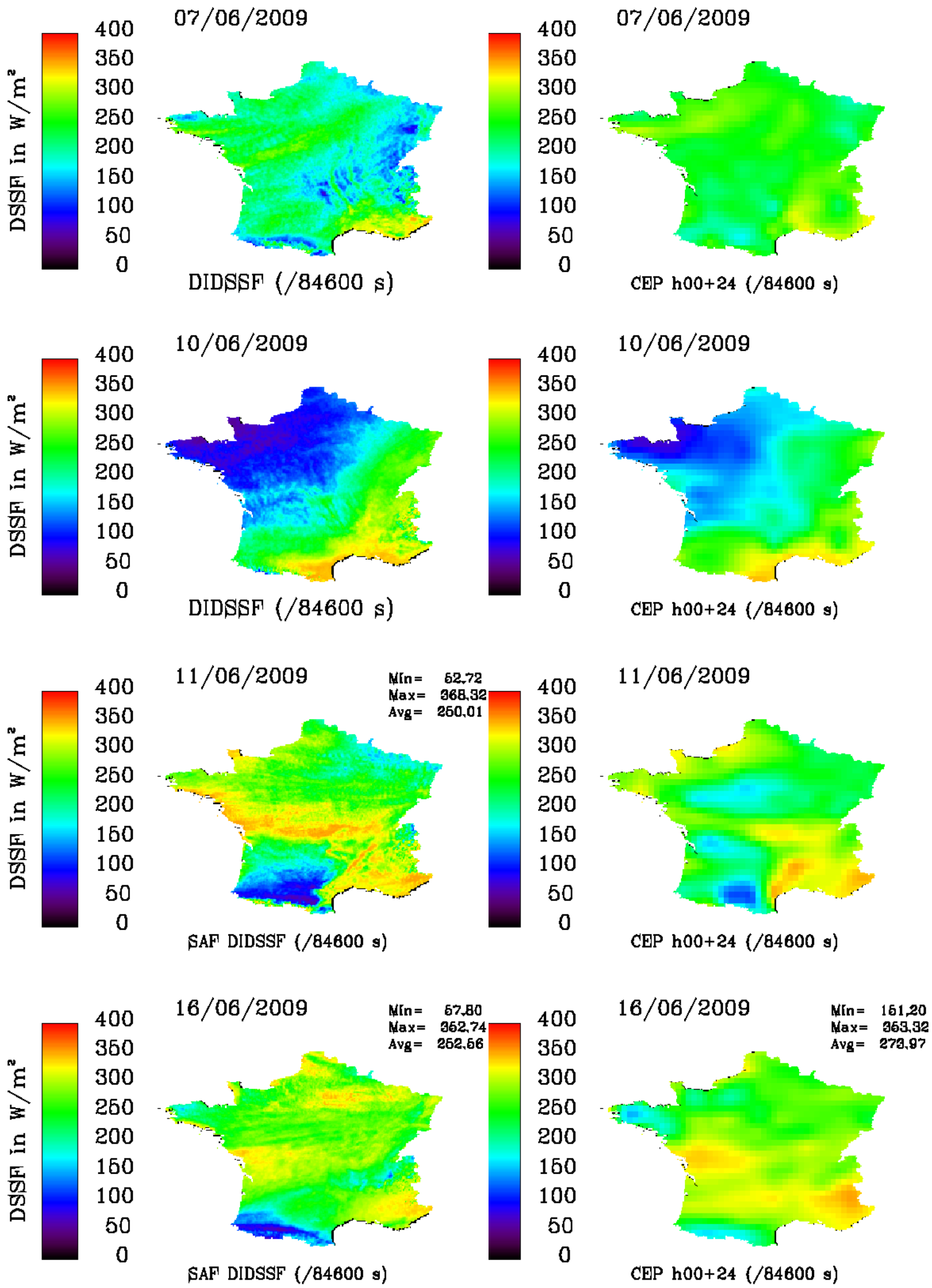


Figure 20: Same as figure 19.

