Management and Exploitation of Solar Resource Knowledge

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Abstract

Knowledge of the solar energy resource is essential for the planning and operation of solar energy systems. In past years there has been substantial European and national funding to develop information systems on solar radiation data, leading to the situations that several data bases exist in parallel, developed by different approaches, various spatial and temporal coverages and resolutions including those exploiting satellite data. By comparing these products the users may end up with different results for the same requested sites. The MESoR project has defined a number of benchmarking measures and rules and applied them in several benchmarking exercises. This paper will show key results. To ease access to the data a new broker portal has been developed. The paper will show how it can be used to retrieve data or to make data available within the portal.

1. Introduction

Knowledge of the solar energy resource is essential for the planning and operation of solar energy systems. In the past years a number of data bases giving information on solar resources have been developed, such as the European Solar Radiation Atlas (ESRA), the projects SoDa, Satel-Light, PVGIS, PVSAT, PVSAT-2 or Heliosat-3 and the Envisolar project of the European Space Agency (ESA). In addition national services were set up as Meteonorm by Meteotest in Switzerland and SOLEMI by DLR in Germany [1,2]. This has lead to the situation that several different data bases exist in parallel developed by different approaches, various spatial and temporal coverages and different resolutions including those exploiting satellite data. The users comparing information from different data sources for the requested sites may end up with uncertainty that is difficult to deal with.

These multiple efforts have led to a fragmentation and uncoordinated access: different sources of information and solar radiation products are now available, but uncertainty about their quality remains.

At the same time, communities of users lack common understanding how to exploit the developed knowledge.

The project MESoR started in June 2007 and aims at removing the uncertainty and improving the management of the solar energy resource knowledge.

2. Objectives

The project has for main objectives: Guiding, Unifying, Connecting and Stakeholder Involvement:

2.1 Guiding

The first major objective is to guide stakeholders through efficient exploitation of the existing data sources. All sources have different spatial and temporal coverage and spatial and temporal resolutions, conforming to different stakeholders needs. Stakeholders are investors, banks, companies and consultants planning, designing, developing and operating solar energy systems, governmental bodies deciding strategies and policies as well as the scientific community. To guide the stakeholders in relation to their needs the available data sources will be evaluated by benchmarking them to each other. The benchmarking will increase the trust of stakeholders in the solar resource information. A user oriented guide to the available solar energy resources and a handbook of best practices has been prepared. Further, a roadmap to the future objectives and priorities will be developed, describing requirements for measuring systems, including Earth observation systems, services for effective management and deployment of solar resource knowledge and better fulfilment of the demands of the stakeholders.

2.2 Unifying

The second major objective is to ease the access to the existing data sources. For this advanced information web technologies are used. Metadata describing all different sources and a prototype of a web-based broker which guides the user to the different sources based on the metadata has been set up. The broker serves as a standard user interface giving standardized data to the user.

2.3 Connecting

The third major objective is to connect solar resource knowledge to other relevant activities and communities. The connection to INSPIRE (Infrastructure for Spatial Information in Europe) initiative will ensure the use of standards adopted by geographical information providers in Europe. The project activities relate to the "Power" programme of the NASA, the GMES (Global Monitoring for Environment and Security) contribution of the European Commission to the GEOSS (Global Earth Observing System of Systems), and the Implementing Agreements of the International Energy Agency (IEA), especially the Task 36 on "Solar Resource Management" implemented within the Solar Heating and Cooling Agreement.

2.4 Stakeholder Involvement and Disseminating

Stakeholder involvement has been the fourth major objective of this proposal. This was done by a survey of the stakeholder needs, the development of training material

3. Benchmarking

Benchmarking is the largest activity within the MESoR project. The aim of the benchmarking exercise is to establish a coherent set of benchmarking rules and reference data sets to enable a transparent and comparable evaluation of the different solar radiation data sources. The rules are developed in conjunction with the IEA Task 36 on "Solar Resource Management" of the Solar Heating and Cooling Implementing Agreement and shall serve as a standard for benchmarking to make results comparable.

