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SoDa: a project for the integration and exploitation of networked solar radiation databases

Lucien Wald [1], Michel Albuisson[1], Clive Best [2], Catherine Delamare [3], Dominique Dumortier [4], Elena Gaboardi [5], Annette Hammer [6], Detlev Heinemann[6], Richard Kift [7], Stefan Kunz [8], Mireille Lefèvre[1], Sébastien Leroy [9], Mario Martinoli[5], Lionel Ménard[1], John Page[7], Tamas Prager [10], Corrado Ratto [11], Christian Reise [12], Jan Remund[8], Aniko Rimoczi-Paal[10], Erik Van der Goot[2], Fritz Vanroy[4], and Ann Webb[7]

Abstract

The project SoDa (solar data) answers the needs of industry and research for information on solar radiation parameters with a satisfactory quality. The methodology is user-driven with a large involvement of users in the project, who gauge the progresses and achievements. A prototype servicehas been developed, using Internet

[1] Groupe Télédétection & Modélisation, Centre d'Energétique, Armines / Ecole des Mines de Paris, BP 207, 06904 Sophia Antipolis cedex, France, E-mail:lucien.wald@ensmp.fr
[2] Joint Research Center, European Commission, Ispra, Italy
[3] Les Presses de l'Ecole, Armines / Ecole des Mines de Paris, Paris, France
[4] Ecole Nationale des Travaux Publics de l'Etat / CNRS, France
[5] iCONS, Italy
[6] University of Oldenburg, Germany
[7] University of Manchester - Institute of Science and Technology, United Kingdom
[8] Meteotest, Switzerland
[9] Armines, Paris, France
[10] Hungarian Meteorological Service, Hungary
[11] University of Genoa - Department of Physics, Italy
[12] Fraunhofer Institute for Solar Energy Systems, Germany

technology, that integrates and efficiently exploits diverse networked information sources to supply value-added information. Access to data and applications has been greatly improved; efforts were made on interpolation methods and satellite data processing to achieve better quality and increase time and space coverage of the information. Applications were developed or networked to supply information actually needed by customers, and not only raw data.

1. Introduction

Information on solar radiation is a critical issue for the use of solar energy and several environmental domains. Solar radiation is measured by ground networks of measuring stations, but well-controlled measurements have only been available in a limited number of sites. National networks often comprise only a few stations, even in Western Europe and Northern America. In other parts of the world, it is scarce. Such data are non-existent for the oceans. The result is that there is a large discrepancy between user request and available information.

Large gains in terms of efficiency, costs, etc. will be attained by engineers, companies, agencies and research institutes if relevant information were more easily available for virtually any geographical location at any time. Information and communication technologies could play a major role in solving this problem. Recent projects have demonstrated the usefulness of image processing techniques for extracting solar radiation information from Earth observation satellite images. Reliable validated routines have been established at some meteorological offices and research institutes. Efforts have been made to collect, store and disseminate solar radiation information. Some achievements have been obtained at international and national levels, through international research programs. Several databases are now available, some of them being available through a WWW server.

However these efforts are not sufficient enough. Three major problems have been identified and should be solved to supply the customers with information relevant to their requests: improved access to information, improved space and time description / knowledge of the radiation field and related quantities, improved matching to actual customer needs.

2. The SoDa project

Several initiatives are operationally producing assessments of the global radiation at ground level for large geographical areas. Probably the most widely known is the ISCCP program (International Satellite Cloud Climatology Project) and its brother, the SRB (Surface Radiation Budget) program which freely provide free maps of the monthly-averaged daily radiation sums for the entire world on a grid of 2.5° x 2.5°. Several meteorological offices are offering similar products with a finer geographical grid but covering a narrower area, e.g. Meteo-France. These products are of very great interest to their originators and to specialized researchers in meteorology. They have limitations for a non-standard ‘meteorological user’ in several aspects, e. g. geographical coverage, space and time resolution, unsuitable types of data with respect to the various types of request by customers, unsuitable presentation of the information, excessive data volume with respect to the user’s computer system (hardware, software). They usually assume the skills of the end-user lie in handling basic meteorological data.

Digital atlases (MeteoNorm 2000; European Solar Radiation Atlas 2000) have been recently created which are more relevant to the field of renewable energies. Presented on CD-ROMs, they comprise a database (maps, time-series of ground measurements, synthetic reference years, geographical information...) and software to exploit it (user interface, data management, result presentation, import-export capabilities...). The software also includes models for the computation of parameters of higher level. The European Union funded Satel-Light project offers a database of solar radiation data derived from satellite images, which can be accessed through the WWW and produces value-added information mostly for daylighting purposes (Fontoynont *et al.* 1998; Reise *et al.* 1999). Though limited to the solar energy domain, these atlases and servers are excellent examples of what can be done to bring to users the information they require starting from basic meteorological measurements.

