Quality Assessment Report

1 Technical features - station and instruments

Site name:	**BMS, USA**
Latitude, longitude [°]:	39.742000, -105.180000
Altitude [m a. s. l.]:	1829
Location on a map:	https://apps.solargis.com/prospect
Type:	Ground measurements
Source:	SRRL
URL:	https://midcdmz.nrel.gov/apps/sitehome.pl?site=BMS
Attribution:	Andreas, A.; Stoffel, T.; (1981). NREL Solar Radiation Research Laboratory (SRRL): Baseline Measurement System (BMS); Golden, Colorado (Data); NREL Report No. DA-5500-56488. http://dx.doi.org/10.5439/1052221
Time step:	5 minutes
Quality assessment status:	T R M I P

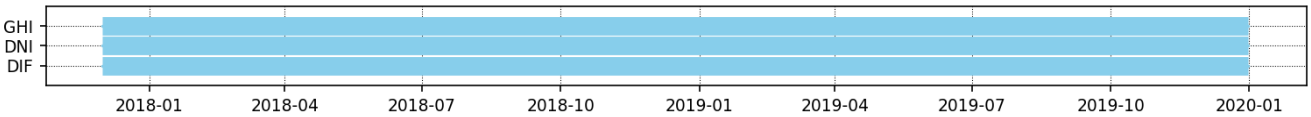

Fig. 1: Data availability for individual parameters

Tab. 1: Instruments installed at the station

Name	Type	Description	Class	Manufacturer	Model	Units	Uncertainty
GHI	GHI	Pyranometer	Class A	Kipp & Zonen	CMP22	W/m²	< ± 2.0 % (daily)
DNI	DNI	Pyrheliometer	Class A	Kipp & Zonen	CHP 1	W/m²	N/A
DIF	DIF	Pyranometer	Class A	Kipp & Zonen	CMP22	W/m²	< ± 2.0 % (daily)

Tab. 2: Test groups

Test group	GHI	DNI	DIF	GTI	RHI	ALB
Group_1	GHI	DNI	DIF	-	-	-

Multi-component tests are applied only for test groups with GHI, DNI, DIF or GTI columns.

2 Results of quality assessment

Prior to the comparison with satellite-based solar resource data, the ground-measured irradiance was quality-assessed by Solargis. Quality assessment (QA) is based on BSRN methods and methods implemented in-house by Solargis. The tests are applied in two runs: (i) first, the automatic tests are run to identify the obvious issues; next (ii) by the visual inspection we identify and flag inconsistencies, which are of more complex nature. Visual inspection is an iterative and time-consuming process.

The automatic QA tests may include:

- Correction of time shifts
- Identification of missing values
- Evaluation of measurements against sun position (Sun below and above horizon)
- Comparing the data with possible minimum and maximum physical limits
- Multi-component tests i.e. evaluation of consistency between solar radiation components (GHI, DNI and DIF) or relevant couples (GHI, RHI, DIF or GTI)
- Detection of outliers and patterns (TEMP)
- Tracker malfunction (DNI and DIF)

Automatic quality assessment can be applied on solar and meteorological data. The data readings not passing one or more QA tests were flagged.

Tab. 3: Availability of data readings for BMS station

	Data availability	
Sun below horizon	108 739	49.7%
Sun above horizon	110 257	50.3%
Total data readings	218 996	100.0%

Tab. 4: Summary of quality assessment results

Type of test	Occurrence of data readings (Sun above horizon)					
	GHI		DNI		DIF	
invalid values	517	0.5%	517	0.5%	517	0.5%
sun below horizon	0	0.0%	0	0.0%	0	0.0%
below minimum physical limit	53	0.0%	2	0.0%	42	0.0%
above maximum physical limit	0	0.0%	0	0.0%	6	0.0%
consistency issue	746	0.7%	746	0.7%	746	0.7%
two-component tests	1	0.0%	0	0.0%	1	0.0%
shading	3 387	3.1%	3 429	3.1%	0	0.0%
dirt, soiling	0	0.0%	9 671	8.8%	0	0.0%
post filtering	252	0.2%	222	0.2%	328	0.3%
not specified data issue	4	0.0%	0	0.0%	0	0.0%
Total excluded data readings	4 960	4.5%	14 587	13.2%	1 640	1.5%
Passed data readings	105 297	95.5%	95 670	86.8%	108 617	98.5%
Total data readings	110 257	100.0%	110 257	100.0%	110 257	100.0%

