IEA PVPS Task 16

Worldwide benchmark of modeled solar surface irradiance

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PVPMC, 23 August 2022

Technology Collaboration Programme
by IEA

Motivation for benchmarking

SolarAnywhere®

"SolarAnywhere is the **most trusted, accurate & validated** solar resource dataset available"

SOLARGIS

"Multiple independent studies have found Solargis to be the **most reliable solar database**"

SOLCAST

"Produce highly accurate historical irradiance estimates with the **lowest uncertainty available on the market**."

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Reference radiation data

Comparison to ground measured irradiance data

- Includes Tier 1 & 2 stations
- 1 min data resolution (GHI, DNI, DIF)
- Years: 2015 -2020

Tier 2 station examples

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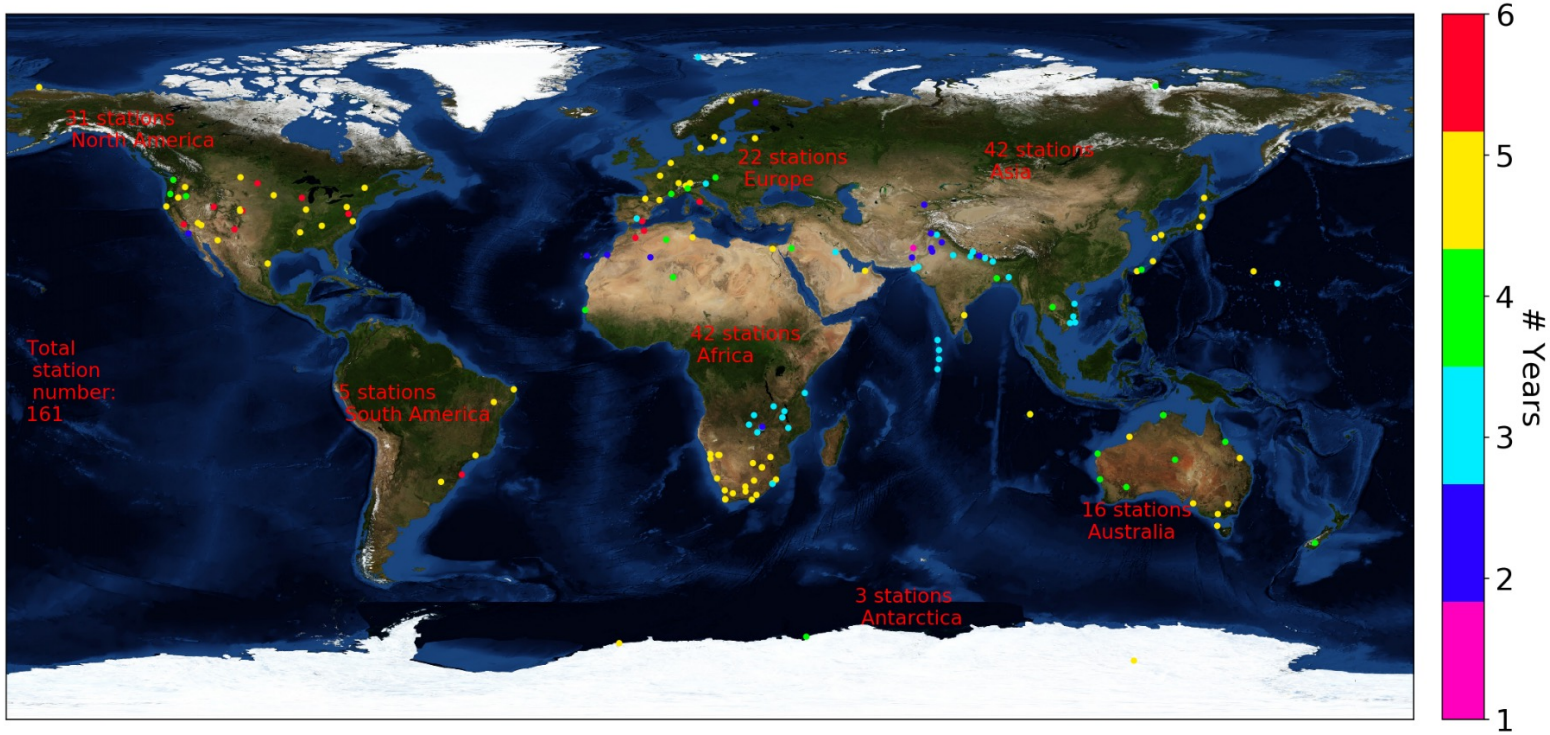
Ground stations