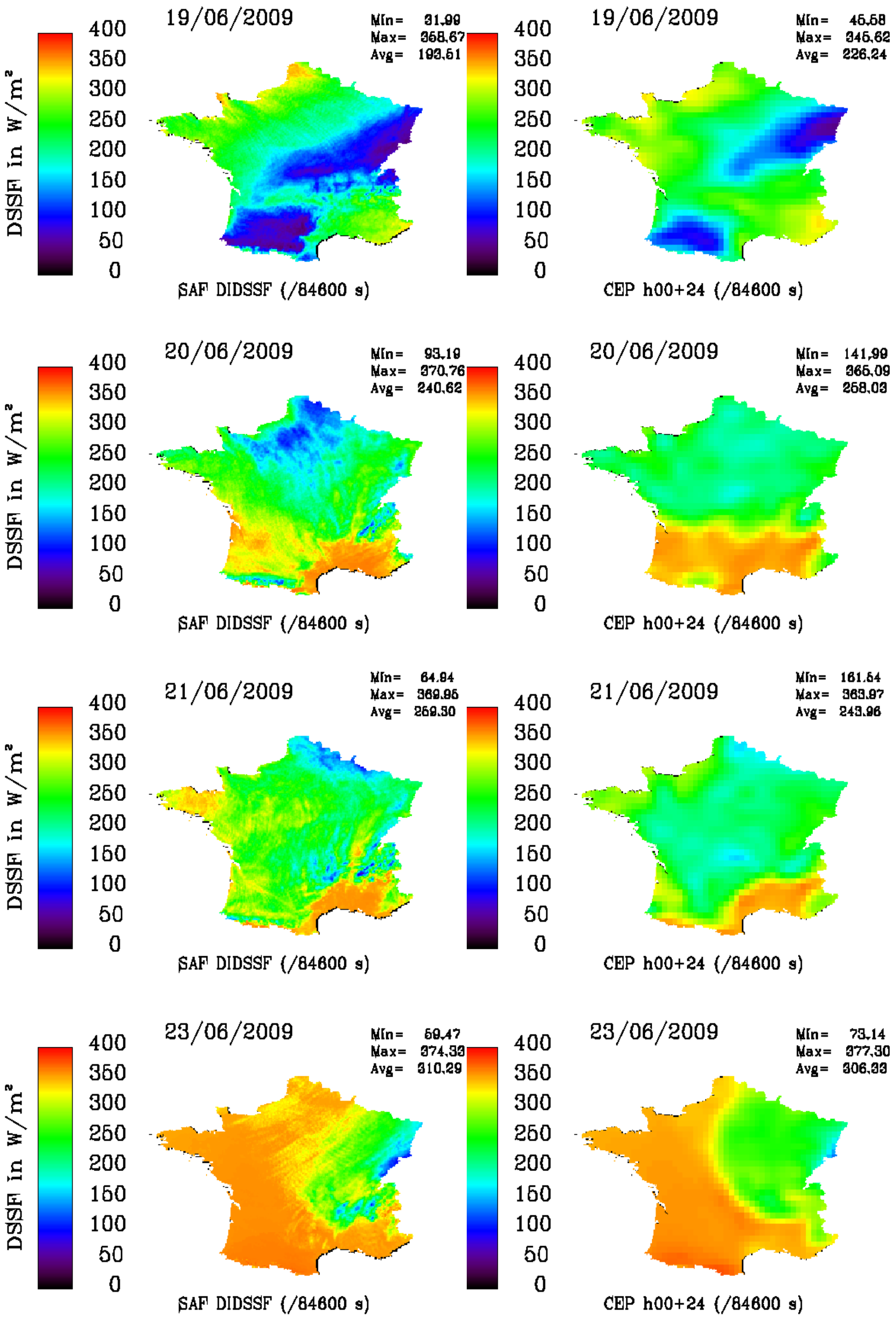


Figure 21: Same as figure 19.

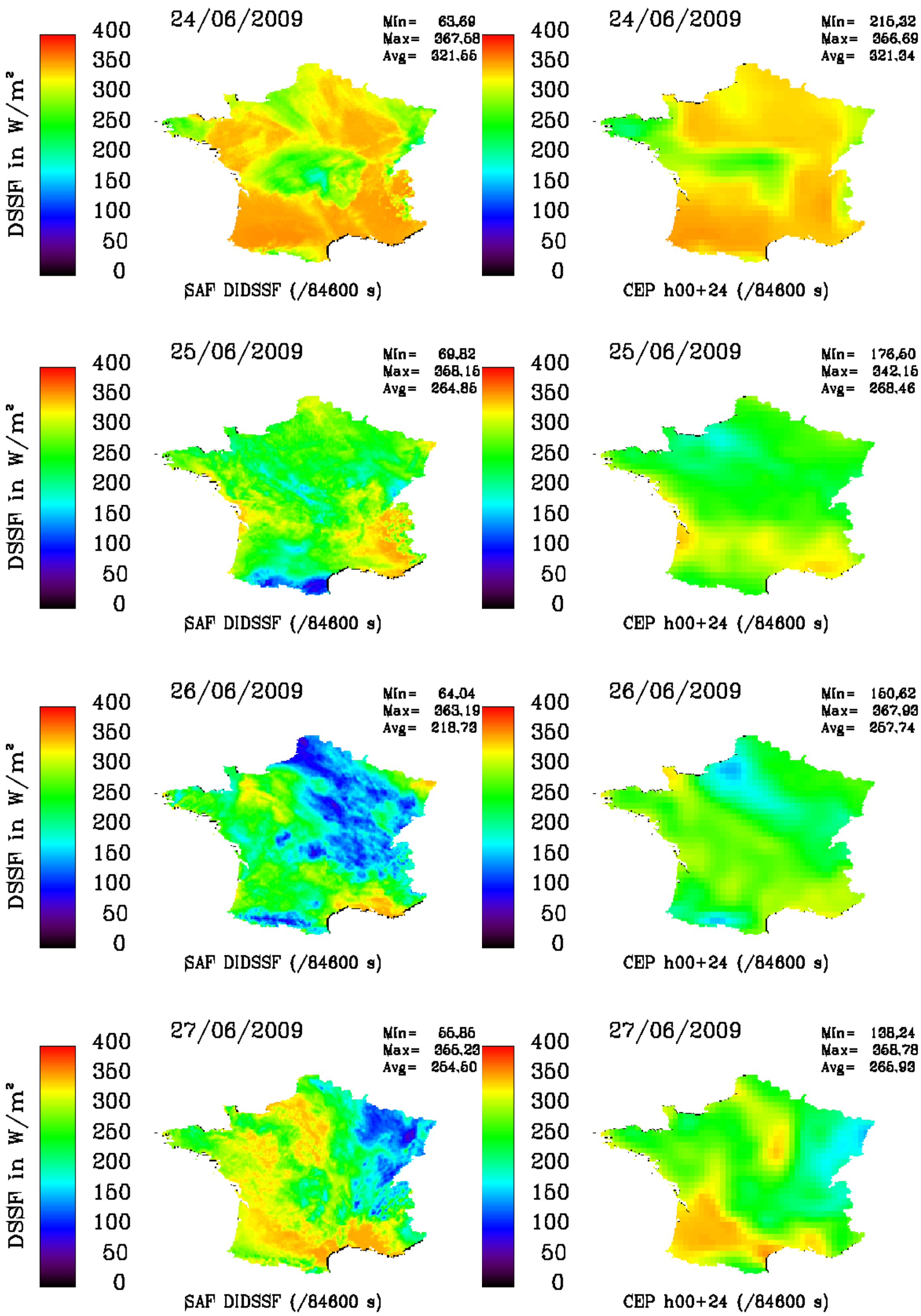


Figure 22: Same as figure 19.