3.1 Reference data

This activity focuses on collection of high quality ground measurements which can be used as a reference in the benchmarking exercises. The measurements should be conducted with high accuracy, high frequency and traceable maintenance of the equipment. Data has been collected from the Baseline surface radiation network (BSRN), International Daylight Measurement programme (IDMP), the meteomedia network, the World Radiation Data Center (WRDC) and the Global Atmospheric Watch (GAW) programme. In addition further measurements were collected from scientific institutions, providing they fulfil the quality criteria above.

A common quality control procedure has been defined for all broadband time series data. The parameters for the quality assessment have been deducted from the Baseline Surface Radiation Network Operation Manual [3] and operational experience of the partners involved. The quality control has been described in [4]

3.2 Benchmarking measures and rules

Benchmarking of solar radiation products can be done in different ways. If a kind of reference data is available which is assumed to be the "truth", the modelled data sets can be compared and ranked how well they represent the reference data. But there is not always reference data available: e.g. for solar radiation spatial products (maps). Here benchmarking can assess the uncertainty of mapping products by their cross-comparison.

For site specific time series there are a number of different measures for benchmarking. A first set is based on first order statistics. These are the well known bias, root mean square deviations, standard deviations, their relative values to the average of the data set and the correlation coefficient. They compare how well data pairs at the same point of time compare with each other. They are important if one needs an exact representation of real data, e.g. for evaluations of real operating systems or forecasts of solar radiation parameters.

This exact match is not always important, e.g. for system design studies. Here the similarity of statistical properties as frequency distributions is more important than the exact match of data pairs. The MESoR project therefore suggests a number of parameters based on second order statistics. [5].

In the examples shown below the first order measures BIAS and RMSD (root mean square deviation) as well as the second order measure KSI% - which informs on the dissimilarity of modelled am measured distributions- are applied.

Solar maps can be benchmarked in two ways, either point based or map based. The point based benchmarking is similar to the time series benchmarking. Data is extracted from the maps and compared to the measurements ("ground truth"). First and second order statistics can be applied. Map based cross comparison of solar radiation provides means for improved understanding of regional distribution of the uncertainty by combining all existing resources (calculating the average of all) and quantifying their mutual agreement by the means of standard deviation. A sample evaluation has been done with five spatial data bases: ESRA, PVGIS, Meteonorm, Satel-light and NASE SSE.

Figure 3: Ground measurement stations in the MESoR benchmarking exercise I

3.3 Sample Benchmarking results

The MESoR project also applied the developed benchmarking. Within MESoR several different benchmarking exercises have been performed. The exercise I which is shown here focuses on DNI for the years 1996 to 2000 in Europe. The stations Nantes, Vaulx-en-Velin and Thessaloniki were excluded in the DNI evaluation as they did not contain a DNI measurement but only global and diffuse.

The results presented here compare three different data sets providing hourly data, SOLEMI from DLR, EnMetSol from Oldenburg University, and Satel-light from ENTPE. Meteonorm is only included for the KSI% test. As the Meteonorm hourly data are synthesised from interpolated monthly averages. RMSD (root mean square deviation) makes no sense in this case. The bias may be used if the data is not included in Meteonorm. The overall bias was low for all databases, 1% for SOLEMI, 4% for Satel-light and -1% for EnMetSol. The RMSD is 48% for SOLEMI and 36% for Satel-light and EnMetSol. As stated above, bias is the key figure for prefeasibility project evaluation, while the match of the frequency distribution is gainesimportance for system design and system operation. Due to the variability of the distribution functions for the different sites the KSI% gives only a relative measure for the model quality for a given site site. A general judgement on the performance different model has to compare the ranks of the models over all sites.

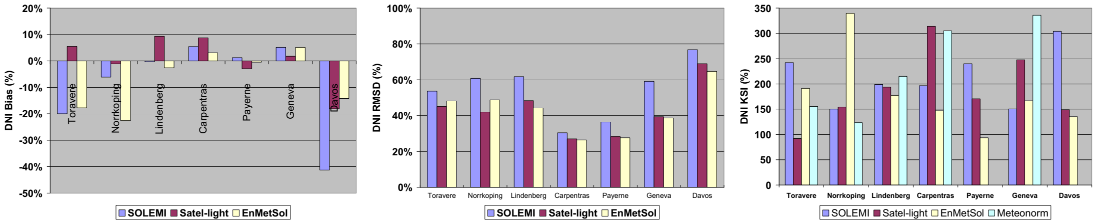

Figure 4: Benchmarking results from MESoR Exercise I for DNI. Bias (left), RMSD (middle), KSI% (right). Station names from left to right are Toravere, Norrkoping, Lindenberg, Carpentras, Payerne, Geneva and Davos.

