SolarGIS: New Web-Based Service Offering Solar Radiation Data and PV Simulation Tools for Europe, North Africa and Middle East

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Abstract

A new online service SolarGIS offers solar energy industry fast and easy access to solar radiation and air temperature data within Europe and the Mediterranean region. Geographical databases consist of high resolution solar radiation (global, diffuse and direct normal irradiance) and air temperature. Solar radiation database covers period 2004-2010, and is calculated from Meteosat MSG data using new high-performance algorithms. Derived solar parameters are calculated at a spatial resolution up 80 meters using new terrain disaggregation method and Digital Elevation Model SRTM-3. Air temperature database is calculated at spatial resolution of 1 km from ECMWF ERA Interim data source covering period 1991 to 2009. Access to the data is managed via a map-based interface with geographical search functionality exploiting Google Maps API. This service offers to solar energy industry a unique and standardized access to primary and derived data available at various time scales – from yearly and monthly averages to daily, hourly and 15-minute values. Simulation tools enable calculating solar parameters and PV power potential for any fixed-mounted or suntracking solar energy system.

1. Introduction

A number of data and software options are available in Europe and worldwide [1,2]. However, there are still options to improve efficiency of site selection, planning, and design of solar energy projects. SolarGIS (http://solargis.info/) is a new generation web service offering a range of unique features. The core of the system is based on **(i)** a new high resolution climate database, systematically build from satellite and meteorological sources, and with extensively validated accuracy. The innovation of the SolarGIS web system builds on grounds introduced to solar community by PVGIS web prototype [3]: **(ii)** fast and easy geographical navigation using interactive maps, **(iii)** easy to understand tools for accessing and display of data and simulation software for solar energy systems.

2. Primary database

At present the data geographically cover major parts of Europe, Turkey, North Africa and Middle East. Until end of 2010 the extent will cover complete continent of Africa. Besides solar radiation and temperature it includes also high resolution Digital Elevation Model (source SRTM-3, spatial resolution 80 metres in Central Europe), data about land cover and population. In order to provide fast access to these resources data are organised in data structures that are optimised for a point access.

2.1. Solar radiation

A new model for high-performance calculation of Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) from satellite was implemented for Europe, Middle East and Africa [4]. The model is designed for operational processing of Meteosat MSG satellite data at full spatial and temporal resolution, geographically covering Europe, Middle East and Africa. The algorithms are based on the Heliosat-2 calculation scheme [5] and the approach of [6].

The key enhancements of the new model include: (1) multi-spectral satellite information to improve classification of snow/land/cloud signals, (2) a new algorithm to more accurate calculation of lower bound preserving diurnal variability, (3) implementation of backscatter correction (4) variable upper bound for dynamic range and cloud index calculations, (5) new clear sky model, adapted DirIndex model for calculation of DNI from Global Horizontal Irradiance, and (7) downscaling with high resolution DEM to include local variability of solar irradiance (algorithm published recently by [7]).

A new broadband simplified version of the SOLIS model [8] is implemented in the calculation scheme. This model allows fast calculation of clear-sky irradiance from three input parameters characterizing the state of the atmosphere: water vapour, aerosol content and aerosol type (urban, rural, maritime and tropospheric).

Two global atmospheric data sets are implemented in the clear-sky model: water vapour (WV) and Atmospheric Optical Depth (AOD), both received from ECMWF [9]. New AOD data set is one of the main outcomes of the European project GEMS. It better captures daily variability, especially events with extreme atmospheric load of aerosols and water vapour. Thus it reduces uncertainty of instantaneous GHI and especially DNI estimates. Main accuracy improvements were achieved in reduction of Root Mean Square Deviation (RMSD) and improved distribution functions.
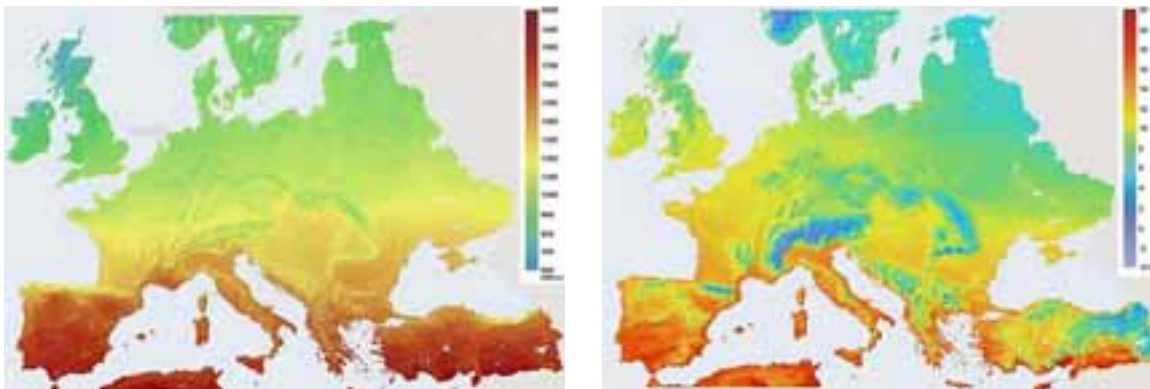

Fig. 1. Sample data from the SolarGIS database: annual sum of global horizontal irradiation (left), and annual average of air temperature (right).

