Developing a Guide for Non-experts to Determine the Most Appropriate Use of Solar Energy Resource Information

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Abstract

Knowledge of the solar energy resource is essential for the planning and operation of solar energy systems. There are a large number of different data sources available which makes it difficult for the non-expert in solar resource assessment to judge which source might be appropriate for a specific application. The United Nations Environmental Programme (UNEP) therefore supported the development of a Guide which will help users to make an educated decision about which data set to choose among several different available. The Guide basically consists of two tables. The first one is a description of the data sources. The second table consists of recommendations of minimum requirements in the characteristics of the data depending on different applications.

1. Introduction

Knowledge of the solar energy resource is essential for the planning and operation of solar energy systems. Solar data sets differ in spatial and temporal resolution, time period covered, and methods used. Some of these datasets are available for free, while some are not, and they all may provide different results. As a result, most users cannot verify the suitability of a given solar dataset or map based on the purpose of the use of their assessment. This can lead users to abandon their search or make non-appropriate use of the information. A simple Guide can help alleviate this problem, if it is developed through an open and inclusive consultation. The results of this study will provide guidance in data qualification and the selection of data sources for specific applications and give a better indication of the suitability of the available data sources. Therefore, aiming at developing better guidance about the energy application of solar resource information a user-friendly tool, or "Guide", has been designed to help experts and non-experts make an educated decision as to which solar data sets are appropriate for use depending on the type of solar application. The Guide has been developed in a joint effort between UNEP and the International Solar Energy Society (ISES) and in cooperation with principal experts in the solar radiation field (IEA/SHC Task36 [2], MESoR [3], and networks of active consultancies). The Guide basically consists of two tables. The first one is a description of the data sources. The second table consists of recommendations of minimum requirements in the characteristics of the data depending on different applications.

This paper starts with a short description of the characteristics of solar resources, which may help to understand why the tables were developed. Chapters 3 and 4 describe the two tables and the final chapter describes how the guide works.

2. Characteristics of solar resources and resource estimates

To understand the needs for different applications, it is helpful to first provide a short insight into the characteristics of the solar resource. Solar radiation is highly variable in time and space. The variability is mainly driven by weather: Atmospheric turbidity and clouds. This variability in time and space as a function of weather patterns can be significant over short distances and short time scales. Solar radiation data for monitoring and operating solar radiation systems has to be very site-specific to capture the temporal variability due to weather patterns.

Since planning and designing solar energy systems focuses on long term time scales, the data used in the design has to represent what can be expected in the long term future of a solar energy system. The annual sum of incoming solar radiation can change significantly from year to year due to natural interannual climate variability. Everybody remembers hot or very rainy summers. Figure 1 shows the annual variability of global horizontal and direct normal radiation at two sites in Germany and the USA. The small figure on top shows a time series of annual sums of global horizontal radiation in Potsdam from 1937 to 2000. The lower graph shows the maximum deviations of moving averages from 1 to 15 years compared to the long term average of all years in the data sets. It can be seen that at least 10 years of data are necessary to stay within the limit of ±5% of the long term average. This has nothing do to with the uncertainty of measurements or models, this is just natural variability. This curve shows that if a project is based on short term measurements of only a year of two, the estimation of the resource may differ substantially from what can be expected at this site in the long term.