The analysis of the KSI% showsthat the deviations of measured and modelled distribution functions may be quite remarkable. This means that even if bias is well met, the match in the distribution functions needs further improvement. There is no clear difference between the various databases. The map based cross-comparison of five data sources (Fig. 2) shows that there are regions with higher disagreement between individual databases. The main drivers of such differences are imperfections of cloud detection models (especially in mountains and snow/ice conditions), interannual variability, high differences in the existing aerosol and water vapour databases, lack of high-quality data in some regions, complex terrain and climate conditions in mountains and in coastal zones. The uncertainty in these regions can be decreased by detailed analysis of the above mentioned determining factors, followed by improved modelling procedures.

3.4 Benchmarking Conclusions

The developed benchmarking measures and rules do not give clear recommendations on which data set should be used for selection of sites, system design or support of power plant operation. But the project has developed transparent measures and rules, including the new ones for quality assessment of the distribution functions, which are recommended to the solar community. Following these standardised benchmarking rules, it should be easier to select a database meeting the user specific needs.

4. Unifying Access

The second major objective of the MESoR project is to unify and ease access to solar resource information. This builds upon experiences made within the SoDa portal, adopting interactive mapping and analytical features from PVGIS web system. The original SoDa portal was built with proprietary software and communication protocols. As the World Wide Web evolved over recent years, we decided to build a new web portal within MESoR, using open source software with support from a large development community and standardised web services. This makes the new portal more sustainable (in terms of software development), and the connection to the portal easier and more open (as only widely accepted standards are followed).

The portal serves as a broker to solar resource information and services. It does not itself contain and maintain data; instead it links databases and services within one single point of entry and a common user interface. Databases and services are hosted by their providers, who keep control over their data and applications.

Metadata are essential to exchange knowledge between applications. They describe objects to be exchanged (e.g. a time series of irradiance, a geographical location, a date…). After a series of consultations with several bodies involved in standards, such as ISO, GEOSS (Global Earth Observation System of Systems), INSPIRE (Infrastructure for Spatial Information in Europe) and national meteorological offices, a thesaurus has been defined which is specific to solar resource. A thesaurus is a set of terms that describe the solar resource.

A prototype of the broker has been set up during the project. A new user interface has been designed, including the API (application programming interface) of Google Maps. Users can therefore use the full capabilities (geographical search, maps and images) of Google to identify their sites and select the right locations or regions. As this interface is easy to use and applied already in many other applications, the user is likely to be familiar with it. The front page of a service gives the site selection window and some descriptive information of the service, as a general description, property rights, credits, inputs and outputs descriptions and benchmark procedure results if relevant. The results can be written to the browser window or saved in a specific format (e.g. spreadsheet-compatible). The available databases can be selected by the menu on top of the page. The figure below shows two sample screenshots of the current prototype (see http://project.mesor.net).

5. Conclusions

The European Union funded project MESoR, in close collaboration with International Energy Agency and their SHC and SolarPACES Implementation Agreements, has brought new benefits for solar energy industry, policy, research, education and broad community:

- Standardised rules are defined for transparent benchmarking of solar radiation products (site observations and spatial databases). The benchmarking exercises provided by the MESoR consortium have improved understanding of the state of the art of solar resource assessment, and the solar products available for Europe.
- A new web portal has been developed, offering technology for harmonised and easy-to-use access to solar radiation and related databases and tools. The portal is based on the use of open source software and implementation of international standards. The MESoR portal already links several data sources and it is intended to be used as one-stop shop for those who need data for their projects.
- The MESoR consortium has developed and improved links to all international scientific and policy initiatives that are relevant to solar renewable energy. Active participation in these initiatives has facilitated transfer of scientific know-how to "daily life".
- The MESoR consortium has identified further needs for research and development in enhancing the solar resource knowledge, which have been described in the road map documents of the project.
- The handbook on solar resources and best practices summarises the existing knowledge in a user friendly interpretation and layout, and offers access to this knowledge to the solar energy community.