Compared to other approaches, the advancements of the model improved results in mountains, coastal and arid zones, and for periods with snow coverage. IEA SHC Task 36 and MESOR [10] recommendations were used for database validation using data from more than 60 ground measurement stations for GHI and 30 stations for DNI. The relative mean bias (rMB) for GHI is 1.1%,

and root mean square difference (rRMSD) is 18.5%, 9.6% and 4.8% for hourly, daily and monthly data, respectively. For DNI rMB is -0.8%, and rRMSD is 35.6%, 21.9% and 9.3%, respectively.

Solar radiation data are available from March 2004 onwards at 15-minute or aggregated time domains, in high spatial resolution.

2.2. Air temperature

Air temperature is derived by disaggregation of ECMWF ERA Interim data to a final grid resolution 1 km. In the disaggregation high-resolution digital terrain model SRTM-3 is used to adapt vertical gradient of temperature from low resolution ERA grid cells to 1-km grid. Primary data include 6-hourly values covering a period from 2001 to 2009. By temporal interpolation, 15-minute time steps are calculated from the primary data in SolarGIS applications.

Accuracy of monthly statistics was validated using observations from more than more than 700 ground stations: mean bias is close to 0.1°C and RMSD is ranging between 0.4° and 0.6°C.

3. Web-based applications

The volume of databases extends several terabytes, and therefore the only way to access them is via online applications. In year 2010 three applications have been started in SolarGIS. They use an interactive geo-location and geographical search interface (based on Google Maps and search technology). A number of derived data products and simulations are calculated from the primary database. All transactions are accompanied by and reports in standardized formats: csv, xls, and pdf.

3.1. SolarGIS iMaps

The first map-based prototype for solar energy was made within PVGIS project [3].

Fig. 2. SolarGIS iMaps – interactive maps.

The main task in SolarGIS was to adapt new geoinformation approaches and web technologies and to make search of information and map exploration more efficient and understandable also for non experts.

The iMaps application enables interactive browsing of maps (spatial resolution up to 250 metres): solar radiation and temperature from a continental to local scale. Other support maps are also available: terrain, land cover, population and standard Google maps. For any point clicked on a map, the system interactively shows values of annual solar radiation (global horizontal, global irradiation for 30° and for 2-axis tracking surfaces, diffuse and direct normal irradiation) and air temperature (yearly average, January and July). In addition, support information about terrain, land cover and population are also displayed. The information in the database is stored in optimised data formats so that the site-specific information is on-click available in full resolution for the whole database extent.

The system is designed to provide a users fast access to key information needed for a site selection or comparison. Map-based technology shows information in a spatial context, thus a user can better understand regional changes of climate resulting from proximity to a seaside, mountains, terrain shading, elevation, etc.

3.2. SolarGIS climData

In different stages of solar project development raw data are needed. Finding site-specific high-quality data, such as solar radiation and air temperature is not straightforward task; it often demands a lot of time, and results in approximate solutions. Still it is very difficult to access data in many countries or regions at the comparable quality and accuracy [1, 2].
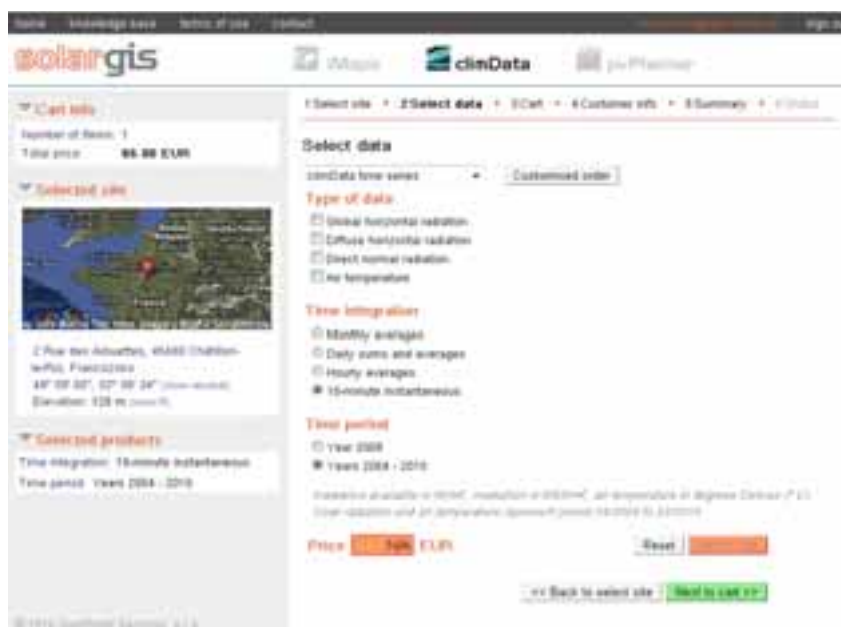