The project SoDa is based on this considerable previous experience, and uses it as a springboard to answer customer needs by an efficient use of advanced information and communication technologies. An integration of information sources of different natures within a smart network is realized (see online at http://www.soda-is.org). These sources include databases containing solar radiation parameters and other relevant information (Figure 1). Several of these databases originate from an advanced processing of remote sensing images. Several were available separately. The information sources also include application-specific user-oriented numerical models and advanced algorithms. The system is being validated through users trials. The project SoDa focuses on several applications: energy-conscious building design, daylighting, vegetation, environment, climate change, oceanography, health and industrial use of renewable energies.

3. Improving access to information

A prototype of an intelligent system (IS) performs the integration and exploitation of diverse networked information sources that are geographically dispersed. It offers a common access point implemented as an Internet server. The user request may be beyond the content of the available databases (e.g., sizing of photovoltaic panel). To that end, the system includes application-oriented algorithms. The system is flexible and is capable of integrating other databases and new application-oriented algorithms, as demonstrated by several resources provided by institutes not members of the SoDa project.

The project relies upon available and reliable data exchange protocols and on systems to guide, connect, and transfer data across computer networks. Applications are interfaced to the Web at the provider's premises. The HTTP based Geo-Temporal Searching (HGS) technology is used; it defines a mechanism whereby remote databases can be searched through a single standard HTTP interface. It provides a Service Discovery layer. This allows online retrieval of a hierarchical structure of all databases available for search through HGS.

A simple XML schema was defined for the exchange of information between the SoDa IS (the core of the service) and the various applications that are called upon to execute the request. All applications are described in XML in the SoDa IS. The adoption of the XML is a definite advantage with respect to the adoption of the SoDa service by providers. They do not have to change their own format; a simple cgi script converts the SoDa XML into the provider's metadata.

Standard user interfaces were defined for the description of the space and time attributes of the user request that are automatically called when launching an application. In that way, it facilitates the declaration of an application. From the user point of view, it permits to present the applications in a homogenous way. These interfaces are defined in the SoDa XML as metatags.

The outputs of a service are expressed in XML. A converter permits to shift to HTML at user's will or to any customised XML using a XML style sheet selected by the user. A style sheet was created for producing "comma separated values" (CSV) ready to be ingested in standard spreadsheets.

The SoDa service represents a large improvement in information access in solar radiation domain. Having a common access point makes it easier to the customers who do not have to remember and store several URLs (one stop shop). The standardisation of the interfaces querying the space and time attributes of a request and the adoption of standards for describing these attributes are also facilitating the uptake by the users. The standardisation of the outputs is a major improvement. Before, users were spending efforts to cope with the various formats produced by the various meteorological offices. The large efforts spent in the selection of the most appropriate chaining of proven algorithms to answer customer needs beyond measurements are improving access to information. By making these chains available, the SoDa service offers the most accurate way to get the information. This is enforced by the networking capabilities of the Soda service. Since any provider can easily declare an application, the SoDa service is capable of shifting from one algorithm to a more appropriate one and consequently is capable of offering the best service available.

4. Improving knowledge on the solar radiation

The existing databases are very diverse. The parameters are various: sunshine duration, cloudiness, global irradiation, its diffuse and direct components, spectral distribution, atmospheric turbidity, atmospheric aerosol optical thickness, etc. The support of the information is diverse, too: long time-series are available for a few hundreds of measuring stations (pin-point measurements) while shorter time-series are available for pixels. These pixels have various sizes: from 5 to 250 km; geographical coverages are also various as well as time periods and time samplings. Formats are different. Non-radiation parameters are also of interest in this project, such as terrain elevation and topography (e.g., water bodies). This knowledge is exploited for the computation of advanced application-oriented information or the modeling of space and time structures of the radiation. Daily calibration factors of the satellite sensors are provided by another database on the Web. Other databases and resources outside the consortium may be integrated in the prototype service on a voluntary basis.

Efforts were made to consolidate the databases. Additional information was incorporated, and the time and space coverage were increased by an appropriate processing of data from the Earth observation satellites (Rigollier, Wald 1998, 1999). Whenever possible, fusion of ground based measurements (contained in the databases) and satellite-derived assessments were performed by means of geostatistics or similar techniques. It has proved very fruitful in providing high-quality information for solar radiation (Beyer *et al.* 1997). Additional relevant information was incorporated in the co-operating resources whenever possible. Air temperature and atmospheric turbidity are such additional parameters. It may be either an existing database that is acquired by the consortium, or may result from extensive computations made using the available information sources or others. Another example is the availability of terrain elevation data that allows the computation of the slopes, and further the irradiation on slopes.

Apart data, other sources of information are applications (Figure 1). Applications are available to check the quality of solar radiation measurements, to predict the global irradiation for a given atmosphere, or its diffuse component on an inclined surface, the long wave irradiance etc. End-users applications simulate crop yield or predict the quantity of domestic hot water that can be produced.