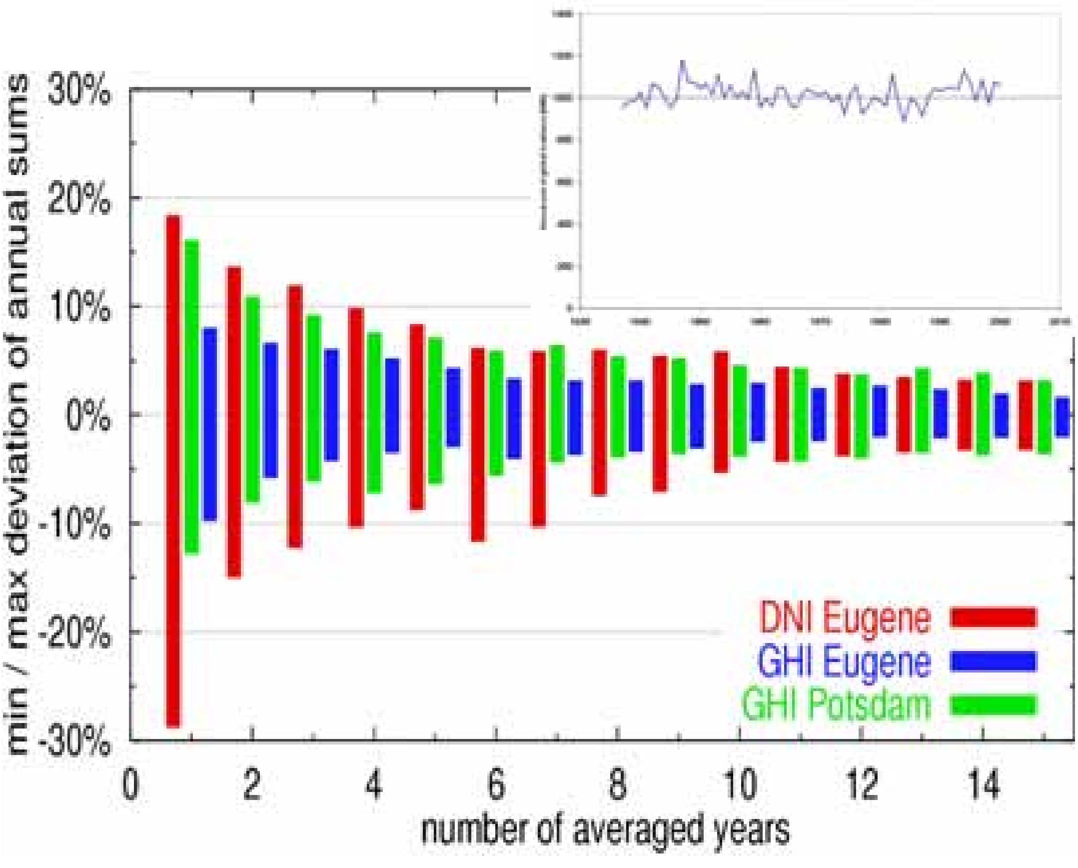
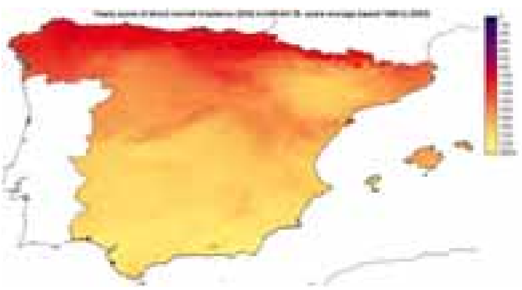


Figure 1: Annual variability of solar radiation. The top right figure shows the annual sum of global horizontal radiation in Potsdam for 63 years from 1937 to 2000. The graph shows the maximum and minimum deviation. The graph shows that in order to stay within a margin of ±5% at least a ten year average is needed.

Figure 2 is an example of the spatial variability of solar radiation. The left figure is a five year average of direct normal radiation in Spain. The right figure shows the annual differences in each year to this five year average. The patterns are quite different each year and the deviation and values change over short distance. This means that if one knows the deviation of data for the current year to a long term average on one site, one cannot transfer this result to the next site. Resource assessments have to be site specific.



Average of the direct normal irradiance from 1999-2003

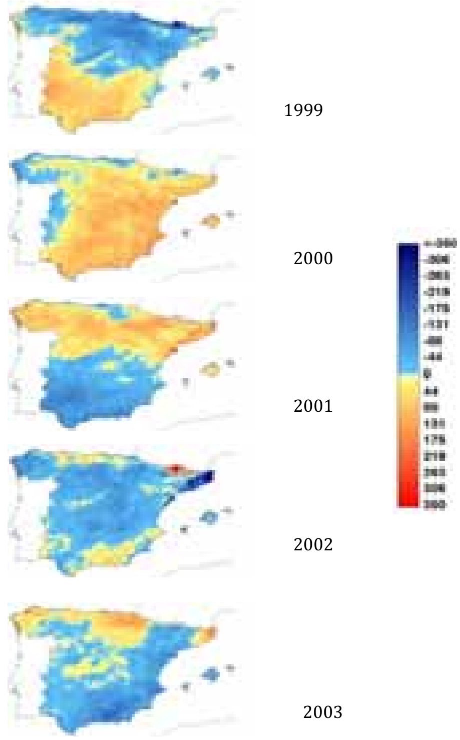


Figure 2: Spatial variability of the solar radiation, five year average (left figure) and annual differences to the average (right figure).

These two examples show two important features of a good resource assessment: it needs to be based on long term data (at least 10 years) and must have a high spatial resolution of a few kilometres. Satellite based resource assessments can provide both: satellite raw data is archived for many years and data from meteorological satellites in geostationary orbits has a very high spatial resolution.

