Supplement

Nomenclature

Acronym	Definition
AEMET	Agencia Estatal de Meteorología: Meteorological State Agency of Spain
AERONET	AErosol RObotic NETwork
AE	Angström Exponent
AOD	Aerosol Optical Depth
BRL	Boland-Ridley-Lauret diffuse fraction model
BSRN	Baseline Surface Radiation Network
CAMS	Copernicus Atmosphere Monitoring Service: ECMWF tool for atmospheric composition knowledge
CENER	Centro Nacional de Energías Renovables, National Renewable Energy Centre of Spain
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
DWD	Deutscher Wetterdienst: German Meteorological Service
ECMWF	European Centre for Medium-Range Weather Forecasts
FMF	Fine Mode Fraction
gg	Assymetry factor
GHI	Global Horizontal Irradiance
GSEE	Global Solar Energy Estimator
IARC	Izaña Atmospheric Research Center: AEMET Observatory of Izaña, Tenerife, Spain
MAE	Man Absolute Error
MBE	Mean Bias Error
Md	Median
MOL-RAO	Meteorologisches Observatorium Lindenberg, Richard-Aßmann-Observatorium: DWD Observatory Lindenberg, Lindenberg (Tauche), Germany
NEO	Navarino Environmental Observatory, Messinia, Greece

OMN	Office national de la météorologie, "Météo Algérie": National Meteorological Office of Algeria
PDFs	Probability Density Functions
PMOD/WRC	Physikalisch-Meteorologisches Observatorium Davos / World Radiation Center, Davos, Switzerland
PV	Photovoltaic
QC	Quality Check
r	Weighted correlation coefficient
rMBE	Relative Mean Bias Error
RMSE	Root Mean Square Error
RTM	Radiative Transfer Model
SDA	Spectral Deconvolution Algorithm
SSA	Single Scattering Albedo
SV	Solar Visibility
SZA	Solar Zenith Angle
TOC	Total Ozone Column (in DU)
TPM	Faculty of Technology, Policy, and Management, Delft, the Netherlands
UTC	Coordinated Universal Time
WMO	World Meteorological Organisation

Evaluation Metrics

The formulas for the evaluation metrics used are the following:

1. Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{1}{N}\sum(x_{mod} - x_{obs})^2}$$

2. Mean Absolute Error (MAE)

$$MAE = \frac{1}{N}\sum|x_{mod} - x_{obs}|$$

3. relative Mean Bias Error (rMBE)

12 $$rMBE = \frac{1}{N}\sum\left(\frac{x_{mod} - x_{obs}}{x_{obs}}\right) \times 100\%$$