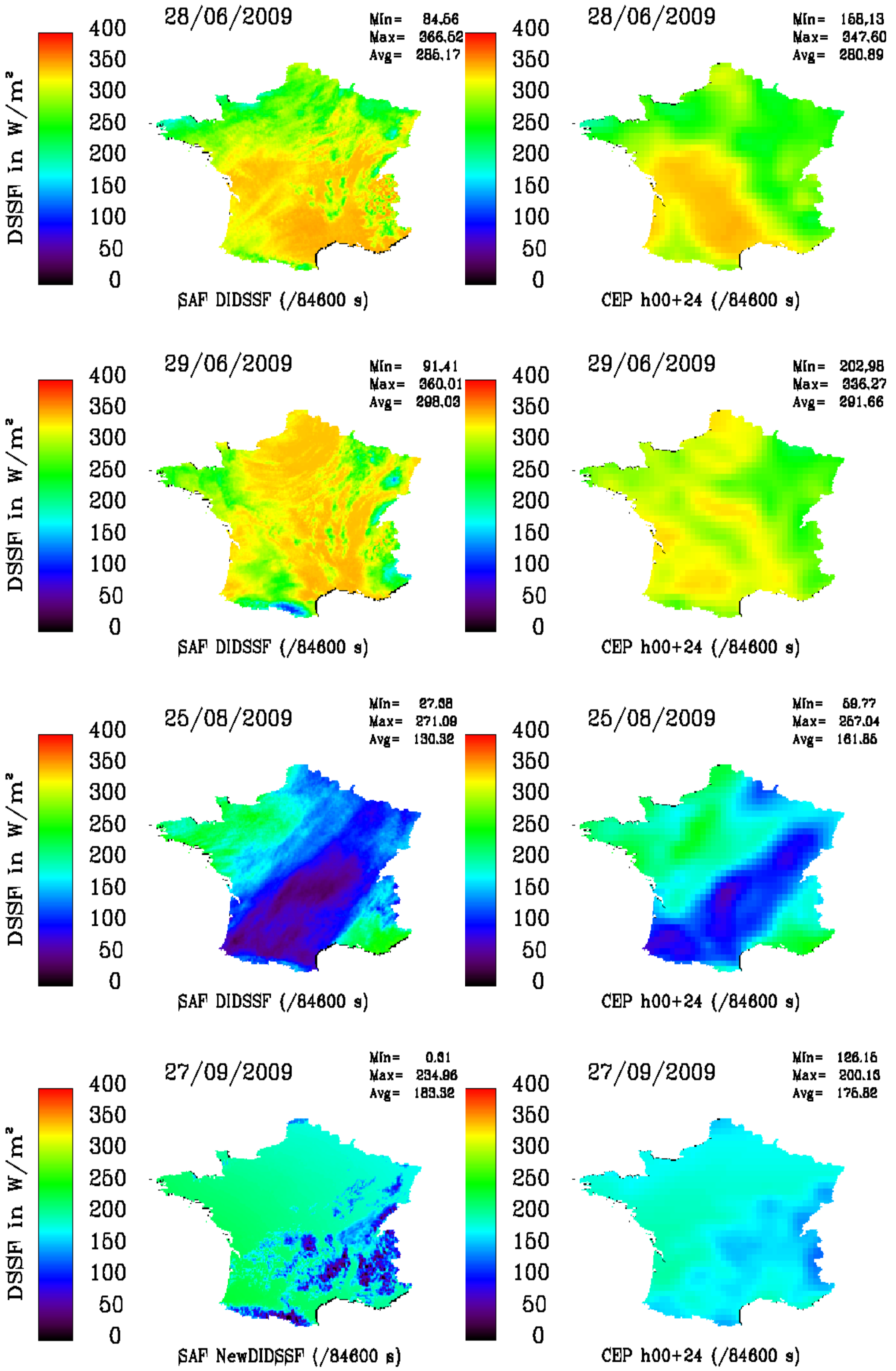


Figure 23: Same as figure 19 with also 2 dates in August and September.

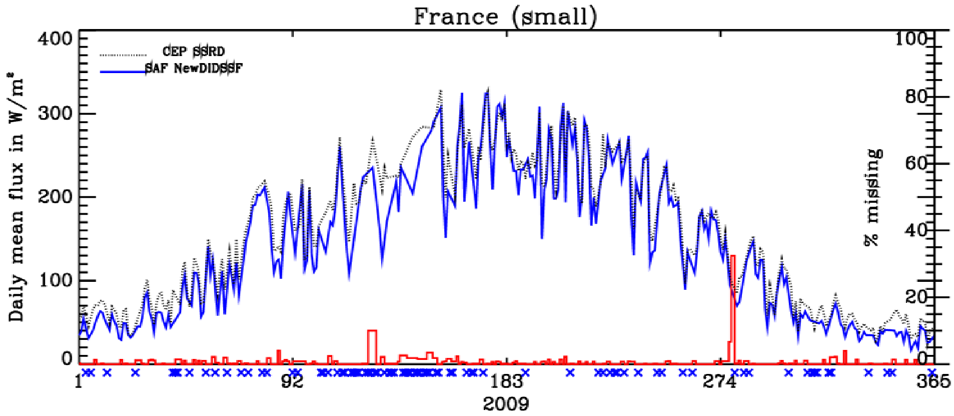


Figure 24: Comparison of DIDSSF (blue) products with SSRD (ECMWF) (black) over France.

3.2 Comparison against ground measurements from BSRN stations

The validation effort of DIDSSF product was further supported in considering ground measurements issued from 6 BSRN (Baseline Surface Radiation Network) stations plus Roissy (airport station in France) in some cases. The location of these stations is such that they represent various environmental and climate conditions, which will strengthen the reliability of the DIDSSF product over a broad geographic coverage. Actually, the station of Toravere (Estonia) is located in northeastern Europe and is characterized by the presence of snow and frequent cloud coverage. The station of Cabauw (The Netherlands) is found near the coast. The station of Carpentras (France) is instead a mid-latitude station. The station in Tamarasset (Algeria) belongs to a semi-arid climate while Sede Boqer (Israël) is rather a desert site. Finally, the station of Izaña (Spain) locates in Canaria Islands, which is marked by high topography (2381m).

Figure 25: Map with the location of the 6 BSRN stations initially selected for the comparison.

The period selected for comparison is the whole year 2010. Prior July 14, data sets considered here were issued from a re-processing that mirrors the processing of the NRT chain. The graph below confirms this statement with a perfect overlap between results from the two processing chains for the 2 dates in common (14 & 15 July).

Besides, Figure 26 reveals that percentage of missing value of DIDSSF is still matter of improvement.