But satellite data have limitations in temporal resolutions and therefore it is generally not possible to model all local effects. In addition, some of the input data sets (e.g. currently aerosols) are not available in high spatial resolutions. Ground measurements are therefore a necessary and helpful addition to satellite-based resource assessments. A major advantage of the inclusion of ground-based instruments is that they can register the solar radiation at very high temporal sampling rates of 1 min or even less. Such data are very useful for modelling transient effects in solar thermal systems e.g. at sunrise and sunset or the passage of a cloud.

3. Information about data sources

Table 1 gathers a selected number of the existing satellite-based solar radiation datasets as a practical sample of information and at the same time provides the features of each dataset. Table 1 does not intend to include all existing data sets, however it is open to be expanded on by the suggestions of providers, additional datasets and the respective metadata can be inserted by contacting the UNEP officer in charge of this Guide. For each dataset the following information is provided:

1. Organisation providing the data
2. Geographical coverage
3. Source of data: geostationary satellites, or a combination of geostationary satellites and ground stations
4. Spatial resolution: the minimum distance between two adjacent features or the minimum size of a feature that can be detected by a remote sensing system (units in km)
5. Temporal resolution: refers to the frequency with which images of a given geographic location can be acquired (15 min, 30 min, hourly, daily, monthly, annual….).
6. Time coverage. Period of time the data have been acquired (including start and end periods)
7. Component: The solar components contained in the dataset, i.e. GHI, DNI, TPI, DFI, PAR, Diffuse, Global in-plane, Global Tilt
8. Validation information available - published articles, preferably peer-reviewed & third-party (primary) authored, providing RMSE & MBE results with documented methodology, and using IEA/SHC Task 36 [2] and/or MESoR [1] benchmarks
9. Validation Type – none provided/not available (blank), conference paper, peer reviewed paper or third party authored peer reviewed using IEA/SHC Task 36 and/or MESoR benchmarks[i]:
10. Low Mean Bias Error (MBE): low difference between an estimator's expectation and the true value of the solar parameter being estimated. Considered Low when: <5% GHI; <10% DNI [ii]
11. Low root mean square error (RMSE): The root mean square error measures the differences between values predicted by a model and the values actually observed. Considered Low when: <120W/sqm hourly GHI; <160W/sqm hourly DNI
12. Frequency distribution metrics, eg KSI, OVER, available? If yes, values and link should be provided
13. Current data available / Near real time data
14. Availability: Free data sets or for sale
15. Website (where available)

See Table 1 below, which includes an example of the datasets included.

4. Recommendations on minimum characteristics

The second table (Table 2 in the Guide) takes the same metadata but relates it to a number of different applications, such as investment planning for different types and sizes of systems, operation of systems, policy analysis and science. For each application Table 2 provides a recommendation of the minimum characteristic to be fulfilled, e.g. in terms of spatial and temporal resolutions, for a data set to be suitable for this specific application.

See Table 2 below.

Table 1: Extract from the Data sets:

DATA SET	Providing organisation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Validation Type (1)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NASA-SSE	NASA	World	multiple satellites	100 km	Daily	1983-2005	GHI-DNI*	DNI is NASA-SSE. Literature and Conference. Benchmarked within IEA Task 36	bench marked	yes*	n/a	no	no	free	eosweb.larc.nasa.gov/sse	*DNI available only on a monthly basis; DNI bias exceeds 10% poleward of 60 degrees
Swera-40k	NREL	13 countries	US-Airforce cloud cover	40 km	Monthly	1985-1991	GHI-DNI	SWERA website		yes	n/a	no	no	free	swera.unep.org	Model based on histogram of 1985-1991 RTNEPH data; not updated by NREL
Swera 40k	INPE	Brazil and South America	satellites	40 km	Monthly	1995-2005	GHI, DNI, Tilt, DIF, PAR	MARTINS, Fernando Ramos ; PEREIRA, E. B. ; ABREU, Samuel Luna de . Satellite-Derived Solar	peer reviewed	Yes	Yes	Yes	No	Free	swera.unep.org	* DNI only for Brazil
Swera-10k	SUNY	13 countries	geostationary satellites	10 km	hourly	1999-2005	GHI-DNI	Conference articles	conference paper	yes	yes	n/a	no	free	swera.unep.org	** only selected sites are hourly
Swera 10k	INPE	Brazil	satellites	10 km	Monthly	1995-2005	GHI, DNI, Tilt, DIF, PAR	MARTINS, Fernando Ramos ; PEREIRA, E. B. ; ABREU, Samuel Luna de . Satellite-Derived Solar	peer reviewed	Yes	Yes	Yes	No	Free	swera.unep.org	
Swera 10k	DLR	Ghana, Ethiopia, Kenya, Bangladesh	geostationary satellites	10km	annual	3 years out of 2000-2003	GHI, DNI	Solar Energy Article	peer reviewed	yes	yes	n/a	no	free	swera.unep.org	
Solemi	DLR	Europe Africa Middle East	geostationary satellites	5 km	hourly	1991-2005	GHI-DNI	Mesor-Reports, Benchmarked within MESOR	bench marked	yes	yes	yes	no	for sale***	www.solemi.com	***one year free via MESOR
EnMetSol	University of Oldenburg	Europe Africa	geostationary satellites	3 km	hourly	1995-present	GHI-DNI	Mesor-Reports, Benchmarked within MESOR	bench marked	yes	yes	yes	yes	for sale***	www.energiemeteorologie.de	spatial resolution changes in 2005 to 0.005o, on request 15 or 30min values are available
Heliosat-1	Mines ParisTec	Europe Africa	geostationary satellites	30 km	monthly (DNI), daily (GHI)	1985-2005	GHI-DNI	Solar Energy Article; Benchmarked within MESOR	Peer reviewed				no	for sale*** 1985-1989 free	http://www.soda-is.com/eng/map/index.html	
Heliosat-2	Mines ParisTec	Europe Africa	geostationary satellites	5 km	1/4 hourly	2004 - present	GHI-DNI	Mesor-Reports & Solar Energy, Benchmarked within MESOR	bench marked	yes	yes	yes	yes	for sale***	http://www.soda-is.com/eng/map/index.html	***one year free via MESOR
Satel-Light	ENTPE	Europe	geostationary satellites	5 km	1/2 hourly	1996-2000	GHI-DHI**	Mesor-Reports, Benchmarked within MESOR	bench marked	yes	yes	yes	no	free	http://www.satel-light.com/	DNI must be calculated from horizontal direct DNI
NSRDB-SUNY	NREL	USA northern Mexico	geostationary satellites	10 km	hourly	1998-2007	GHI-DNI	NREL-Report	Peer reviewed	yes	yes	yes	no	free	http://rredc.nrel.gov/solar/old_data/nsrdb/	
Solar Anywhere	Clean Power Research	USA northern Mexico	geostationary satellites	10 km	hourly	1998-present	GHI-DNI	Solar Energy Article	peer reviewed	yes	yes	yes	yes	for sale	www.solaranywhere.com	
NRC-SUNY	Natural Resources Canada	Canada, below 60degrees	geostationary satellites	10 km	hourly	1998-2000	GHI-DNI	Ongoing Validation by CanMet		yes*	yes*		no	free		increased bias in winter due to prevalence of snow
PVGIS	EU-JRC	Europe, Africa	ground stations, satellite (Africa)	interpolation of variable density stations	monthly	1981-1990 (EU), 1985-2004 (Africa)	GHI, G inclined	Benchmarked within MESOR	bench marked	yes	N/A	N/A	no	free	http://re.jrc.ec.europa.eu/pvgis/	
SolarGIS	GeoModel	Europe, North Africa, Middle East	geostationary satellites	4 km disaggregated to 0.2 km	1/4 hourly	2004-2010	GHI, DNI, Diffuse, Global in-plane, Air	paper: Cebecauer et al. ASES SOLAR 2010 Conference	conference paper	yes	yes	yes	yes	for sale	http://solargis.info	Online shop for variety of data sets, including air temperature, PV planning tools
Meteonorm	Meteotest	World	combo measurements, mat. models	interpolation of variable density	hourly, minute	typical years (climatology 1981-2000)	GHI-DNI, inc.	Meteonorm-Reports, Meteonorm-Reports; Benchmarked within MESOR	bench marked	yes				for sale	www.meteonorm.com	
IRSOLAV	IRSOLAV - CIEMAT	Europe North Africa	geostationary satellites	5 km	hourly	1994-2009	GHI-DNI	Solar Energy Article	peer reviewed	yes	yes		no	for sale		
LTS	CENER	EUROPE, MENA, Australia	NWM, combo measurements	3 km to 9 km	hourly	typical	GHI-DNI	Renewable Energy article and Solarpaces congress	peer reviewed	yes	yes	yes	yes	for sale	na***	***Site specific

Table I: Datasets (cont.)