161 stations

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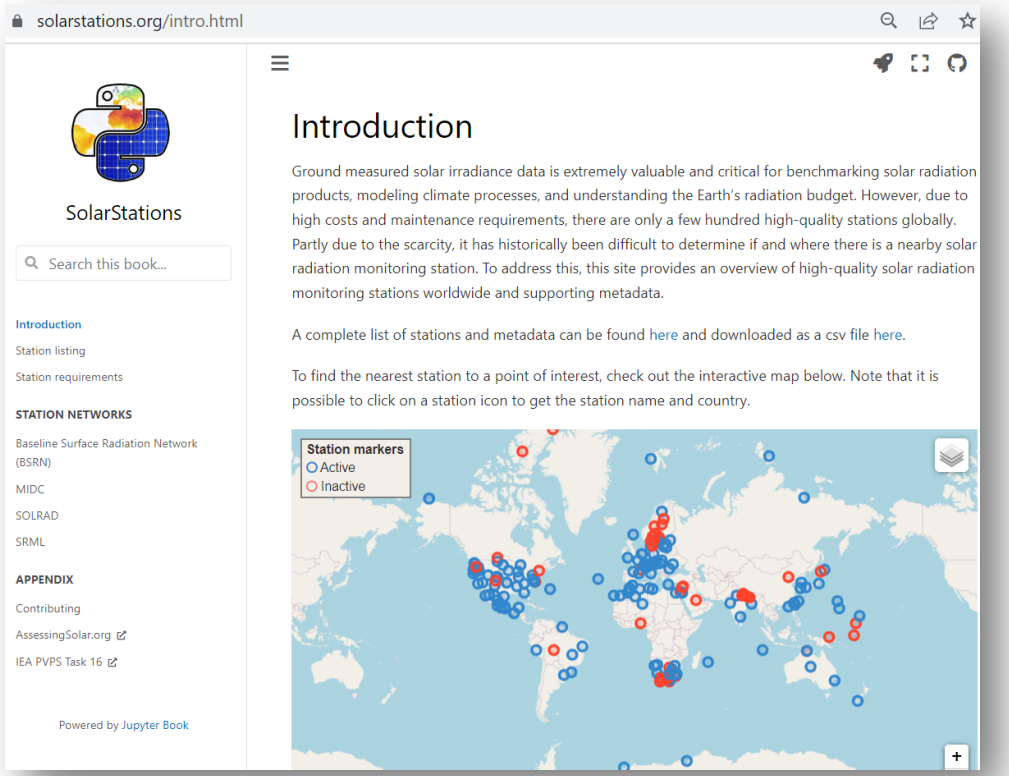
SolarStations.org

Catalog of metadata

- Latitude / longitude
- Operating period
- Webpage
- Etc.

Open source!



https://github.com/AssessingSolar/solarstations

Need for quality control

- Soiling
- Local obstructions (trees, buildings, etc.)
- Snow/dew on instrument
- Tracker misalignment
- Instrument malfunction
- Incorrect calibration
- Sensor tilt

Quality control

- Remove questionable / erroneous data
- Reduce uncertainty of dataset

Step 1: automatic checks

- Physically possible limits[a]
- Extremely rare limits[a]
- Three component test[a]
- Normalized K-tests[b]
- Tracker misalignment test[c]