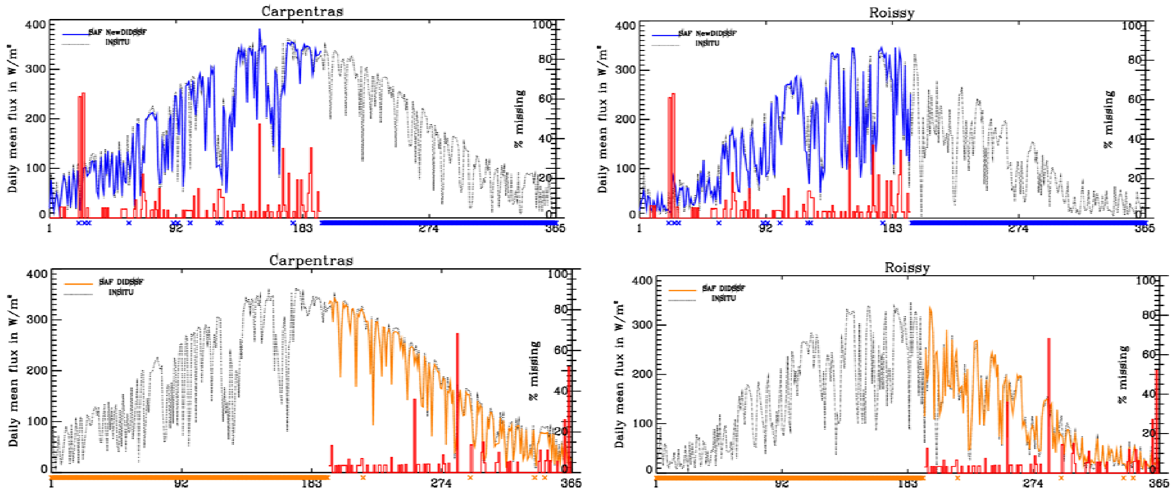


Figure 26: Comparison of DIDSSF and in situ measurements for Carpentras (left) and Roissy (right) based on re-processing (top) and nominal operational chain (bottom) in 2010. Red lines display the percentage of missing data for each day.

The accuracy assessment of measured DIDSSF from SEVIRI must be appraised respectively to the users specifications displayed in Table 1. Therefore, for the sake of a straightforward analysis, the results are organized by range of relative errors according to optimal (less than 5%), target (within 10%) and threshold (within 20%) values plus values beyond 20% of precision.

Table 18: Classes of relative error (expressed in %) for DIDSSF product for the 3 European BSRN stations. (see Table 1 for definition of these errors).

	CABAUW				CARPENTRAS				TORAVERE			
	<5%	<10%	<20%	Other	<5%	<10%	<20%	Other	<5%	<10%	<20%	Other
JAN	13.64	27.27	31.82	27.27	9.09	22.73	36.36	31.82	4.55	4.55	13.64	77.27
FEB	9.52	9.52	23.81	57.14	5.00	25.00	60.00	10.00	18.18	4.55	31.82	45.45
MAR	41.18	52.94	5.88	0.00	35.29	52.94	5.88	5.88	11.76	5.88	41.18	41.18
APR	66.67	16.67	11.11	5.56	66.67	16.67	5.56	11.11	26.32	31.58	21.05	21.05
MAY	37.50	25.00	18.75	18.75	53.33	26.67	20.00	0.00	26.67	26.67	6.67	40.00
JUN	61.54	23.08	15.38	0.00	78.57	7.14	7.14	7.14	45.45	0.00	27.27	27.27
JUL	33.33	33.33	22.22	11.11	90.00	10.00	0.00	0.00	71.43	14.29	14.29	0.00
AUG	42.11	26.32	31.58	0.00	84.21	0.00	5.26	10.53	37.50	18.75	25.00	18.75
SEP	40.00	10.00	25.00	25.00	70.00	10.00	20.00	0.00	11.76	23.53	23.53	41.18
OCT	9.09	40.91	22.73	27.27	40.91	27.27	22.73	9.09	23.81	28.57	19.05	28.57
NOV	12.50	25.00	20.83	41.67	16.67	37.50	29.17	16.67	8.33	12.50	12.50	66.67
DEC	5.00	5.00	30.00	60.00	15.00	0.00	55.00	30.00	5.00	5.00	20.00	70.00

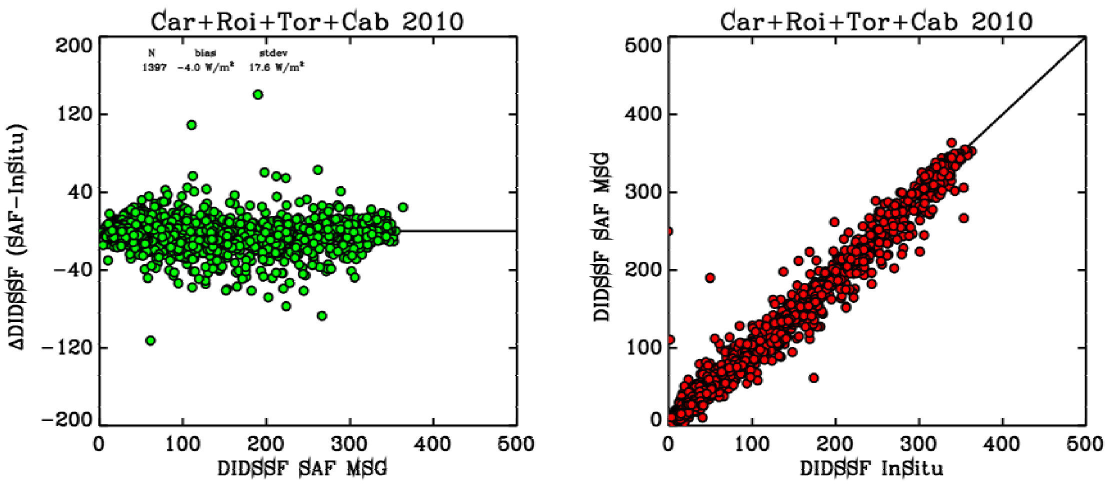


Figure 27: Scatter plots between the daily averages of the satellite estimates of DIDSSF and the daily averages from ground measurements in 2010 for the 3 BSRN stations plus Roissy.

