FEATURES AND PERFORMANCE VALIDATION OF Solargis SOLAR RADIATION MODEL FOR JAPAN

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SUMMARY: We present methods and performance validation of Solargis model for the territory of Japan. The model provides subhourly time series of solar radiation at high level of spatial detail. The validation shows the uncertainty of yearly estimates to be ±4% for global horizontal irradiance, and within ±8% for direct normal irradiance. High accuracy of the model data allows for its use in bankable evaluation of technical design and financing of solar power plants. The model outputs are updated in real time and they are also used in regular monitoring and forecasting of solar power at the level of a single site or for large portfolios of solar power plants.

Keywords: Solargis, solar resource, solar model

INTRODUCTION

Well-designed modern solar models deliver high accuracy solar radiation for almost any location. They benefit from data produced by high resolution satellite instruments and global atmospheric models and they rely on high accuracy solar measurements. On the example of Solargis approach at the territory of Japan, this abstract discusses computation of solar radiation and the model accuracy. In the extended manuscript, we will discuss also the challenges and benefits of solar modelling and the prospects for accuracy improvements in close future.

SOLARGIS MODEL

Solargis represents models and high-resolution global database of solar resource and meteorological parameters updated in real time. The geographical extent covers the land surface between latitudes 60º North and 55º South. Japan and East Asia is covered by data from year 2007 onwards (Figure 1).

Solar radiation is calculated by grid-based numerical models, which are parameterized by a set of inputs characterizing the cloud transmittance, state of the atmosphere and terrain conditions. An overview of the Solargis model and its uncertainty is discussed in [1, 2].

Clear-sky Global Horizontal Irradiance (GHI) is calculated by the simplified SOLIS model by Ineichen. This model allows fast calculation with good precision for any type of climate. Variability of clear-sky atmospheric conditions is described by aerosols, water vapour and ozone. For Japan, the following data are used:

- Atmospheric Optical Depth (AOD), calculated by MACC-II/CAMS project (ECMWF) and delivered at a spatial resolution of app. 75 km and 125 km. The daily AOD aggregations are used to capture the highly variable nature of aerosols. This improves statistical distribution of irradiance values.
- Water vapour is also highly variable, but it has lower impact on accuracy of GHI and DNI. The daily aggregated values are derived from GFS and CFSR databases (NOAA NCEP).
- Ozone has negligible influence on the broadband solar radiation, therefore in Solargis it is implemented as a constant.

Effect of clouds is calculated from the satellite data in the form of **cloud index** (cloud transmittance). Cloud index is derived by relating radiance recorded by the satellite in several spectral channels and surface albedo to the cloud optical properties. Solargis model uses data from MTSAT and HIMAWARI8 satellites (JMA). The calculation scheme is based on a modified Cano approach.

To calculate **all-sky global horizontal irradiance** in each time step, the clear-sky GHI is coupled with cloud index.

Direct Normal Irradiance (DNI) is calculated from all-sky GHI by modified version of the Perez Dirindex model. Diffuse irradiance for tilted surfaces is calculated by the Perez transposition model. The calculation includes also terrain disaggregation by Ruiz Arias model (spatial resolution is increased to grid cell of approx. 250 meters).

MODEL VALIDATION

Solargis model is validated by solar measurements available at more than 250 public meteorological stations, and at numerous commercial measurements sites, worldwide. Tables 1 to 3 show the GHI and DNI model accuracy statistics for Japan and South Korea. We use only data from high accuracy (BSRN-standard) stations. The use of ground measurements from other sources can be limited, typically because they use less accurate sensors and apply less rigorous operation and maintenance standards. Limited or no quality control of measurements poses also a barrier for their use in validation.

The validation statistics, shown below, is determined by two sources of uncertainty: (i) model algorithms and of the input atmospheric and satellite data, and (ii) accuracy of the sensors, reliability of maintenance and the level of data quality control.