15 automatic flags for each timestamp →

1: test passed
0: test failed
nan: test incomplete

Easy to implement

Well documented

Insufficient for some errors

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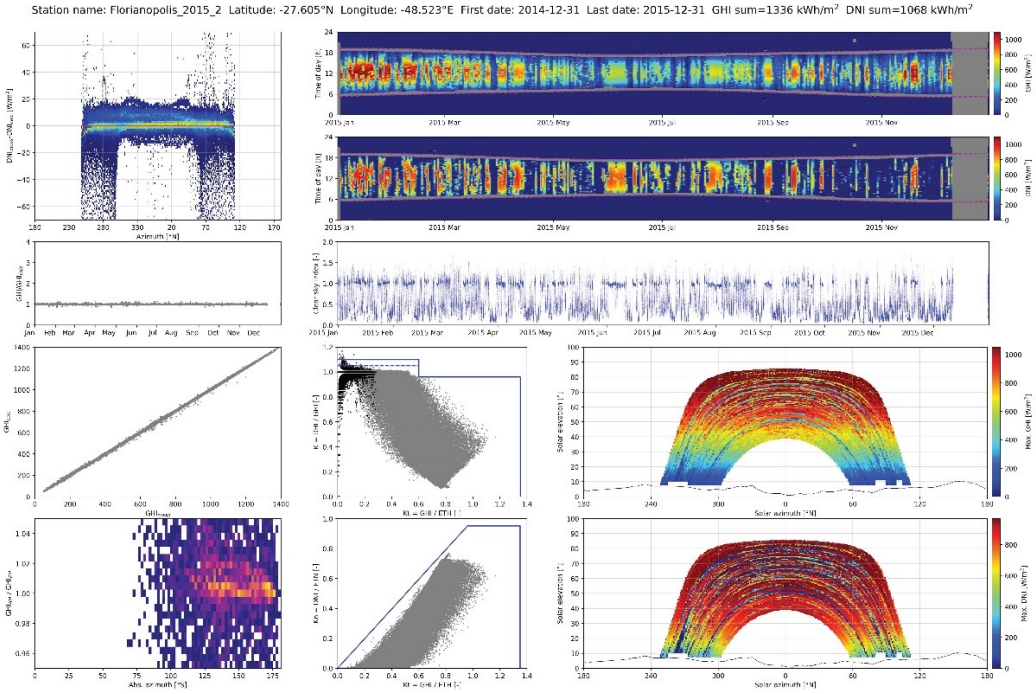
References
[a] Long and Dutton (2002)
[b] Geuder et al. (2015), Gueymard (2017)
[c] Peruchena (2020)

Step 2: visual inspection

- Visual check by an expert
- Three versions
  - Original data
  - With automatic flags
  - Final data
- Python code available
  github.com/AssessingSolar/solar_multiplot



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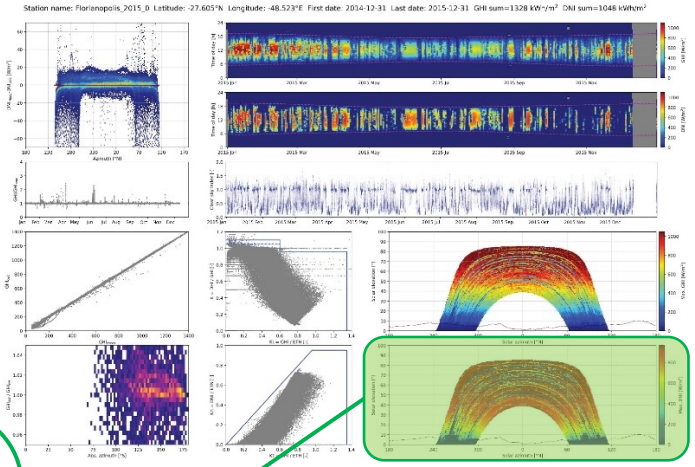
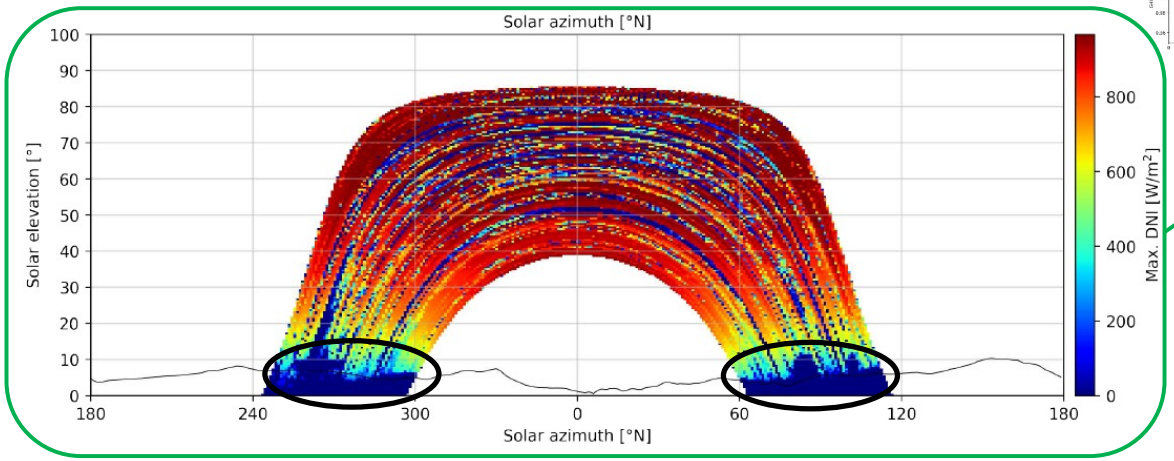
Multiplot: heat maps (elevation vs. azimuth)