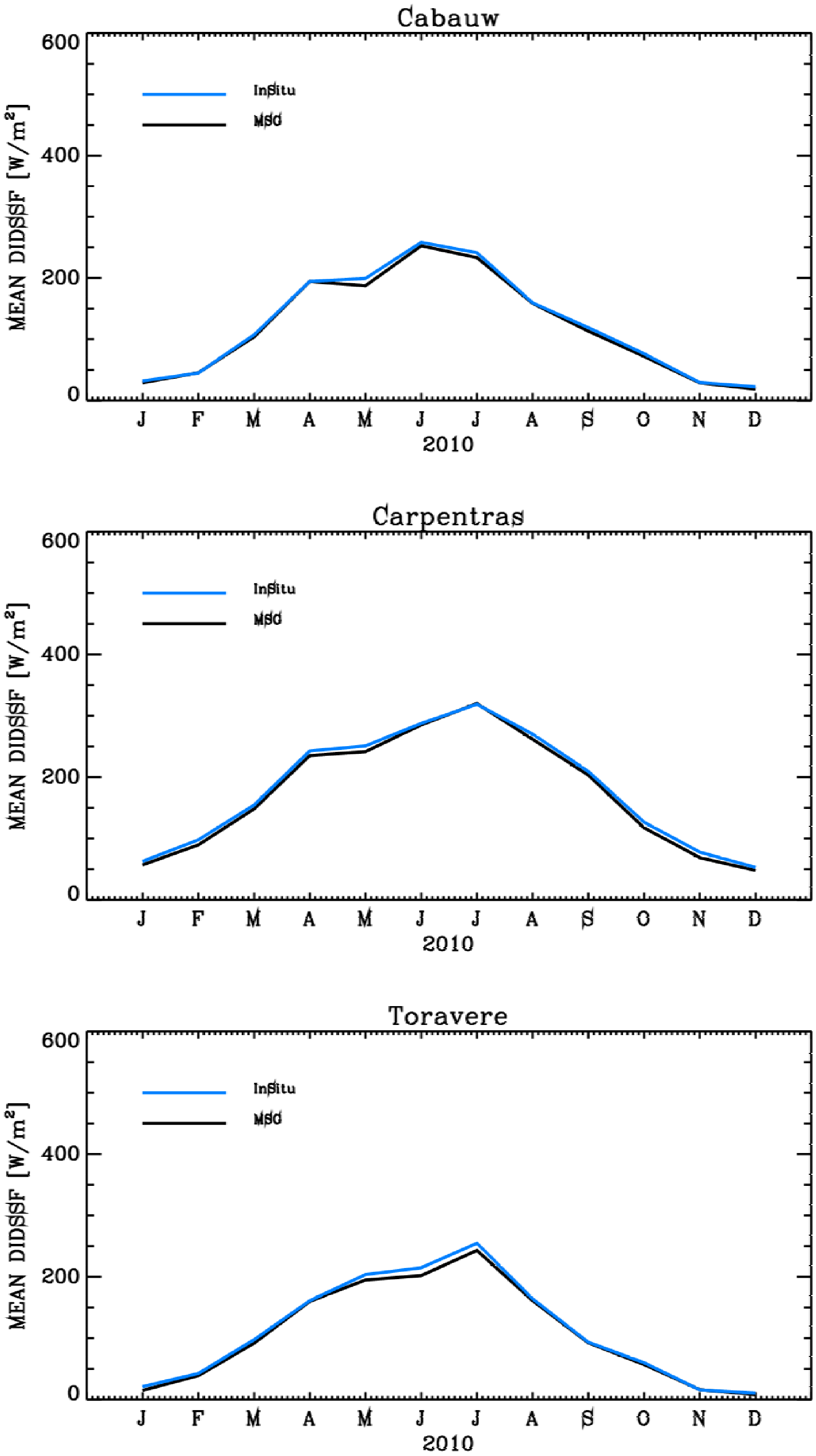


Figure 28: Seasonal variability of monthly-averaged daily DSSF (DIDSSF) from SEVIRI (black curve) and from ground measurements (blue curve) for the 3 European BSRN stations in 2010.