On one hand the MESoR project brings standardisation, harmonisation, unification, and coordinated approach, on the other hand it has identified a number of new items in the *"to do"* list in both R&D and application fields. To mention some of them:

- Current solar radiation methods, resource data and products need further improvements in order to reduce risk and improve efficiency and reliability of solar energy technology.
- Further integration of information and communication technology with available satellite, and meteorological data streams, supported by high-resolution global data sets, will substantially streamline access to data and derived products requested by service providers and the solar industry.
- The solar resource community is committed to continue in fast development of data and services to support technology operation and maintenance (prefeasibility, project development, system monitoring, forecasting of power generation). The issues of grid integration and demand/supply management are discussed more often then ever. However, solar resource community needs targeted support to keep the pace with development and worldwide deployment of solar energy technology.

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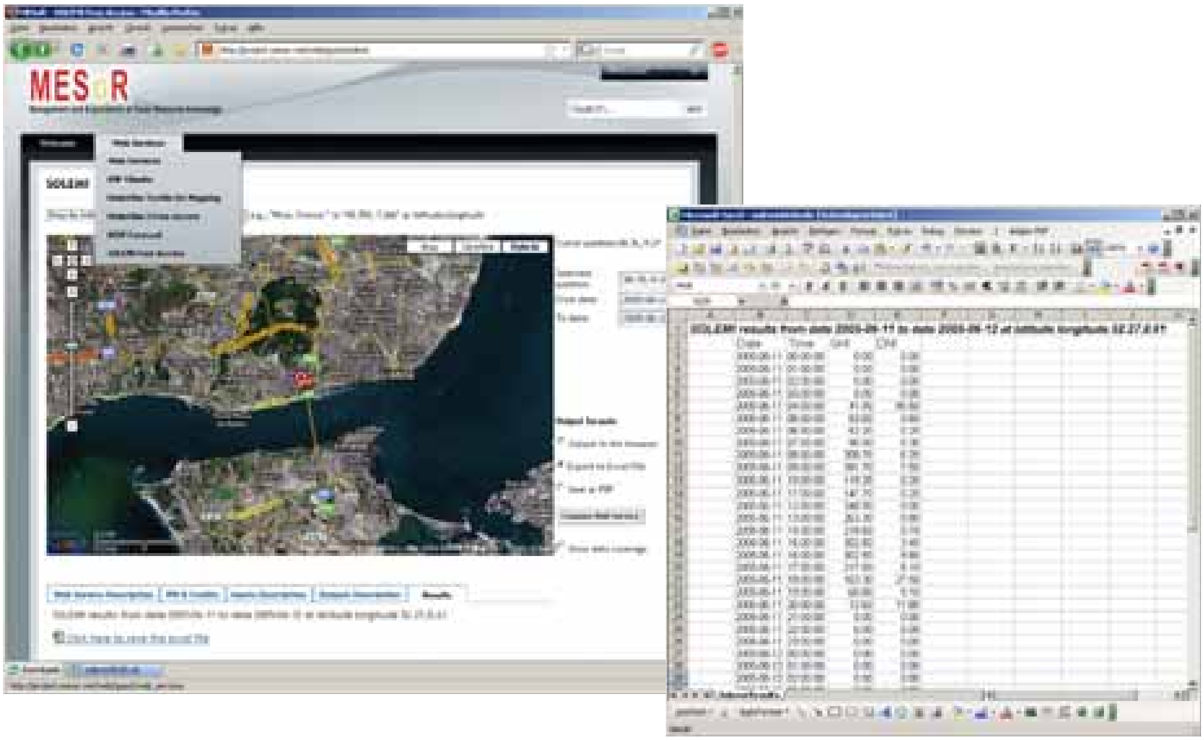

The prototype of the MESoR broker portal. A sample time series has been extracted in an Excel spreadsheet format.

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