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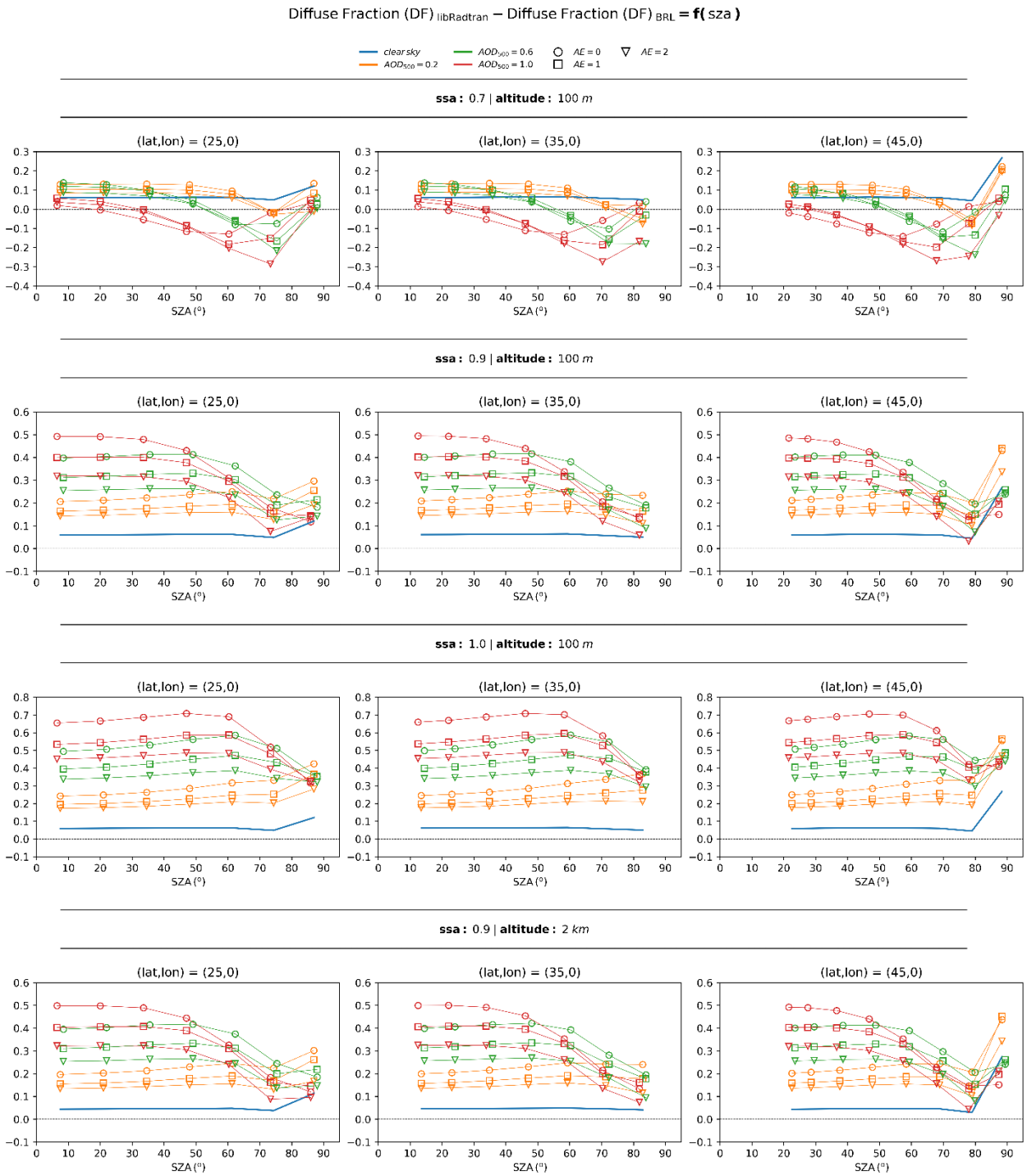

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Figure S1. Difference between the diffuse fraction derived directly from the computations of DHI and GHI using libRadtran and the one estimated by applying BRL to the libRadtran-computed GHI for surface albedo 0.8