Table 2: Minimum requirements for different applications[iii] [iv]

	Minimum spatial resolution (km) [illegible]	Minimum temporal resolution	Minimum time coverage (years)	Solar radiation components	Peer-reviewed or third party-validated?	Database has been benchmarked according to IEA Task 36	Low Bias (<5% for GHI and <10% for DNI) (1)	Low root mean square error (< 125 W/sqm for hourly GHI and < 180 W/sq.m for hourly DNI) (1)	Frequency distribution metrics, e.g., KSI, OVER, available? (1)	Use of multiple independent data source	On site measurement *	Current data available / Near real time data
Investment Decision										recommended always	recommended always	No with the accuracy needed
Site selection	10	annual long-term (map)	10	GHI or DNI	yes	no	yes	n/a	n/a	yes	no	no
Pre feasibility	100	annual long-term	5	GHI or DNI	yes	no	yes	no	no	yes	no	no
Feasibility	10	hourly	10	DHI or DNI	yes	yes	yes	no	no	yes	no	no
Design and construction												
PV offgrid systems (4)	10	hourly	10	GHI	yes	yes	yes	no	yes	yes	yes	yes
PV Small systems	10	monthly	5	GHI incl	yes	no	yes	no	no	no	no	no
PV Medium sized systems	10	hourly	5	GHI + DNI, in	yes	yes	yes	no	yes	yes	yes	yes/no
PV Large systems	10	hourly	10	GHI + DNI, in	yes	yes	yes	no	yes	yes	yes	yes
Tracking / concentrating PV	10	hourly	10	GHI + DNI, in	yes	yes	yes	no	yes	yes	yes	yes
Solar hot water	100	monthly	5	GHI incl	yes	no	yes	no	no	no	no	no
Solar cooling	100	monthly	5	GHI incl.	yes	no	yes	no	no	no	no	no
CSP	10	hourly	10	DNI	yes	yes	yes	no	yes	yes	yes	yes
Daylighting		hourly	5	Illuminance	yes	no	yes	no	no	no	no	no
Solar Process Heat	10	hourly	10	GHI	yes	yes	yes	no	yes	yes	yes	yes
Due diligence	10	hourly	10	GHI + DNI	yes	yes	yes	no	yes	yes	yes	yes
Commissioning / System Acceptance	10	hourly	10	GHI + DNI	yes	yes	yes	no	yes	yes	yes	yes
Operation										recommended always	recommended always	No with the accuracy needed
Performance monitoring (does the system work correct?)	10	hourly	n/a	GHI + DNI	yes		yes	yes	less important	no	no	yes
Performance improvement (how to improve system performance)	10	hourly	n/a	GHI + DNI	yes		yes	yes	less important	no	no	yes
Forecasting	10	hourly	n/a	GHI	yes		yes	yes	less important	no	no	yes
Energy policy										recommended always	recommended always	YES
Potential assessment	10	annual long-term (map)	5	GHI	yes	yes	yes	n/a	n/a	yes	no	no
Design of support instruments, e.g. levels of tariffs, incentives,	10	annual long-term (map)	10	GHI	yes	yes	yes	n/a	n/a	yes	no	no
Climate policy										recommended always	recommended always	No with the accuracy needed
Climate models	25	daily	VARIABLE	GHI	yes	yes	yes	no	no	no	no	no
Impact assessment models	10	daily	10	GHI+DNI	yes	yes	yes	no	no	no	no	no
Climate monitoring	25	annual	20	GHI+DNI	yes	yes	yes	no	no	yes	yes	yes
Science										recommended always	recommended always	No with the accuracy needed
Energy system analysis (Systems, components)	10	hourly	n/a	GHI + DNI (5	yes	yes	yes	no	yes	no	no	no
System simulations	10	hourly	n/a	GHI + DNI (5	yes	yes	yes	yes	yes	no	no	no
Grid integration studies	10	hourly	5	GHI	yes	yes	yes	yes	yes	no	no	no

5. Operation of the Guide

The online user-friendly Guide helps expert and non-expert users to decide which solar resource data sets are the most appropriate depending on a type of application that the user is interested in. Figure 3 depicts how the Guide works. The Guide relates information back to Tables 1 and 2 above.