Table 1. Validation sites in Japan and South Korea

Site name	Source	Lat. [º]	Long. [º]	Ele. [m]
Ishigakijima	BSRN	24.3367	124.1633	11
Tateno	BSRN	36.05	140.1333	25
Sapporo	BSRN	43.06	141.3283	17
Fukuoka	BSRN	33.5817	130.375	3
Minamitorishima	BSRN	24.2883	153.9833	7
Yonsei University	Solarflux	37.5644	126.9349	88

Table 2. Validation of Direct Normal Irradiance

	Bias		Root Mean Square Deviation [%]		
	[W/m^2]	[%]	Hourly	Daily	Monthly
Ishigakijima	2	0.7	43.7	25.7	4.9
Tateno	-2	-0.7	39.4	22.4	3.4
Sapporo	5	1.4	53.4	33.8	7
Fukuoka	-15	-4.4	40.3	25.7	8.2
Minamitorishima	-1	-0.3	28.3	14	2.3

Table 3. Validation of Global Horizontal Irradiance

	Bias		Root Mean Square Deviation [%]		
	[W/m^2]	[%]	Hourly	Daily	Monthly
Ishigakijima	-5	-1.3	24.2	14.3	2.3
Tateno	0	-0.1	20.4	10.7	2.4
Sapporo	-4	-1.4	29.1	17.1	3.4
Fukuoka	1	0.2	24	13.6	3.2
Minamitorishima	-2	-0.4	15	7.2	1.4
Yonsei Univ.	10	2.7	17.9	9.6	3.4

UNCERTAINTY OF MODEL ESTIMATES

Validation statistics provides a good tool for the scientific model evaluation. To be more practical, the statistical measures are converted into uncertainty, which better characterizes probabilistic distribution of error, and it is better understood by solar industry.

In situation of limited number of high accuracy validation data, and limited time coverage of the model (only 11+ years of model data is available for East Asia) the way of evaluating the uncertainty is to consider normal distribution of error (which is great simplification, but practical) and to apply confidence intervals for estimating its probabilistic nature. This allows to calculate different probability scenarios. For example, **P50** value represents the most expected value, from which various levels of confidence can be expressed. In solar resource assessment and solar electricity modelling, 80% probability of error occurrence is often assumed, as it can be easily used for calculation of P90 values for GHI or DNI (**P90** represents a value that would be exceeded with 90% probability). Thus, the uncertainty in this abstract is considered as 80% probability of the occurrence (or 90% probability of exceedance) of error.

The most important value by project developers, technical consultants and finance is the uncertainty of the long-term yearly estimate at the level of a project site. The model uncertainty can be estimated from bias values calculated in the region.

Analysis for Japan (considering the global context) leads to the following statement:

- In approx. 80% of cases, the uncertainty of yearly model estimates is within ±4% for GHI and ±8% for DNI.
- Higher uncertainty can be expected in high mountains and snow regions, coastal zones, and in highly urbanized and industrial areas.

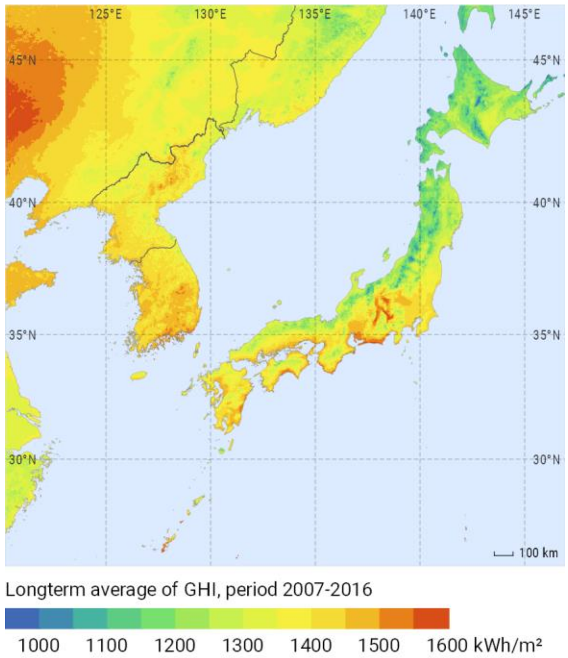

Figure 1. Global Horizontal irradiation map: Subset of Japan and neighboring countries

CONCLUSIONS

Solargis model shows good accuracy in Japan, and globally. The solar data is used for prospection and development of solar power plants. The model updates data in real time, which is used for regular evaluation of solar assets, and for forecasting and management of solar power at the level of individual sites and electricity grids.

References

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