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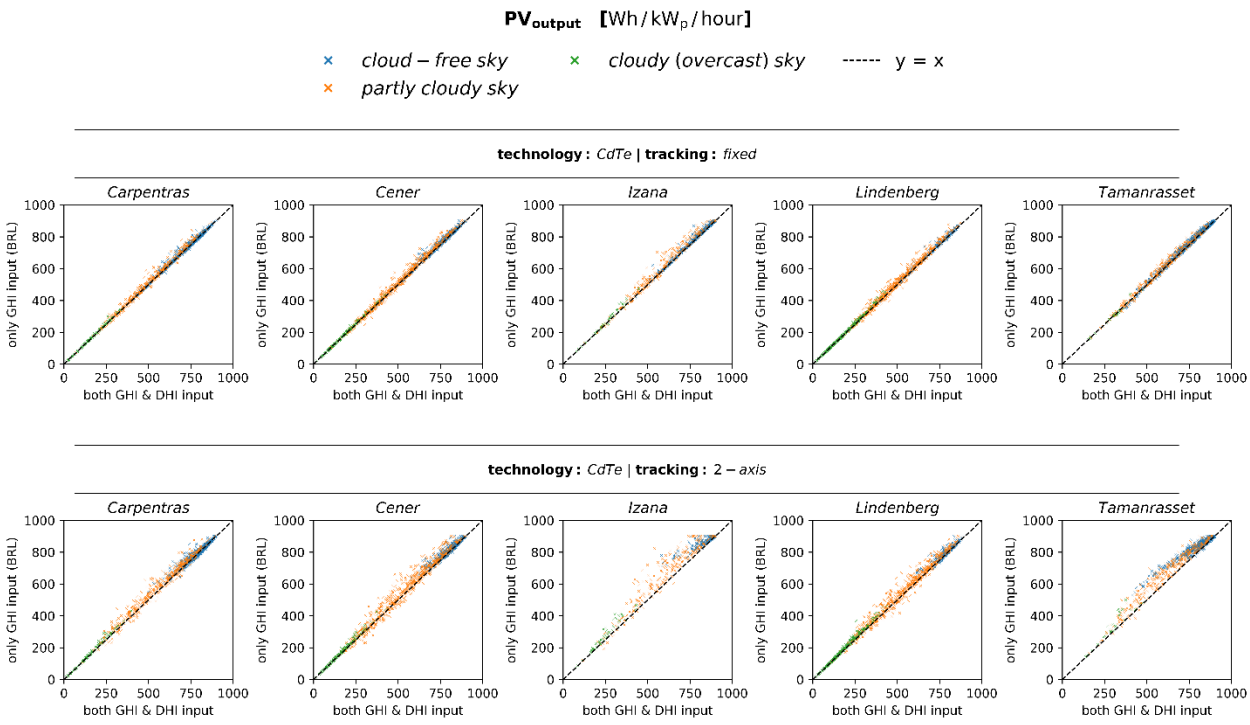

Figure S2. Comparison of the estimated hourly PV power generation between simulations performed using GSEE with input data consisting of either only GHI or both GHI and DHI under varying cloudiness conditions for panels with CdTe technology