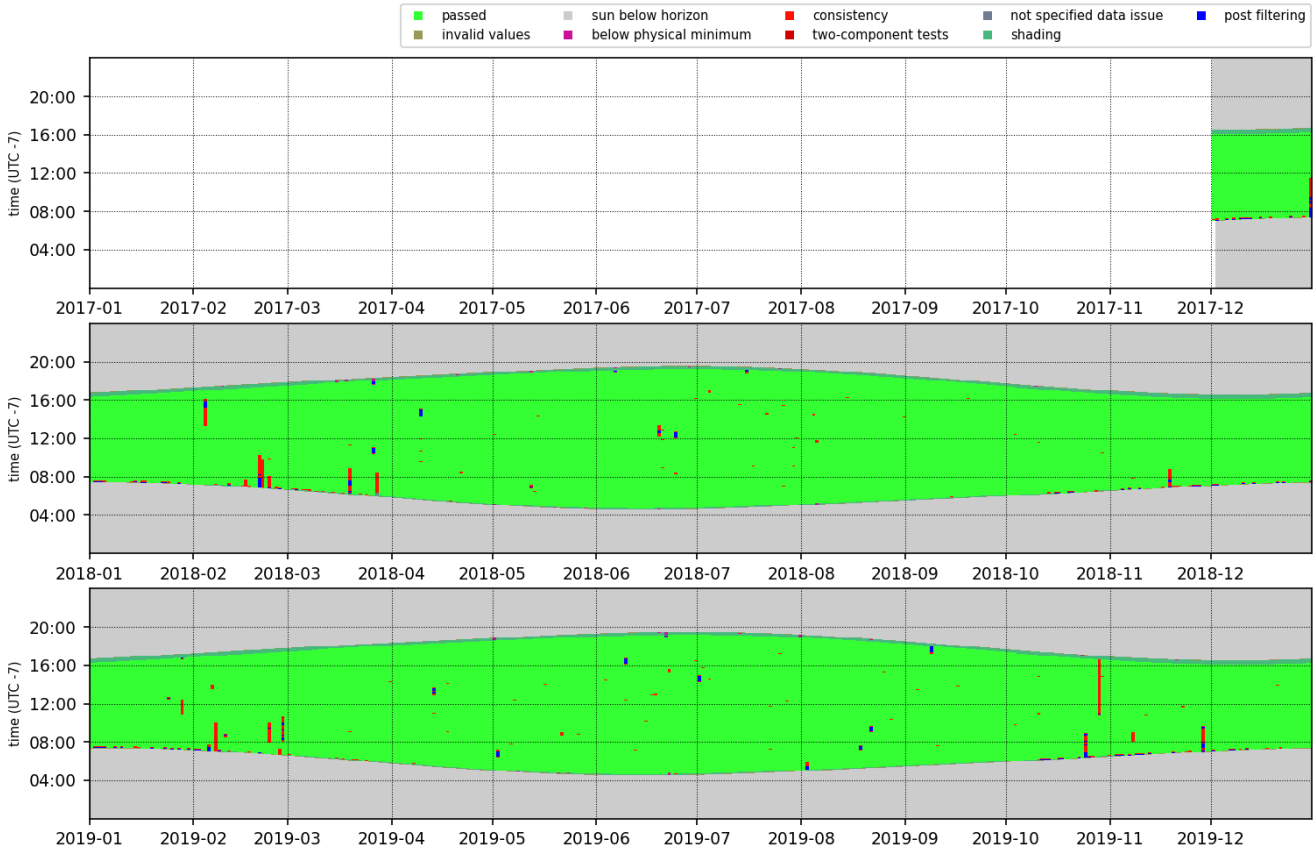

Fig. 2: Overview of quality assessment results for GHI

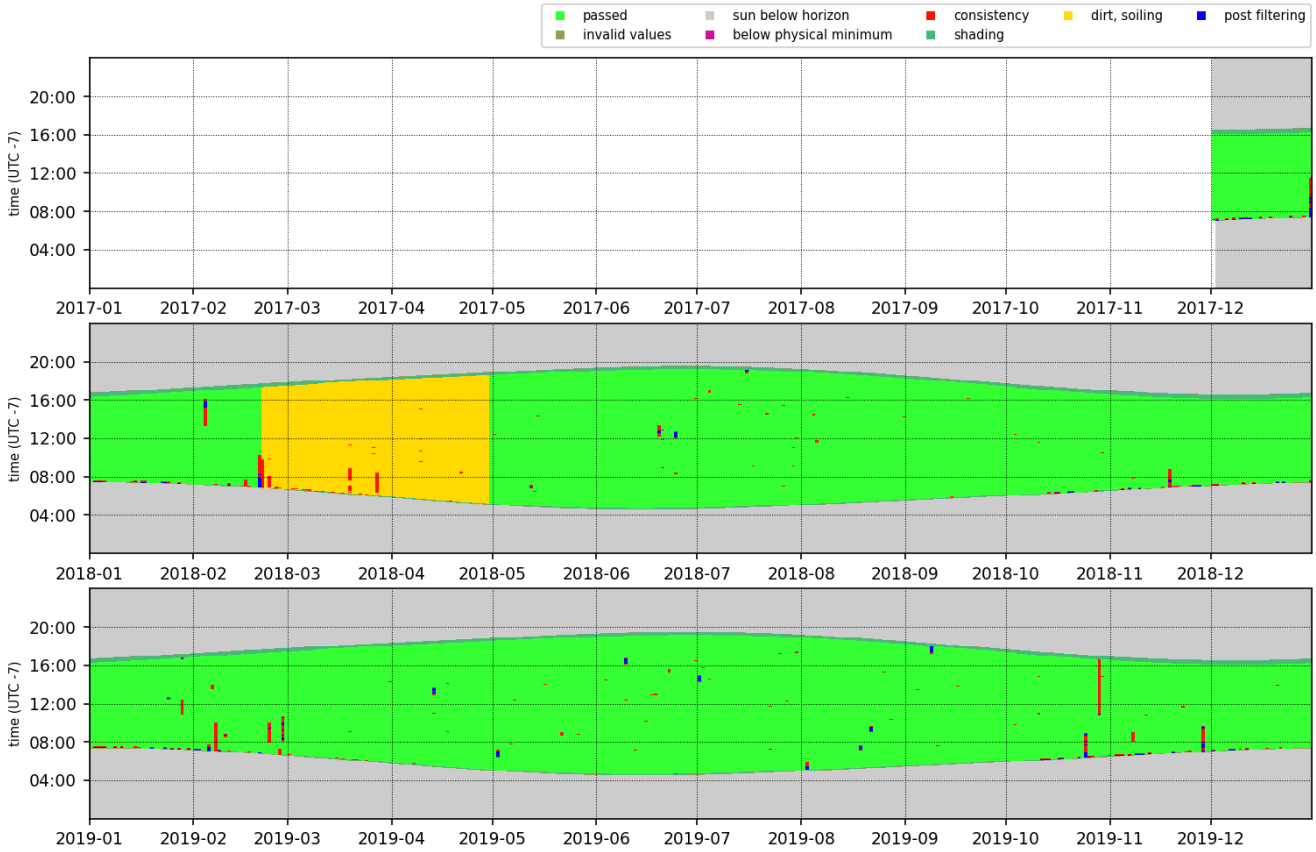

Fig. 3: Overview of quality assessment results for DNI

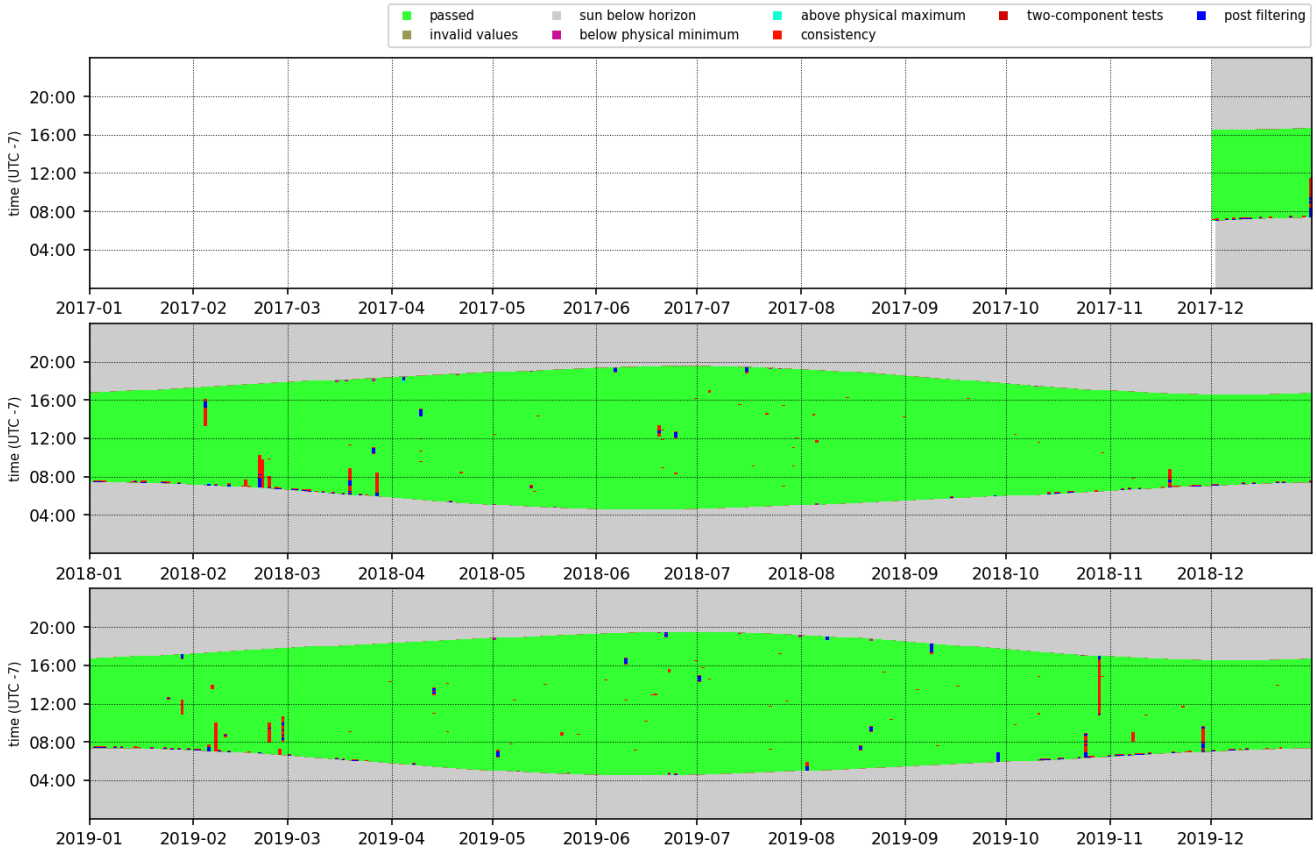

Fig. 4: Overview of quality assessment results for DIF

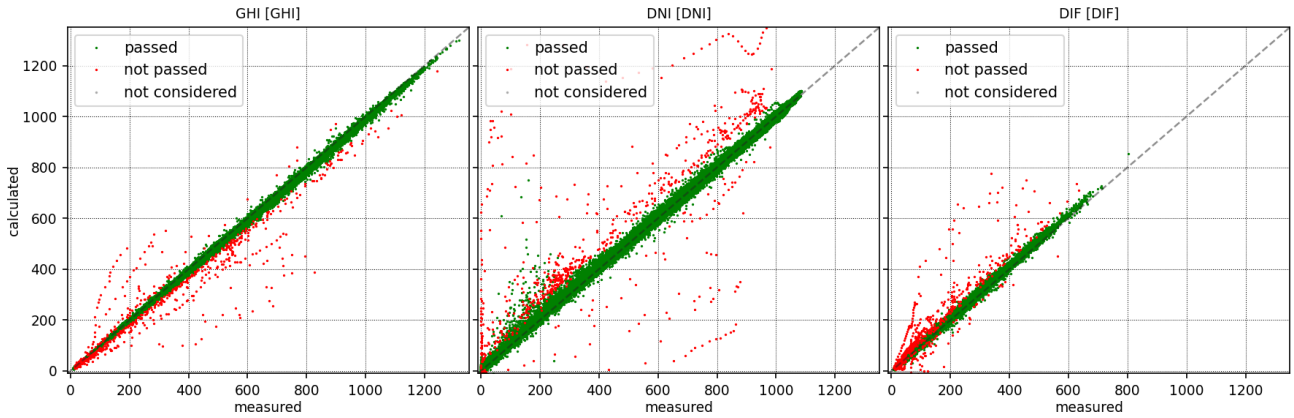

Fig. 5: Consistency plot of test group Group_1

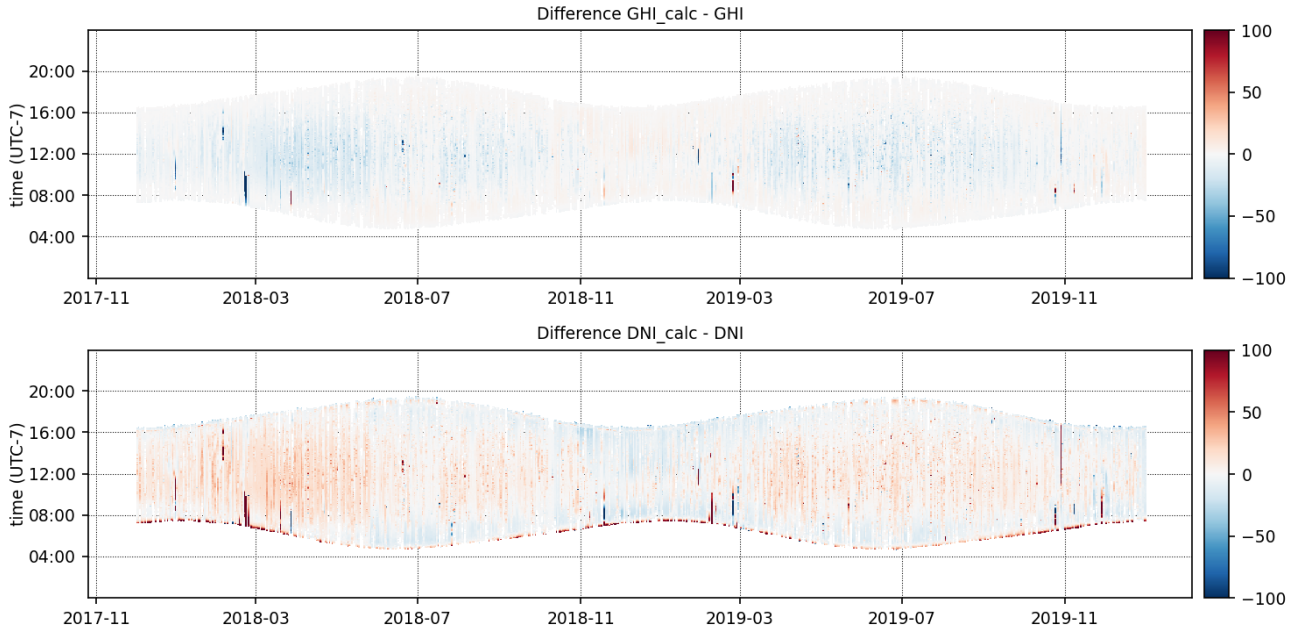