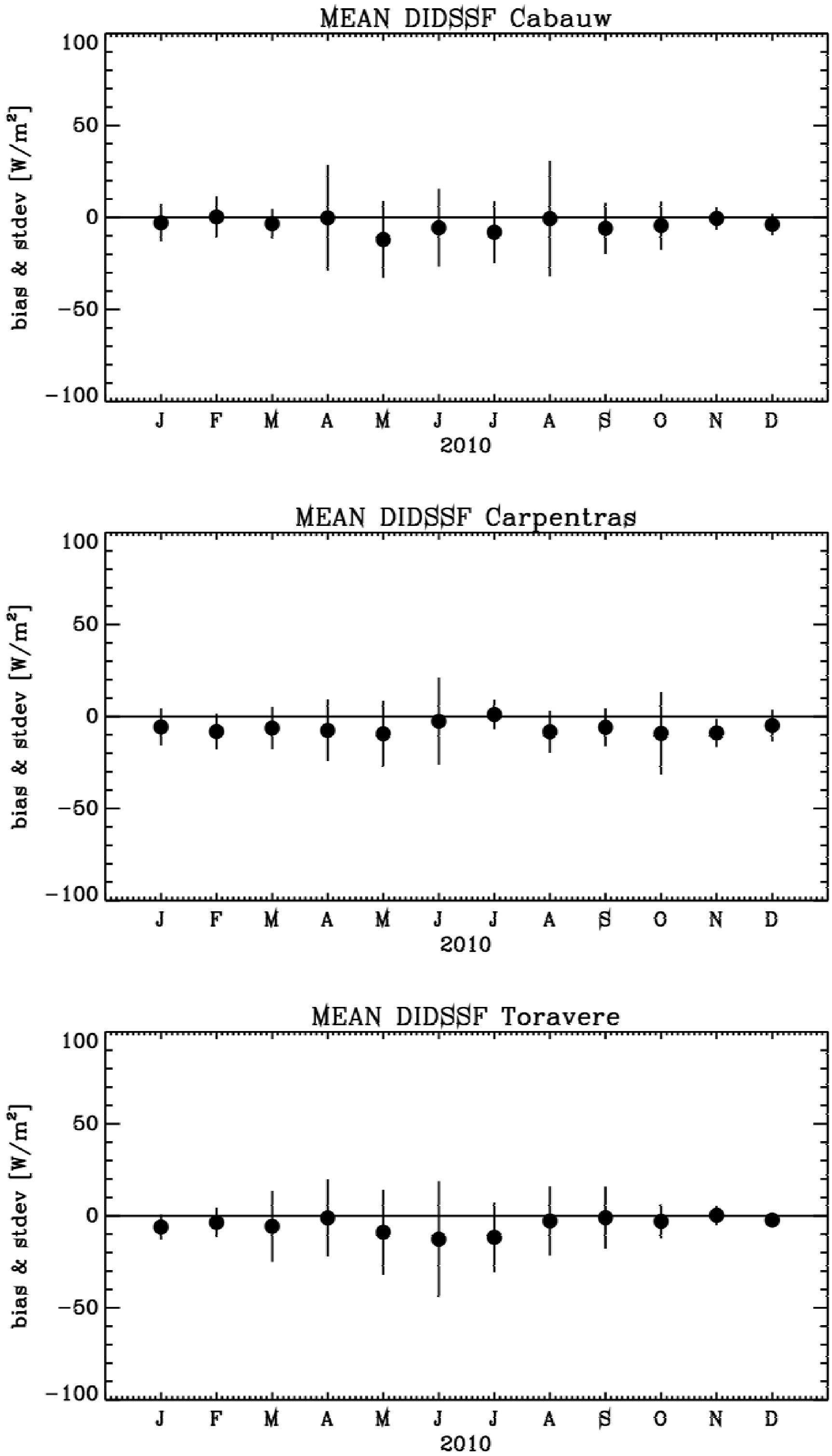


Figure 29: Seasonal variability of monthly-averaged statistics (bias, stdev) of daily DSSF (DIDSSF) (black curve) against ground measurements for the 3 European BSRN stations in 2010.

Table 19: Classes of relative error (expressed in %) for DIDSSF product for the 2 African BSRN stations. (see Table 1 for definition of these errors).

	SEDE BOQER				TAMANRASSET			
	<5%	<10%	<20%	Other	<5%	<10%	<20%	Other
JAN	53.85	15.38	19.23	11.54	69.23	26.92	3.85	0.00
FEB	34.62	26.92	26.92	11.54	96.15	3.85	0.00	0.00
MAR	16.00	44.00	28.00	12.00	75.00	20.83	4.17	0.00
APR	8.33	37.50	45.83	8.33	58.33	33.33	8.33	0.00
MAY	25.00	33.33	33.33	8.33	54.17	33.33	4.17	8.33
JUN	21.05	57.89	15.79	5.26	42.11	10.53	36.84	10.53
JUL	15.79	57.89	21.05	5.26	47.37	21.05	21.05	10.53
AUG	4.35	65.22	30.43	0.00	73.91	17.39	8.70	0.00
SEP	0.00	48.15	33.33	18.52	70.37	7.41	14.81	7.41
OCT					68.00	20.00	12.00	0.00
NOV					81.82	13.64	4.55	0.00
DEC					85.00	15.00	0.00	0.00

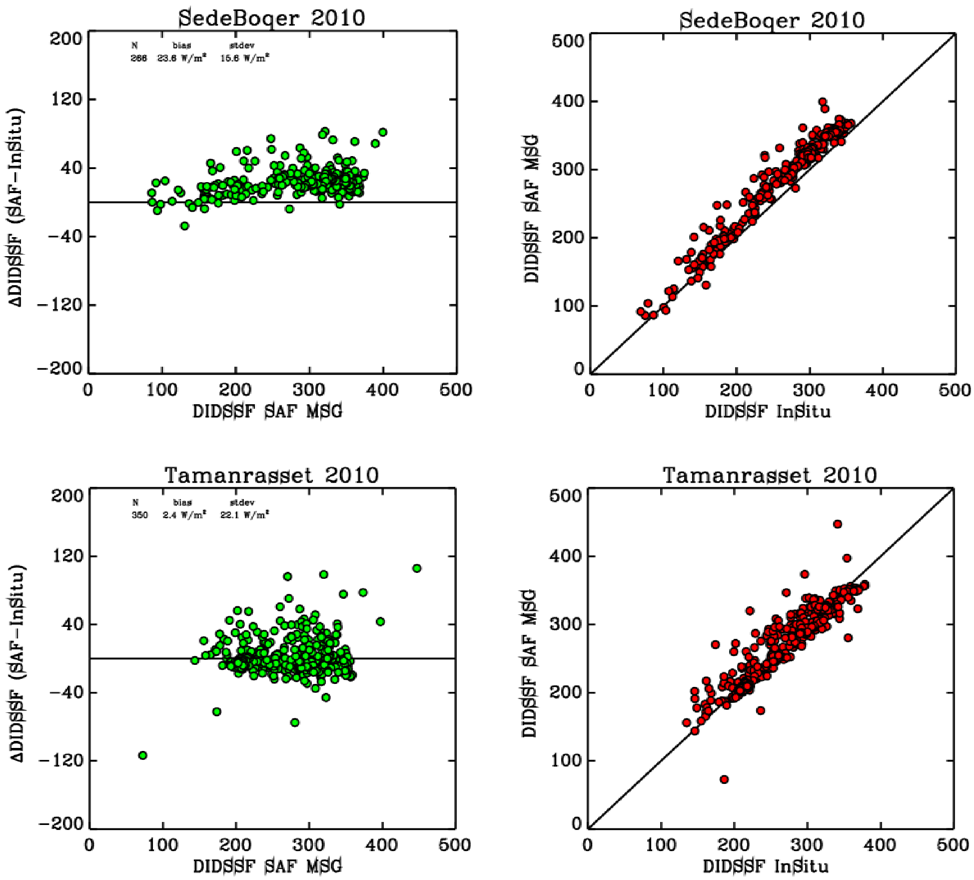


Figure 30: Scatter plots between the daily averages of the satellite estimates of DIDSSF and the daily averages from ground measurements in 2010 for the 2 African BSRN stations.

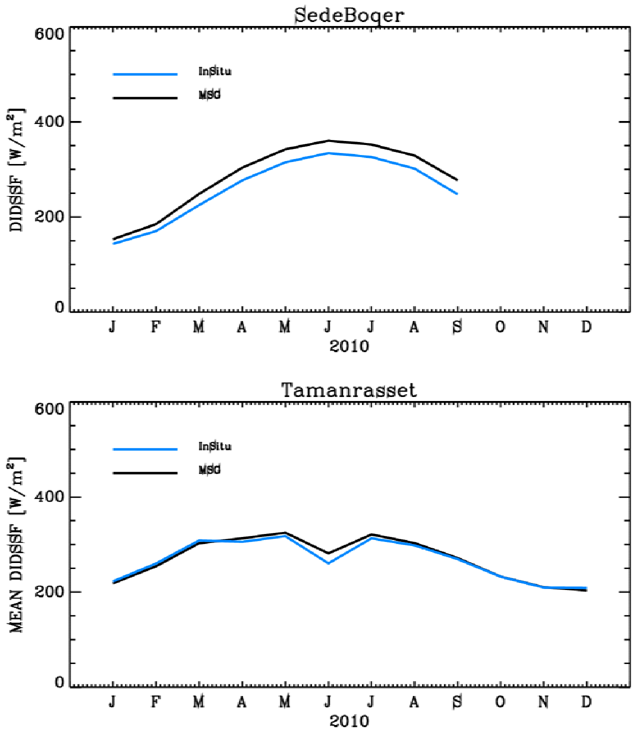


Figure 31: Seasonal variability of the daily DSSF (DIDSSF) from SEVIRI (black curve) and from ground measurements (blue curve) for the 2 N-African BSRN stations in 2010.