Detects

- Shading
  - Horizon
  - Vegetation (e.g. trees)





Modeled data

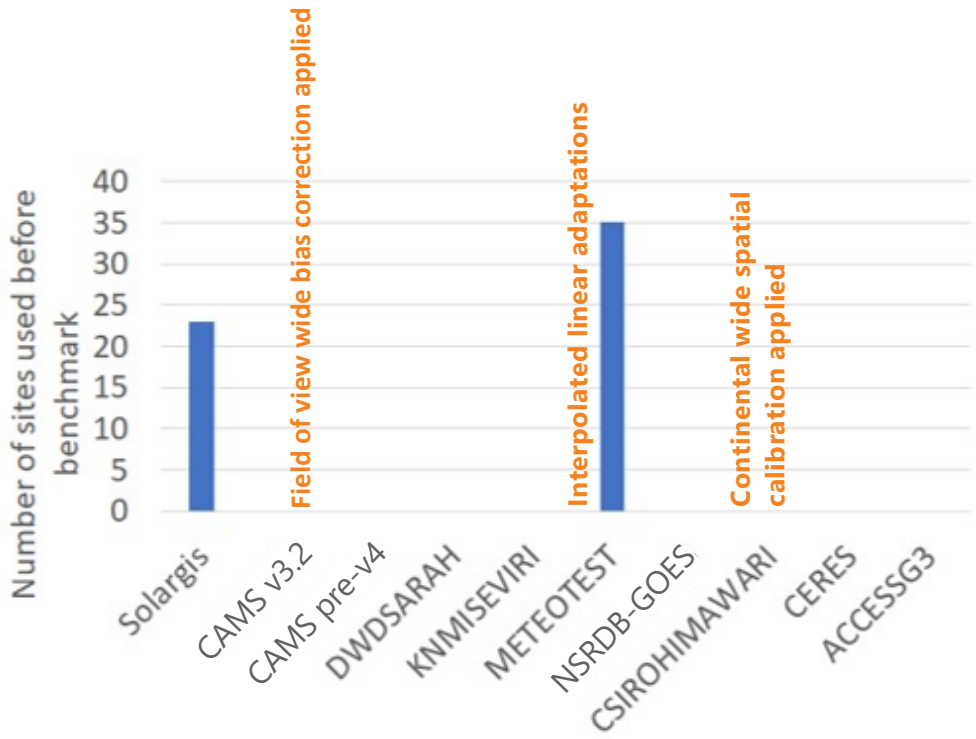
- 10 satellite and NWP model test data
- Benchmarking: 60 min