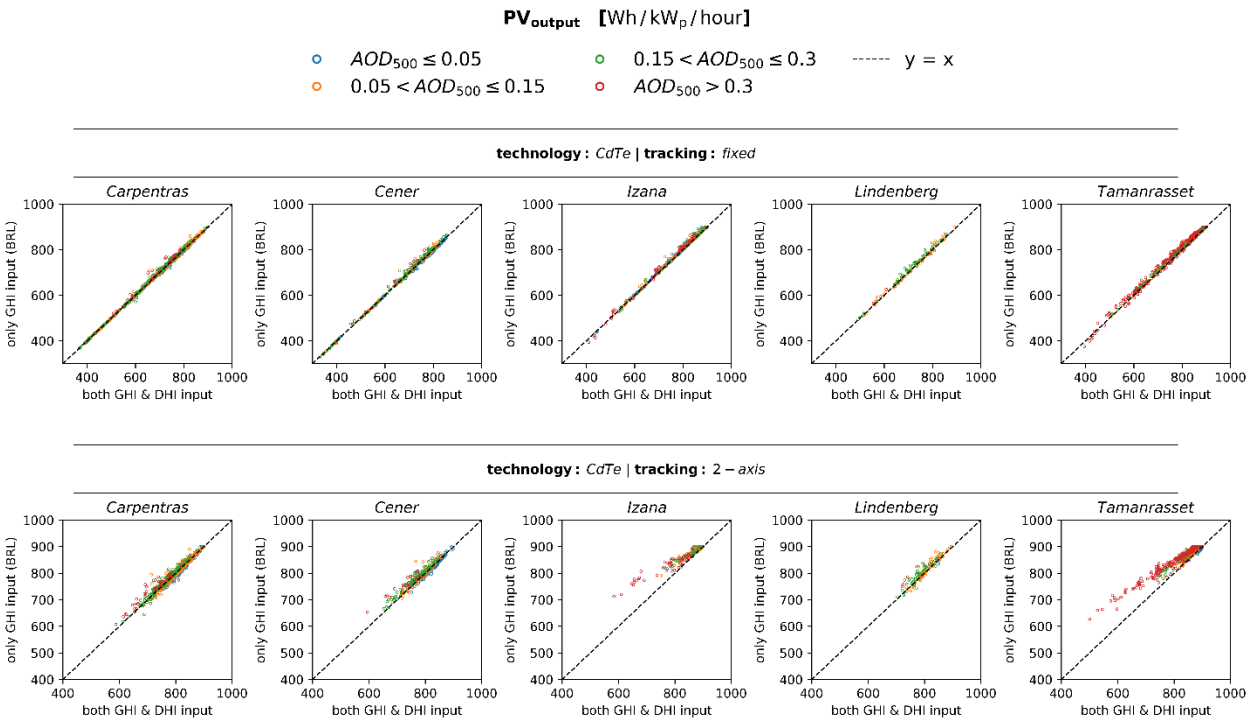

Figure S3. Comparison of the estimated hourly PV power generation between simulations performed using GSEE with input data consisting of either only GHI or both GHI and DHI under varying aerosol conditions for panels with CdTe technology

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Table S1. Evaluation metrics for GSEE performance within hourly intervals in Carpentras, comparing simulations with diffuse fraction from measurements and from the BRL model

STATION: Carpentras		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		12.6	6.6	0.8	20.8	12.5	1.2
All-Sky scenes (cloudiness)	cloud-free	9.2	4.6	0.4	14.8	8.7	0.5
	partly cloudy	19.5	12.5	2.3	32.5	23.9	3.8
	cloudy (overcast)	5.8	3.0	2.0	10.5	6.1	4.6
Cloudless-Sky scenes (aerosol load)	low	4.7	3.4	-0.4	9.5	7.5	-0.8
	moderate	4.3	2.2	0.1	7.8	4.7	0.0
	high	6.4	4.0	0.6	11.0	7.8	0.9
	very high	14.9	10.2	1.6	22.7	17.2	2.6

Table S2. Evaluation metrics for GSEE performance within hourly intervals in Tamanrasset, comparing simulations with diffuse fraction from measurements and from the BRL model.

STATION: Tamanrasset		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		13.6	9.3	1.0	40.4	27.8	3.8
All-Sky scenes (cloudiness)	cloud-free	11.5	8.0	0.8	35.3	23.4	2.9
	partly cloudy	20.1	15.0	2.0	56.1	45.7	8.1
	cloudy (overcast)	8.4	5.2	-0.1	45.3	30.1	11.2
Cloudless-Sky scenes (aerosol load)	low	3.2	2.0	0.2	6.6	4.0	0.3
	moderate	5.4	4.6	0.6	13.0	10.5	1.2

Table S3. Evaluation metrics for GSEE performance within hourly intervals in Cener, comparing simulations with diffuse fraction from measurements and from the BRL model.

STATION: Cener		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		14.5	8.2	1.2	27.1	16.7	2.3
All-Sky scenes (cloudiness)	cloud-free	11.7	6.4	0.8	19.5	11.9	1.3
	partly cloudy	19.3	12.4	2.0	37.5	26.4	4.1
	cloudy (overcast)	4.7	2.7	1.6	11.2	6.3	4.6
Cloudless-Sky scenes (aerosol load)	clear sky / low	4.0	2.5	-0.2	7.9	5.5	-0.4
	moderate	6.9	3.1	0.4	11.4	6.2	0.6
	high	8.7	6.2	1.0	15.4	12.8	1.8
	very high	NaN	NaN	NaN	NaN	NaN	NaN

Table S4. Evaluation metrics for GSEE performance within hourly intervals in Lindenberg, comparing simulations with diffuse fraction from measurements and from the BRL model.