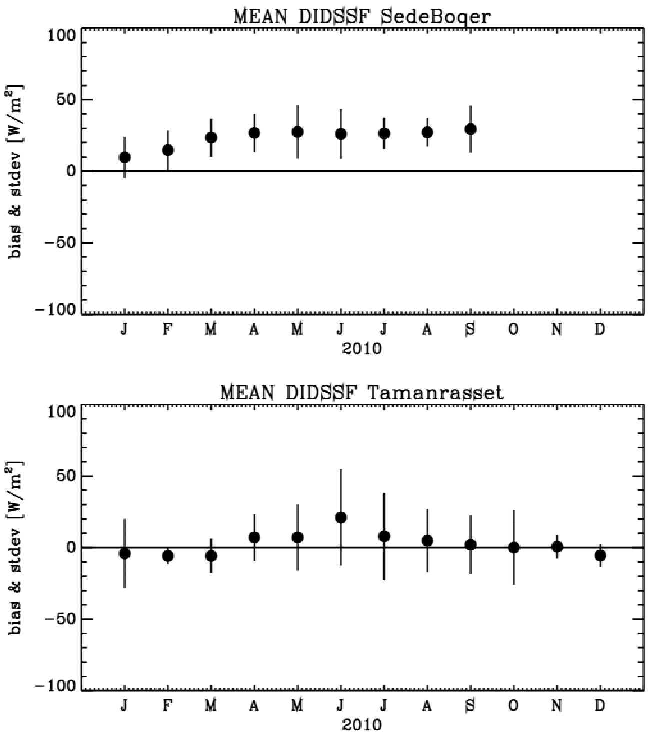


Figure 32: Seasonal variability of monthly-averaged statistics (bias, stdev) of DIDSSF (black curve) against ground measurements for the 2 N-African BSRN stations in 2010.

Tables 18 and 19, respectively for European and N-African BSRN stations, report results of analysis showing a good agreement with relative errors less that 10%, or even 5%, as it could be expected by the users. More critical situations, at least in Europe, occur for the months of January and December during which period a low quantity of solar energy is reaching the land surface. This is particularly true for Toravere, which is the northernmost station. However, the conversion of these uncertainties into solar radiation based on Figures 27-28-29 shows that it is not a real issue, as it will concern only a few W/m^2. Users requirements in Table 1 will be fulfilled then since absolute errors less than 20 W/m^2 for incoming radiation are obtained even far below 200 W/m^2 of solar irradiance. During spring and summertime periods, it becomes frequent that the precision on DIDSSF even falls within the optimal threshold of 5% in relative precision.

For Northern Africa stations, favourable comparison for DIDSSF is obtained particularly for Tamanrasset where the product performance is mostly within the target to optimal range. An overestimate of DIDSSF is particularly evident for Sede Boqer with positive bias values between 20 W/m^2 and 30 W/m^2. The worse values of the statistics are likely to be associated with missing values of DIDSSF product in May and June 2010. Considering that clear situations largely dominate, the only proposed explanation today could be an underestimate of the aerosol correction and the possible impact of a better prescription of the diffuse down-welling radiation with correct.

It is worth emphasizing here that a better quality check of ground measurements, including thorough calibration monitoring, may be necessary as it is recommended for high levels of solar illumination (beyond 300 W/m^2 most of time for Sede Boqer). Incidentally, an inspection of the quality of ground measurements was found for Izaña station (Canarias Islands) could not support a dedicated exploitation (for instance a surface albedo of 1.2 was found, which may doubtful the measurements). Indeed, the magnitude of the discrepancy between DIDSSF and BSRN may explain there by the location of the station at high latitudes. For instance, clear sky scenario may be observed at the station whereas this latter is surrounded by lower parts of the islands covered by stratocumulus. This leads to satellite classifications of cloudy or partly cloudy. Therefore, the station at Izaña is appraised to be not representative of the signal at the pixel scale and was discarded from the comparison.

4. Conclusion

In the Product Requirement Table (PRT), a specification of 5% is quoted for the relative accuracy of the down-welling surface short-wave radiation flux product. The exact definition for accuracy requirements is always hard to set, except for within the context of specific applications and approaches to deriving products. Although SAF requirements given should therefore be taken as broadly indicative, what we provide are values for standard deviation, which seems to satisfy most users if we take for reference the conclusions of the Users Workshop organized. When it comes to small quantities, absolute accuracy could be found useful. For presenting our results of the validation studies against ground measurements, we therefore calculated and listed the values of bias and standard deviation in absolute as well as in relative units. The relative quantities were calculated with reference to the average of the DSSF values in the respective sample of data points. However, since the occurring DSSF values are highly dynamic and exhibit very low values for low elevation (consistent with zero for practical purposes) it is worth noticing that it may not be found appropriate to quantify the precision of estimates of DSSF physical quantity in term of relative unit.

For clear sky conditions the bias calculated on the basis of the whole data period for the six European stations Carpentras, Roissy, Evora, Toravere, Payerne, and Camborne individually exhibits values of +3 Wm^{-2}, +14 Wm^{-2}, +15 Wm^{-2}, +2 Wm^{-2}, +11 Wm^{-2}, and +13 Wm^{-2}, respectively, which corresponds to relative biases of up to 4%. When considering the statistics calculated for individual months more important biases with positive and negative sign can be observed which tend to cancel out over the whole period. Except for Toravere during wintertime (and for very few months for Roissy and Camborne) the monthly bias values remain better than $\pm$10% in all and better than $\pm$5% in the majority of cases.