5. Improving matching to actual customers needs

Advanced exploitation of the databases content was developed. The objective is to improve the quality, taken in a broad sense, of the delivered information, taking into account the expression of the user needs. Efforts were put on the assessment of parameters in any geographical location at any time, and on the provision of advanced parameters and application-oriented information.

Advanced and original interpolation / extrapolation schemes were developed that take into account the latitudinal properties of the meteorological fields, terrain elevation, climatological features of relevance for solar radiation, local climate, and the space and time local characteristics of the solar radiation. These schemes may be seen as data fusion processes that operate at various space and time scales. The information and its change in space and time are described by the means of the multi-resolution analysis and the wavelet transform theory. These schemes are used to create information when missing from that existing. Even if large databases exist covering large periods of time at high-frequency and large geographical areas at high sampling rate, they cannot meet all the users needs. Interpolation schemes are necessary to fill gaps. The original feature of this work is the consideration of interpolation in both the frequency - wavenumber and time - space domains.

Advanced parameters and user-oriented applications information were developed that exploit the databases content and more generally any application available in the SoDa service to precisely answer the customer request. Advanced parameters denote parameters that can be obtained by the application of a fairly simple algorithm or scheme on the databases and other resources. User-oriented applications denote information that results by performing a more sophisticated calculation.

Of particular interest is the solar radiation available on slopes, while measurements are always made on horizontal surfaces. Algorithms were developed to provide such information taking into account the digital elevation model and the optical properties of the atmosphere. Statistical tools are available, as well as simulation tools of typical daily profiles of values starting from monthly averages or from daily sums. Such profiles are useful as inputs to models in various domains. Several other algorithms were developed, many of them at the requests of customers with respect to the available resources in and outside the consortium. Only existing algorithms of proven and satisfactory quality were adopted.

As far as user-oriented applications are concerned, the project SoDa focuses on a few of them. The solar radiation is a key force in vegetation. It is a key parameter in the primary production and biomass, and as such, users in this domain are very keen at a better knowledge. The SoDa service offers the assessment of the fraction of the solar radiation that is available for the photosynthesis or simulation of crop yield for virtually any place in the world. Other applications of interest to the project SoDa are those related to the engineering of solar systems, and to buildings and daylighting. Many user-oriented application tools already exist in these domains and were integrated into the SoDa service.

6. Conclusion

The project SoDa represents a significant step forward beyond the current state of the art and includes substantial original work. The main innovations of SoDa are to offer a smart access to diverse networked sources of information, and to supply the customers with information of high quality. High quality means an improved matching to actual customer needs: the supplied information is relevant to the different user needs and not just raw observed data. It also means an improved access. Finally it means improved time-space coverage and improved time-space sampling.

Since the SoDa service is based on available experience, the prototype is gradually recognized by customers. The developed IT technologies are being exploited in another project with similar databases aspects. The method developed for the assessment of solar radiation from satellite data is being adopted by several customers.

Because the prototype service is directed towards users and provides easy access to sophisticated user oriented information on solar radiation, a number of benefits are expected besides these technical innovations, such as a better efficiency in scientific research and development in all areas where solar radiation makes significant impacts, a better prediction of some natural hazards like photochemical air pollution, snow melt hazards, state of the ground in relation to water run off, low summer river flows due to evapo-transpiration, or a better understanding by industry of the impact of climate on their product in the market-place and on their production processes, leading to improvements in their economic and social performance, cost-savings design of industrial systems, among many others.

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Long-Term Time-Series of Data

- *Daily Irradiation*
  - MARS project – Europe
  - Meteosat-derived data – Europe / Africa
  - NCEP/NCAR reanalysis daily averages
- *Other Data*
  - Radiation on inclined surfaces and air temperature
  - Longwave radiation
  - Monthly means of net radiation balance - Europe
  - 10-day land surface temperature - Central Europe

Climatological Data and Derived Quantities

- *Climatological Data*
  - Monthly means of daily global irradiation
  - Monthly values of Linke turbidity factor
  - Monthly means of air temperature
- *Simulations of Normal Years*
  - Global, diffuse and beam radiation
  - Radiation on inclined surfaces and air temperature
  - Longwave radiation
- *Other Data and Derived Quantities*
  - Frequency of types of sky - Europe
  - Statistics of hourly irradiation - Europe

Simulation of Radiation under Clear Skies

- The position of the Sun in the sky
- Hourly and daily irradiation

Solar Systems - Application

- Simulation of solar domestic water heating systems
- Modeling performance of solar home PV-systems
- Modeling performance of grid connected PV-systems

Daylighting - Application

- Daylight factors of a room

Vegetation - Application

- Dry matter production
- Synthetic time-series for crop simulation
- 10-day vegetation index - Central Europe

Fig. 1: Extract of the series of services available through the SoDa prototype