STATION: Lindenberg		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		16.0	9.7	1.8	26.1	17.0	2.7
All-Sky scenes (cloudiness)	cloud-free	11.8	6.7	0.9	20.7	13.5	1.4
	partly cloudy	20.4	13.9	2.3	32.4	23.5	3.5
	cloudy (overcast)	6.7	3.6	2.4	11.7	6.5	4.6

Cloudless-Sky scenes (aerosol load)	clear sky / low	NaN	NaN	NaN	NaN	NaN	NaN
	moderate	8.9	5.5	0.5	14.9	9.7	0.6
	high	12.6	10.3	1.4	19.5	15.9	2.0
	very high	NaN	NaN	NaN	NaN	NaN	NaN

Table S5. Evaluation metrics for GSEE performance within hourly intervals in Izana, comparing simulations with diffuse fraction from measurements and from the BRL model.

STATION: Izana		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		20.0	11.3	1.5	41.5	22.3	2.8
All-Sky scenes (cloudiness)	cloud-free	12.3	7.2	0.9	26.6	12.7	1.5
	partly cloudy	36.1	25.8	4.3	73.4	55.1	9.3
	cloudy (overcast)	16.8	11.8	4.6	35.5	26.0	11.8
Cloudless-Sky scenes (aerosol load)	clear sky / low	6.8	4.8	0.6	7.8	3.7	0.4
	moderate	9.3	6.5	0.9	20.8	15.0	1.8
	high	11.2	8.6	1.1	31.4	26.2	3.3
	very high	14.1	11.8	1.4	64.5	52.1	7.3

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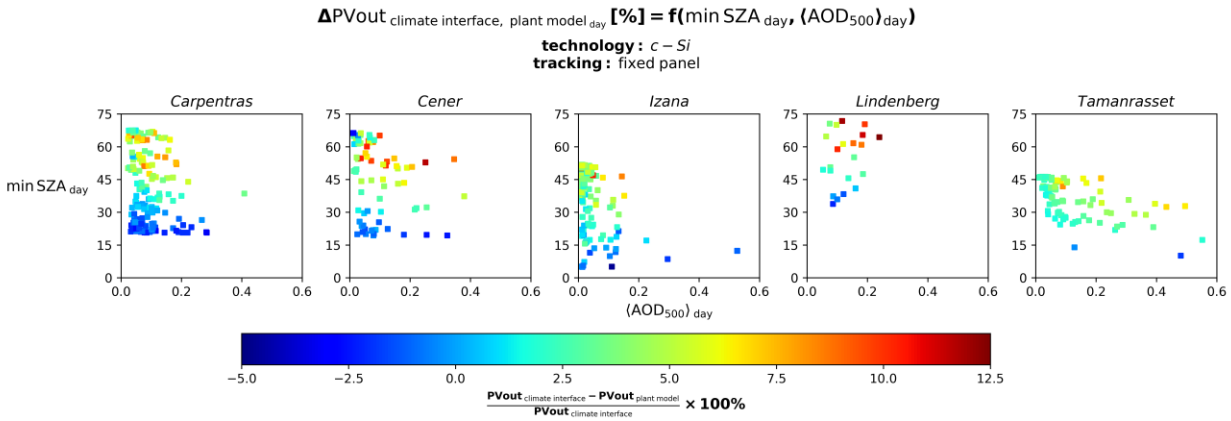

Figure S4. Percentage differences between the daily PV output estimated using the climate interface and the corresponding daily sums from hourly simulations as function of minimum daily SZA and mean daily aerosol load for fixed panels