Fig. 6: Difference plot of test group Group_1

Tab. 5: Quality Control summary

Indicator	Quality	Note
Instrument accuracy		2x Class A instrument (CHP 1, CMP22)
Information on cleaning and maintenance		No information on instrument cleaning
Quality control complexity		Majority of quality control tests applied. Multi-component tests applied.
Availability of valid measurements		Approx. 25 months of DIF and GHI after quality control
		Approx. 23 months of DNI after quality control

Not specified | Very good | Good | Medium | Problematic | Insufficient

Quality assessment summary

Data is measured with high accuracy pyranometers and pyrheliometer, with frequent cleaning several times per week. Issues identified in the data include minor shading and degradation od DNI data for few months. Only passed data records qualifies for model validation.

3 Comparison with model data

The validation statistics were calculated from valid records after quality control and sun elevation higher than 5°.
Dataset 2013533_Solargis_TS_NREL_SRRL_BMS_USA_2017_2019 was used as model dataset for compare statistics.

Tab. 6: Global comparison of hourly values

	Bias		Root Mean Square Deviation, RMSD			Number of data pairs
	[W/m²]	[%]	Hourly [%]	Daily [%]	Monthly [%]	
GHI	-2	-0.4	21.4	10.5	3.9	8390
DNI	29	6.0	37.0	20.3	7.7	7625