Provider	Dataset / model	Main data source	Spatial coverage
DWD	SARAH-2.1	MSG satellites	Full disk, Meteosat
CAMS	CAMS v3.2	MSG satellites	Europe / Africa / Middle East / Atlantic Ocean (Meteosat 2nd Gen. field of view, -66°N to 66°N). Clear sky data available globally.
	CAMS pre-v4		
Meteotest	Meteotest, various sat.	GOES-16, MSG-4, IODC, HIMAWARI-8, Meteotest MOS	Global (-66°N to 66°N)
CSIRO	CSIRO	Himawari-8	Australian continent
NREL (NSRDB)	Physical Solar Model Version 3	GOES	Contiguous United States, part of Alaska, southern Canada, Central America, and part of South America. Longitudes: 25°W - 175°W Latitudes: 21°S - 60°N to the north
Solargis	Solargis v2.x, various sat.	various satellites	Global (60°N to 45/55°S), land area and adjacent sea and oceans. Region between 60-65°N on request.
BoM	BoM APS3 ACCESS-G3	NWP	Global
NASA	CERES	various satellites	Global (60°N to 55°S), land area
KNMI	MSG-CPP algorithm v1	MSG satellites	Full disk, Meteosat

Metrics

Abbr.	Meaning
MBD, rMBD	Mean bias deviation, relative mean bias deviation
RMSD, rRMSD	Root mean square deviation, relative root mean square deviation
MAD, rMAD	Mean absolute deviation, relative mean absolute deviation
KSI	Kolmogoroff-Smirnoff Index
CPI	Combined Performance Index
OVER	Relative frequency of exceedance situations

Regional site adaptation (by data providers)



GHI – North America

GHI rMBD (%)

site / model	ALB	ARI	BAR	BIS	BON	BOU	DES	FOP	GOO	HAF	HER*	LAN	LAS	MAD	OAK*	PAN	ROS	SAL	SEA	SIL*	SIO	SOL	SRR	STR	BUR*	GOL	SET*	Mean	Std	Abs_Mean
SOLARGIS	-0.0	-1.3		-0.5	-3.5	-3.0	-1.0	-1.9	-0.7	0.9	0.1	0.0	-0.5	-0.4	14.5	1.9	-2.5	-0.4	0.7	-2.5	-2.6	-3.1	-0.6	-2.5	-1.7	-1.1	0.9	-0.4	3.4	1.9
NSRDBGOES	0.6	-1.1		1.6	-0.6	-4.9	-2.2	-2.4	0.5	1.6	0.0	1.9	-1.6	1.0	16.5	8.0	-1.1	-0.5	1.5	-1.7	-0.6	-1.4	-0.5	0.4	-2.0	-1.2	1.4	0.6	4.0	2.2
METEOTEST	-1.9	-4.3		-3.7	-9.3	-9.4	-6.4	-12.9	-7.0	-3.6	-7.6	-1.2	-5.5	0.0	17.0	3.9	-6.3	-1.3	-3.4	-7.3	-13.2	-3.2	-2.2	-3.5	-8.8		-9.6	-4.4	6.0	6.1
CERES	-11.7	-2.3	-78.6	-11.0	-8.3	-14.1	-18.6	-27.3	2.4	-9.4	-21.0	11.3	-18.0	-2.2	35.0	23.6	-3.3	-6.1	-3.1	-18.4	-20.6	-10.2	1.4	7.7	-22.5	0.7	-8.8	-6.2	14.4	12.7
ACCESSG3	2.5		-9.4	6.0						5.4	5.6	1.2		9.2	26.7			5.7	4.8	3.4		3.8		-0.5						

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* Indicate Tier 2 station

Results are preliminary!