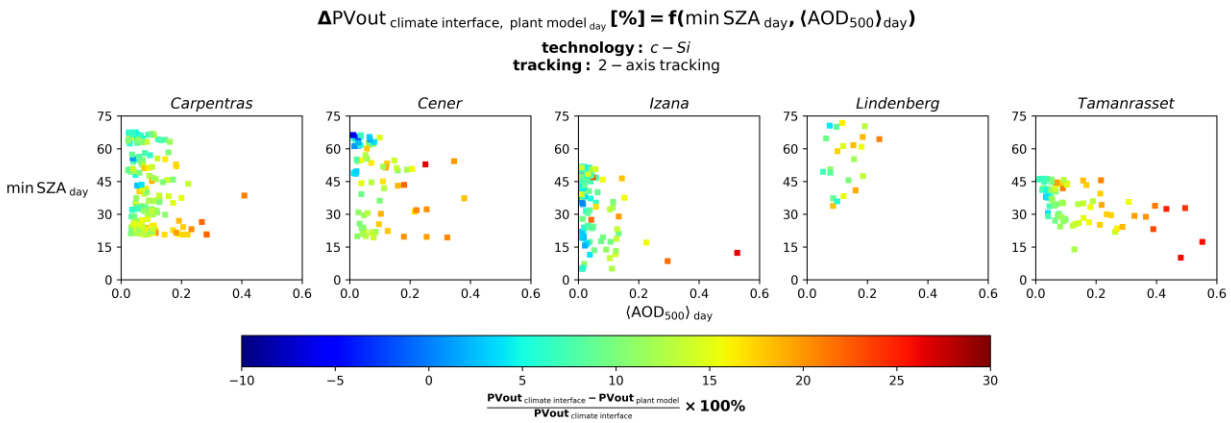

Figure S5. Percentage differences between the daily PV output estimated using the climate interface and the corresponding daily sums from hourly simulations as function of minimum daily SZA and mean daily aerosol load for panels with 2-axis tracking

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Table S6. Evaluation metrics assessing the reliability of GSEE Climate Data Interface in estimating total daily PV output power in Carpentras

STATION: Carpentras		fixed panels			2-axis tracking		
		RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)	RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)
All Days		0.22	0.17	1.7	1.24	1.08	15.5
Sunny (cloudless) Days		0.19	0.15	1.8	1.19	1.08	14.1
Sunny Days: average aerosol load	very-low aerosol	0.18	0.15	2.1	0.82	0.72	10.0
	aerosol-laden	0.19	0.16	1.7	1.28	1.20	15.3

Table S7. Evaluation metrics assessing the reliability of GSEE Climate Data Interface in estimating total daily PV output power in Tamanrasset

STATION: Tamanrasset		fixed panels			2-axis tracking		
		RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)	RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)
All Days		0.24	0.22	3.4	1.45	1.34	19.0
Sunny (cloudless) Days		0.22	0.20	3.4	1.20	1.11	14.4
Sunny Days: average aerosol load	very-low aerosol	0.15	0.14	2.5	0.66	0.62	7.7
	aerosol-laden	0.24	0.22	3.7	1.37	1.31	17.3

Table S8. Evaluation metrics assessing the reliability of GSEE Climate Data Interface in estimating total daily PV output power in Cener

STATION: Cener		fixed panels			2-axis tracking		
		RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)	RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)
All Days		0.24	0.18	2.5	1.28	1.08	16.8
Sunny (cloudless) Days		0.26	0.21	3.3	1.15	1.00	13.6
Sunny Days (average aerosol load)	aerosol-free	0.18	0.15	2.4	0.73	0.60	7.6
	aerosol-laden	0.30	0.24	4.0	1.37	1.28	17.8

Table S9. Evaluation metrics assessing the reliability of GSEE Climate Data Interface in estimating total daily PV output power in Lindenberg

STATION: Lindenberg		fixed panels			2-axis tracking		
		RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)	RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)
All Days		0.24	0.18	2.1	0.99	0.81	15.2
Sunny (cloudless) Days		0.29	0.23	4.4	1.04	0.96	14.6
Sunny Days (average aerosol load)	aerosol-free	NaN	NaN	NaN	NaN	NaN	NaN
	aerosol-laden	NaN	NaN	NaN	NaN	NaN	NaN

Table S10. Evaluation metrics assessing the reliability of GSEE Climate Data Interface in estimating total daily PV output power in Izana