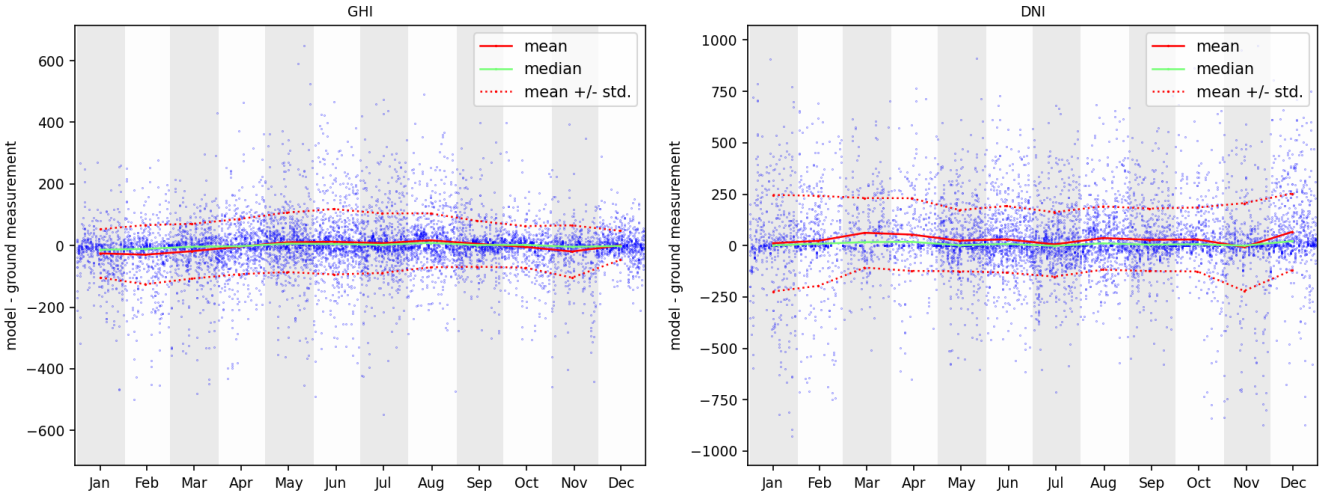

Fig. 7: Deviations of hourly GHI and DNI - BMS
X-axis: day of year DOY; Y-axis: difference between model and measurements

Tab. 7: Monthly comparison of hourly values – number of data pairs

Number of points	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GHI	528	525	687	718	856	837	867	774	706	623	529	740
DNI	528	449	346	370	856	837	867	774	706	623	529	740

Tab. 8: Monthly comparison of hourly values – bias

BIAS [%]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GHI	-8.4	-8.0	-4.1	-0.8	2.7	2.6	1.6	3.6	1.2	-1.2	-6.2	0.2
DNI	2.2	4.6	14.0	15.9	6.8	6.7	1.1	7.6	4.8	5.9	-1.3	12.2

Tab. 9: Monthly comparison of hourly values – RMSD

RMSD [%]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
GHI	27.0	27.0	20.2	19.8	24.6	22.9	19.7	18.8	16.2	18.8	28.2	16.4
DNI	45.2	44.8	40.6	54.8	42.7	36.4	30.8	33.0	26.7	31.3	40.3	36.1

Acronyms

Parameter types

DIF	Diffuse horizontal irradiance
DNI	Direct normal irradiance
GHI	Global horizontal irradiance

Quality control statuses

T / T	Time reference check (missing / done)
R / R	Radiation automatic quality check (missing / done)
M / M	Meteo automatic quality check (missing / done)
I+ / I	Manual quality check (missing / done)
P / P	Post filtering check (missing / done)

Glossary

BIAS	Represents systematic deviation between modelled and measured values (positive bias indicates overestimation and negative bias shows underestimation of the model) and is calculated according to this formula: $$Bias = measured - modeled$$ Bias indicates systematic (annual or seasonal) issues of a solar or meteorological model. It can also indicate systematic problem in measurements. In solar radiation model, this can be determined by insufficient cloud identification, coarse resolution and regional imperfections of atmospheric data (aerosols, water vapour), terrain, sun position, satellite viewing angle, microclimate effects, high mountains, etc. Bias may also indicate a quality issue of the measured data, e.g. misalignment, miscalibration or soiling of a sensor. In solar radiation model, this can be determined by insufficient cloud identification, coarse resolution and regional imperfections of atmospheric data (aerosols, water vapour), terrain, sun position, satellite viewing angle, microclimate effects, high mountains, etc. Bias may also indicate a quality issue of the measured data, e.g. misalignment, miscalibration or soiling of a sensor.
Root Mean Square Deviation (RMSD)	Represents spread of deviations given by random discrepancies between measured and modelled data and is calculated according to this formula: $$RMSD = \sqrt{\frac{\sum_{k=1}^{n}\left(X^{k}_{measured} - X^{k}_{modeled}\right)^{2}}{n}}$$ Considering solar radiation or meteorological model, RMSD reflects inaccuracies of cloud identification (e.g. intermediate clouds), under/over estimation of atmospheric input, data, terrain, microclimate and other effects, which are not captured by the model. Par of this discrepancy is natural - as satellite monitors large area, while the sensor can see only micro area of approx. 1 squared centimeter. Higher RMSD may also indicate lower quality of the measured data, e.g. lower accuracy, miscalibration or misalignment of the instruments, by soiling of sensor due to insufficient cleaning or issues in a data logger. It can also indicate insufficient data quality control.

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