Fig. 3. SolarGIS climData – solar radiation and air temperature data selection dialogue.

SolarGIS offers historical averaged data, as well as time series for a selected time period and temporal resolution up to the recent history for any selected location. The data represents period 2004 to 2010. A user can choose different data parameters (global, direct diffuse, radiation, temperature, etc.) and time scales:

- Long-term averages: monthly and hourly,

- Time series: monthly, daily, hourly and 15minute values.

Data can be exported to xls, csv and PDF formats. Data types are compatible with most used design software. A new release is under preparation offering data in near-real time for sites with existing solar energy installations, enabling thus flexible performance monitoring and audit.

3.3. SolarGIS pvPlanner

The pvPlanner application is a second generation online simulator for photovoltaic systems. It is aimed at providing fast results at any selected site online. It integrates numerical simulation models that result from the latest research [3, 11, 12, 13] with new climate databases [4, 9] using Google Web Toolkit web programming technology.

Fig. 4. SolarGIS pvPlanner – simulation of PV electricity potential.

Optimally, full time series of solar radiation and air temperature are needed for accurate simulation of non-linearities in PV output. Due to computational demand this is not possible in online applications, and therefore simplifications, such as use of monthly-averaged daily profiles of solar data are used, e.g. in [3]. This simplification leads to systematic errors up to more than 3% [12].

The SolarGIS methodology is based on using statistically aggregated solar and temperature data stored in the database with a time step of 15 minutes. Simplified input parameters enable to consider key characteristics of a PV system, such as its position, geometry, type and mounting of modules, efficiency of inverter, and assumed losses in DC and AC sections. The model calculates reflectance losses at the surface of PV modules and losses due irradiance and temperature characterising operating performance of modules in a site-specific climate conditions. The other system losses, mainly at the DC and AC section are to be set by a user.

To consider the nonlinearities in calculation of in-plane solar radiation and PV output, global and direct irradiance for each MSG grid cell (about 4x5 km in Central Europe) is categorised into seven percentiles. Thus, online calculation for each month reads averaged temperature profile and seven irradiance percentiles in each step of 15 minutes. In total about 5500 model runs are needed for calculating PV potential output by pvPlanner for any change of input parameters which is still acceptable and does not evoke long response time. This approach is still a simplification compared to calculating full 15-minute time series, however it reduces error to ±0.7%, and the error is not systematic.

Currently, data from 2004 onwards are implemented in pvPlanner, but in early 2011 the length of the time period will be extended to cover climate era of at least the last 15 years. The spatial resolution of data is equivalent to the MSG grid cell size; however the data are on the fly disaggregated to about 80 metres using terrain elevation and horizon angle values which are pre-calculated from SRTM-3 DEM data.

As described above, implementation of new AOD data and disaggregation algorithms make it possible to evaluate more precisely terrain effects. Roof-mounted systems are supported by tools helping to calculate roof length and area but also roof azimuth.

The pvPlanner application brings fast and easy to understand approach for site selection, prefeasibility, and planning of PV systems. Sites can be compared and different technology options tested. New software tools are available for a comprehensive PDF reporting and data export to common formats.

5. Conclusions

SolarGIS is a commercial system which is based on many years of research and development and experience with running previous online prototypes. It implements new databases, numerical models, and new web and interactive mapping technology, and it aims to substantially increase efficiency in site exploration, prefeasibility and planning of solar energy systems. The main innovative features are:

- High-accuracy databases, developed by new-generation algorithms, extensively validated and documented in technical papers and on the SolarGIS web site.

- Implementation of fast-access data structures to store, interactively process and display large volumes of information.

- Fast and easy to understand access to climate information and simulation tools via web-based services.

- Detailed interactive maps, precise geo-positioning, standardized reporting and transparent transactions facilitating communication between investors, project developers, operators and owners.

The current version of SolarGIS will be enhanced in the end of 2010 to enable access to the most recent solar irradiance and temperature for the purpose of monitoring, auditing and performance assessment of solar energy systems.

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