STATION: Izana		fixed panels			2-axis tracking		
		RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)	RMSE (kWh/kWp/day)	MAE (kWh/kWp/day)	rMBE (%)
All Days		0.28	0.23	3.4	1.12	0.94	11.2
Sunny (cloudless) Days		0.25	0.21	3.1	0.92	0.80	8.9
Sunny Days (average aerosol load)	aerosol-free	0.25	0.22	3.3	0.75	0.65	7.2
	aerosol-laden	0.24	0.19	2.3	1.38	1.31	15.3

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Table S11. Evaluations metrics accessing the reliability of using CAMS solar radiation time-series for modelling PV output power in Carpentras

STATION: Carpentras		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		49.7	36.6	3.9	60.7	43.0	3.8
All-Sky scenes (cloudiness)	cloud-free	35.9	28.4	3.2	41.7	32.5	2.7
	partly cloudy	74.1	56.7	5.7	94.2	70.3	7.1
	cloudy (overcast)	46.7	37.4	11.4	49.2	38.3	13.9
Cloudless-Sky scenes (aerosol load)	low	25.0	20.0	2.1	28.8	22.3	1.5
	moderate	32.5	25.9	3.4	36.7	29.1	2.9
	high	41.8	36.0	5.0	49.0	41.3	4.7
	very high	42.3	36.9	6.1	49.9	44.1	6.3

Table S12. Evaluations metrics accessing the reliability of using CAMS solar radiation time-series for modelling PV output power in Tamanrasset

STATION: Tamanrasset		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		55.9	33.7	-1.0	75.2	46.1	-0.6
All-Sky scenes (cloudiness)	cloud-free	32.4	20.8	-0.7	45.2	29.8	-0.7
	partly cloudy	87.3	67.5	-4.4	111.8	86.9	-3.0
	cloudy (overcast)	124.9	89.2	23.3	210.7	151.6	48.1
Cloudless-Sky scenes (aerosol load)	low	16.6	11.9	0.3	20.8	15.3	-0.6
	moderate	19.7	14.9	-0.4	28.2	20.9	-1.2
	high	29.8	18.9	-0.9	34.9	23.2	-1.0
	very high	31.0	22.9	0.7	48.0	35.5	2.4

Table S13. Evaluations metrics accessing the reliability of using CAMS solar radiation time-series for modelling PV output power in Cener

STATION: Cener		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		63.1	43.0	2.0	75.3	51.2	2.1
All-Sky scenes (cloudiness)	cloud-free	35.6	27.0	0.9	45.6	33.5	0.4
	partly cloudy	82.7	61.1	2.1	99.6	73.4	3.4
	cloudy (overcast)	77.3	50.8	20,7	83.5	53.4	24.8

Cloudless-Sky scenes (aerosol load)	clear sky / low	28.0	21.5	1.7	32.1	25.0	1.1
	moderate	38.5	30.4	2.8	48.3	38.8	2.3
	high	34.3	28.4	2.9	41.7	35.1	2.3
	very high	NaN	NaN	NaN	NaN	NaN	NaN

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85 **Table S14.** Evaluations metrics accessing the reliability of using CAMS solar radiation time-series
86 for modelling PV output power in Lindenberg

STATION: Lindenberg		fixed panels			2-axis tracking		
		RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)	RMSE (Wh/kWp/hour)	MAE (Wh/kWp/hour)	rMBE (%)
All-Sky scenes		66.1	46.7	-1.2	76.2	53.8	-1.4
All-Sky scenes (cloudiness)	cloud-free	37.9	24.9	-1.7	50.7	33.4	-2.5
	partly cloudy	76.4	57.5	-2.6	88.9	67.0	-2.3
	cloudy (overcast)	60.9	42.3	8.0	63.9	43.2	9.5
Cloudless-Sky scenes (aerosol load)	clear sky / low	NaN	NaN	NaN	NaN	NaN	NaN
	moderate	42.3	28.7	-2.5	53.4	24.7	-3.0
	high	40.9	26.4	-2.4	52.6	32.0	-2.8
	very high	NaN	NaN	NaN	NaN	NaN	NaN

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