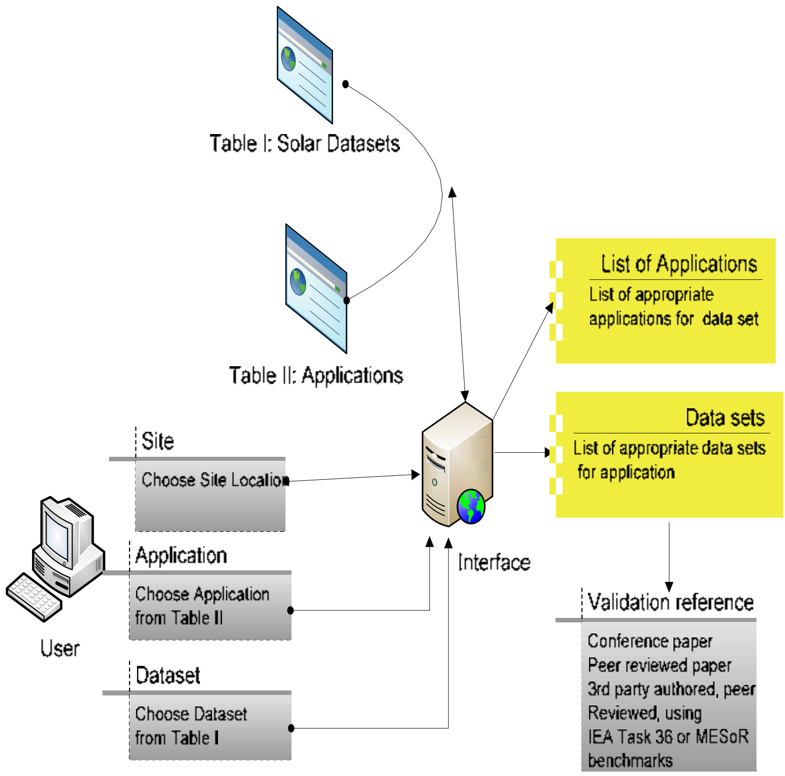


Figure 3. Scheme for the operation of the Guide to determine the most appropriate use of solar energy resource information

The user selects one of the three entry types that are possible: application of the user (see classification of applications in Table 1) and/or location of the site or the solar data of interest. The interface interconnects Table 1 and 2 with the inputs given by the user. As a final output, the Guide provides either a list of relevant datasets for specific purpose or a list of applications a dataset can be used for.

To support the validity of the information presented in both tables, a consultation with experts was undertaken. The experts are members of the IEA/SHC Task 36. They provided input to expand and up-date the metadata in Table 1 and review the requirements in Table 2.

The final Guide will be available on the UNEP Energy Branch website, with links available from the ISES, IEA Task 36, and MESOR websites as well as the SWERA (Solar and Wind Energy Resource Assessment) website, unep.swera.net, where many of the listed data sets can be found. Supporting documentation describing the guide will be available describing the tables and how to use the guide.

References

[1] C. Hoyer-Klick et al, "Management and Exploitation of Solar Resource Knowledge", EuroSun 2008

[2] Task 36 "Solar Resource Knowledge Management" under the International Energy Agency's (IEA's) Solar Heating and Cooling Implementing Agreement

http://www.iea-shc.org/task36/index.html

[3] European Commission-funded MESOR 'Management and exploitation of solar resource knowledge' - http://www.mesor.org/

[3] UNEP/ISES Project "Developing a benchmarking tool for solar energy resources datasets, a globally applicable tool" supporting documentation.

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[i] Peer reviewed papers by third party author would imply higher quality work than a conference paper, but this is not necessarily always the case. Validation references not available for all datasets

[ii] For points 10 -12: When short-term, locally specific solar radiation measurements are available; these can be used to reduce the uncertainty of the satellite modelled estimates for that particular location. Doing so combines the precision of the ground measurements and the long term coverage from the satellite models. There are several methodologies to combine the short-term with the long-term data to obtain a more accurate estimate of the long-term solar resource at the site, ranging from the simple so-called ratio method (taking the model/measurement ratio over their short-term common period and applying this ratio as a model correction over the long term) to more sophisticated methods adjusting the model's underlying parameters (e.g., its turbidity settings) to better match observations, and to optimally combining multiple modelled data sets and ground measurements. These procedure have been shown to be effective as long as the satellite model to be corrected has a sound physical basis and is self-consistent over the long term (i.e., has been validated in a sufficient number of locations to properly account for long term trends and year-to-year variability).

[iii] For low Mean Bias Error (MBE), low Root Mean Square Error (RMSE) and frequency distribution columns, see end note above.

[iv] On site measurements should encompass at least one years worth of ground measurements