DNI – North America

DNI rMBD (%)

site / model	ALB	ARI	BAR	BIS	BON	BOU	DES	FOP	GOO	HAF	HER*	LAN	LAS	MAD	OAK*	PAN	ROS	SAL	SEA	SIL*	SIO	SOL	SRR	STR	BUR*	GOL	SET*	Mean	Std	Abs_Mean
SOLARGIS	2.5	-0.1		0.2	-4.8	-5.3	-0.3	-5.3	-3.5	-1.8	-4.0	-2.6	1.7	-2.5	15.9	2.0	-4.2	-1.2	-5.2	-2.3	-3.8	-1.2	-2.8	-5.1	-4.0	-4.2	-6.4	-1.8	4.4	3.5
NSRDBGOES	6.2	1.8		14.0	6.0	-5.3	-2.5	2.0	5.4	5.5	2.7	10.3	0.1	10.7	26.7	24.9	7.9	5.4	11.4	4.7	6.3	5.2	3.0	10.9	0.8	0.8	8.2	6.9	7.2	7.5
METEOTEST	0.9	-4.8		-3.5	-20.0	-14.5	-7.0	-25.7	-20.5	-4.7	-18.7	-3.8	-6.6	-0.3	18.3	1.8	-6.3	6.9	-9.4	-8.2	-25.9	2.5	-1.8	-5.4	-16.3		-30.8	-8.2	11.3	10.6
CERES	-30.0	-19.8	-82.6	-28.1	-17.9	-29.4	-44.5	-54.7	-15.1	-29.8	-43.9	7.8	-41.6	-17.1	39.9	11.5	-7.4	-11.6	-17.6	-40.1	-43.9	-24.7	-12.7	6.1	-46.8	-14.4	-31.4	-21.7	21.7	26.9

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Results are preliminary!

GHI – Europe

GHI rMBD (%)

site / model	CAB	CAS	CEN	DAO	DAV	KIR	LOC	LYN	MIL	NOR	ODE	PAL	PAY	TAB	TOR	VIS	CAR	JAE*	KAZ	NYA	Mean	Std	Abs_Mean
SOLARGIS	-2.5	0.3	-0.1	-2.1	-1.0		0.5	0.9	1.9	-1.6	1.7	-1.8	-1.7	0.2	-2.3	-2.6	0.6	1.0	2.6		-0.2	1.6	1.3
METEOTEST	-3.6	-0.7	0.9	3.2	5.1		0.5	1.7	0.0	-0.7	8.8	-0.2	-2.2	3.4	-4.9	-7.1	0.1	2.7	2.1		0.9	3.2	2.4
CAMS_v3.2	2.1	-0.0	-2.5	-8.1	-6.7		-2.2	0.5	-1.8	-1.0	7.3	2.5	-2.7	-4.2	-3.2		-1.1	-1.3	4.8		-1.0	3.8	3.1
CAMS_pre-v4	-4.1	-0.8	-2.6	-10.2	-9.0		0.3	-4.5	-1.4	-4.4	-0.2	-3.3	-3.2	-1.8	-8.0	-4.4	-0.9	-2.0	0.8		-3.3	3.2	3.4
KNMISEVIRI	0.7	0.2	-0.2	-17.7	-17.3	-19.1	-3.0	1.9	2.7	0.3	-7.7	0.4	-1.3	-2.7	0.2	-0.8	-0.9	-1.4	-2.3		-2.8	6.0	3.6
DWDSARAH	-1.2	1.7	-1.0	-21.5	-20.4		-1.4	0.2	3.5	-1.6	-5.4	1.7	-3.7	1.7	-2.7		0.9	-1.5	-0.7		-3.0	7.1	4.2
CERES	-3.2	-3.8	-3.5	-8.0	-5.9	4.3	-7.7	3.2	-1.2	-0.1	-7.0	-0.7	-10.0	-6.2	-8.3	-2.4	-8.4	-5.1	-4.1	-38.8	-4.7	3.5	5.1
ACCESSG3		2.0		3.2	4.1		0.2	6.4		4.7	6.0	0.2		2.3		-0.9							

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Results are preliminary!

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Thank you!

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What actionable data do you need?

- How to group results? E.g., Climate, continents, etc.
- What metrics are of interest? Bias, RMSE, etc.
- Raw values (tables) or maps?
- Anonymized results to get commercial providers involved?

Additional criteria

- Only daytime (solar elevation > 0°)
- Each hour is split into 5-minute bins. The hour is considered valid if it contains a minimum of ten 5-min periods which each have at least three valid measurements.
- Measurements below horizon line are discarded
- Assess annual percentage of missing and flagged data