For cloudy sky conditions the bias calculated with the whole data period for the six stations individually exhibits values of +4 Wm^{-2}, +4 Wm^{-2}, -3 Wm^{-2}, +2 Wm^{-2}, -7 Wm^{-2}, and -3 Wm^{-2}, respectively. In the worst case this corresponds to a relative bias of -3%. In the majority of cases the monthly values remain within $\pm$15%, although there are some months, which are much further off.

When considering all data points irrespective of the method applied, biases of +2 Wm^{-2}, +5 Wm^{-2}, +7 Wm^{-2}, +1 Wm^{-2}, -2 Wm^{-2}, and 0 Wm^{-2}, respectively, are obtained for the individual stations. The bias values for the monthly statistics are within $\pm$5% in the majority of cases.

For clear sky data points the standard deviation considering the total available period exhibits values of 33 Wm^{-2}, 47 Wm^{-2}, 37 Wm^{-2}, 50 Wm^{-2}, 55 Wm^{-2}, and 70 Wm^{-2}, respectively, for the six stations. In relative units this corresponds to values between 7% and 19%. When looking at the monthly statistics a range of standard deviations between 13 Wm^{-2} and 111 Wm^{-2} in absolute units or between 5% and 59% in relative units can be observed.

For cloudy sky data points the standard deviation considering the total available period exhibits values of 104 Wm^{-2}, 115 Wm^{-2}, 105 Wm^{-2}, 99 Wm^{-2}, 117 Wm^{-2}, and 109 Wm^{-2}, respectively, which corresponds to relative values between 30% and 53%. The monthly statistics contains values of the standard deviation in the range 21 Wm^{-2} to 191 Wm^{-2} in absolute units or 18% to 75% in relative units.

When considering all data points irrespective of the method applied over the total available period, the standard deviation values of 70 Wm^{-2}, 97 Wm^{-2}, 71 Wm^{-2}, 83 Wm^{-2}, 96 Wm^{-2}, and 95 Wm^{-2}, respectively, are found for the six validation stations. This corresponds to relative values between 17% and 38%. When analysing the monthly statistics the occurring values range between 22 Wm^{-2} and 165 Wm^{-2} in absolute units or between 8% and 72% in relative units. (Note that here the month of December 2004 at Toravere exhibits the best result in absolute units and at the same time the second worst in relative units.)

When discussing the values of the standard deviation and comparing them to the numbers found for other down-welling radiation products, it must be taken into account that the currently available Land-SAF product consists of instantaneous estimates provided at a temporal frequency of 30 minutes. Generating averaged flux products over a certain time interval can substantially reduce the dispersion. For the daily averaged DSSF estimate calculated here for validation purposes only, the obtained standard deviation reduces to the values of 27 Wm^{-2}, 28 Wm^{-2}, 20 Wm^{-2}, 27 Wm^{-2}, 44 Wm^{-2}, and 36 Wm^{-2}, respectively, for the six validation sites. This corresponds to a range between 6% and 18% in relative units.

Considering the averages of the estimates over even longer periods further reduces the dispersion. Such an exercise has not been carried out, but it is approximately equivalent to calculate the standard deviation of the monthly bias values shown in the figures and tables of Section 1.2.3. For the individual validation sites it ranges from 8 Wm^{-2} to 16 Wm^{-2} for the clear and cloudy cases and from 5 Wm^{-2} to 11 Wm^{-2} for the quantities referring to all data points and the daily average.

In order to estimate to which extent the results obtained with the available local validation data and individual product pixels are representative for the whole region, it is useful to consider the dispersion of the bias values within the ensemble of validation sites. The respective standard deviation of the monthly biases typically ranges from 5 Wm^{-2} to 20 Wm^{-2}. However, since only a limited sample of six stations is available, the uncertainty of the calculated estimate is large.

The validation exercise of DIDSSF product reveals that in general about 75% of the values obtained satisfy to users requirements in the range from optimal to target accuracy (up to 10% relative errors in Table 17 and 18) for almost all selected BSRN stations. This is with the exception of wintertime months for which low solar energy is available and cloud coverage is high and persistent. Major discrepancies were noticed for the station of Toravere. For Toravere, skew angles of viewing and illumination lead to cloud misclassification. This latter source of error was neither in favour for a comparison for Izaña station, which does not seem to offer a solar flux to be representative at the pixel scale. For both stations, the original discrepancies between DSSF and ground data on an instantaneous basis are perpetuated in time on the daily-accumulated DSSF (DIDSSF). Nevertheless further methodological improvements are foreseen to address the discrepancies that have been identified and a gain is expected from the use of an operational aerosol product issued from MACC/GEMS initiative. This could improve the comparison for Sode Boqer although results could indicate that appropriate calibration should be confirmed.

To resume, the quality of DIDSSF obviously mirrors original quality of DSSF products and is impacted by the proportion of missing data. At mid-latitude regions and North

Africa, the quality of the results with errors less than 10% will be in favour to support a thorough analysis of DIDSSF by users community.

A first recommendation to users that comes form validation exercise is that on the edge of the SEVIRI disk as due to the degradation in pixel resolution, there may exist a mismatch in cloudiness scenario, respectively clear-sky scenario, between the satellite and the tower flux. Perfect illustration was obtained for the BSRN station of Toravere (Estonia) located northernmost. In this regard, we may suggest the user to be careful in analysing the results. A second recommendation is that relative error may not be significant at high latitude during short duration of the day and low solar radiation reaches the soil background. Again, the station of Toravere provides a typical example. A third recommendation is the influence of the topography. For instance, the station of Izaña (Canaria Islands) is located on a mountain surrounded by valleys. Cloud information may represent the situation in these valleys and not for peak, although reverse scenario may of course also occur. Therefore, how the ground station is representative seems matter of discussion, which could be investigated through a spatial analysis of surface albedo and relief first.

The mechanisms of users feedback information, that is lesson learned, is certainly an important component of the life of the LSA SAF Consortium. It normally comes through forum and at the anniversary (biennal) of Users Workshop. It helps in the exact definition of the specifications, which means the best time / space integration of the product (DSSF, DIDSSF) that could best satisfies requirements in reducing errors. Report on users experiment will also be integrated in a next VR document when sufficient DSSF data sets will have been analyzed such like it can be deemed useful to a broad users community. Besides, information for users about all perspectives for new scientific developments will appear in the ATBD (Algorithm Theoretical Baseline Document) now in preparation.

5. List of references

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