HelioClim-1: 21-years of daily values in solar radiation in one-click

Lucien Wald

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Abstract

The HelioClim-1 database offers daily means of surface solar irradiance for the period 1985-2005 and has been created from archives of images of the Meteosat First Generation satellites. Expectations of users regarding access to similar data were carefully analyzed, especially regarding dissemination of and access to data, and were taken at the heart of the design of the database. Efforts were made to deliver time-series spanning over 21 years very rapidly on the Web with a limited number of clicks. The soundness of the approach by MINES ParisTech is now rewarded by the large number of access to HelioClim-1, approximately 400 per workday, and by the number of scientific publications using these data. The Global Earth Observation System of Systems (GEOSS) has declared HelioClim-1 as a Data Collection of Open Resources for Everyone (GEOSS Data-CORE) in November 2011. A Web processing service (WPS) obeying the OGC (Open Geospatial Consortium) standard has been developed. Being interoperable, it can be invoked in operational routines, such as those under development in the European funded ENDORSE and MACC projects.

1. Introduction

The surface solar irradiance (SSI) is the power received from the sun over the whole spectrum on a horizontal surface at ground level. It has been identified as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS) in August 2010. Knowledge of the SSI and its geographical distribution is of prime importance in several environmental domains, e.g. weather, climate, biomass, and in energy production by means of solar-powered systems.

Accurate assessments of SSI can now be drawn from satellite data and several studies demonstrate the superiority of the use of satellite data over interpolation methods applied to sparse measurements performed within a radiometric network. Blockages were identified that prevent the wide use of satellite-based irradiance information in the solar energy market (Schroedter-Homscheidt et al. 2006). This communication addresses several blockages relating to access to data and shows how the HelioClim-1 database of SSI helps in overcoming them.

2. Expectations of users

Several studies have analyzed and reported on the expectations of users regarding the SSI (Cros et al. 2004; Espinar et al. 2013; Gschwind et al. 2006; Schroedter-Homscheidt et al. 2006). The typology of users dealt with is:

1. companies (engineering bureaus, energy producers, investors, plant managers, maintenance services and electricity grid managers),
2. experts (engineering bureaus, private R&D),
3. public research institutes (engineering bureaus, private R&D),

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4. public authorities and other organizations supporting policy making, incentives and permit delivery at national, regional or local levels, as well as European policy makers in charge of supporting the implementation of EU policies.

A majority of these users need time-series of SSI. The time-series must span over a long period greater than 15 years as the main use of these data relates to investment decision in solar plants and selection of appropriate sites.

Users indicate in surveys that the uncertainty on SSI must be documented. However, the main emphasis is on the efficiency in accessing data. The "on-click access" is an obsession to many users (Espinar et al. 2013; Cros et al. 2004; Gschwind et al. 2006).

3. The HelioClim Project

The HelioClim Project is an ambitious initiative of MINES ParisTech launched in 1997 after preliminary works in 80's to increase knowledge on SSI and to offer SSI values for any site, any instant over a large geographical area and long period of time, to a wide audience (Blanc et al. 2011). It aimed at removing blockages regarding length of available archives of SSI and access to data.

The HelioClim Project covers Europe, Africa and the Atlantic Ocean. It makes full use of the series of Meteosat satellites. These satellites are geostationary and provide synoptic views of Europe, Africa and Atlantic Ocean for meteorological purposes. Initiated by the European Space Agency, the program is currently operated by Eumetsat, a European agency comprising the national weather offices. Images taken in the visible and other channels clearly depict clouds (Fig. 1) and more generally the optical state of the atmosphere and are currently used to assess SSI.

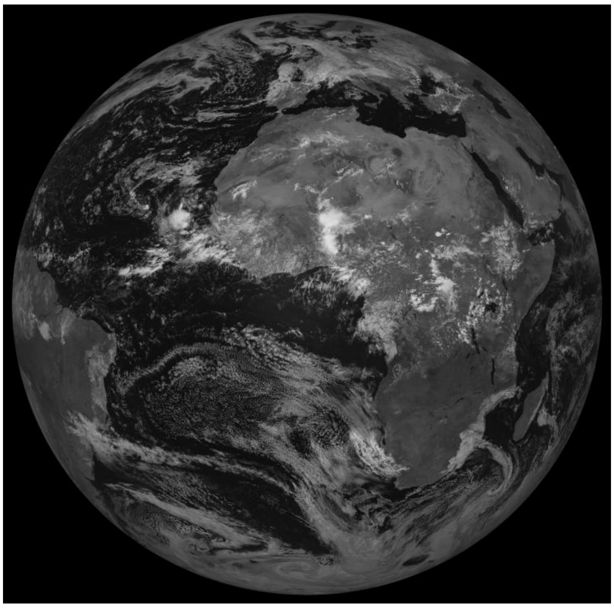

Figure 1.
Example of a Meteosat image in visible channel, taken on 7 September 2010, at 1200 UTC.
Reflectance increases from black to white. Copyright Eumetsat, 2010.

The HelioClim-1 database, abbreviated in HC-1, offers daily means of SSI for the period 1985-2005. It has been created from archives of images of the Meteosat First Generation satellites by the means of the well-known Heliosat-2 method (Rigollier et al. 2004).

Though this communication deals only with HC-1, it is worthwhile mentioning the HelioClim-3 and -4 databases. HC-3 contains 15 min values of the SSI. It has been created in 2004 and is updated daily from images taken by the Meteosat Second Generation satellites. The HelioClim-4 database should be created in October 2013 with a daily update. It will contain values of the global, direct and diffuse components of the SSI.

The agreement of HC-1 with the corresponding measurements made in the World Meteorological Organization network has been reported by several studies and is good as a whole (Blanc et al. 2011). HC-1 can be used to provide a first description of the change in SSI over the 21 years period, thus palliating gaps in ground-based measurements. If an accurate sort of calibration function can be found between existing HC-1 values and measurements, then HC-1 values can be transformed into an accurate and complete time-series reproducing the measurements. The HC-1 database may help in qualifying ground-based measurements by showing noticeable drifts in measurement quality (Blanc et al. 2011).

4. The dissemination of the HelioClim-1 database

SSI databases derived from satellite data are not new. However, they failed to meet the expectations of users on at least two points: the length of the archives, and the efficiency in access. Therefore, these two issues were taken at the heart of the design of the HC-1 database.

Processing the archives of images of the Meteosat First Generation satellites from 1985 to 2005 was a step towards answering the needs for having SSI time-series spanning over a recent period longer than 15 years. For this period, the time-series of images represents about 6 billions of values to be processed to estimate the daily mean of SSI.

These estimates must be stored in an appropriate database. Taking into account that the large majority of users requests time-series for a specific location and not time-series of gridded (maps) values, the original image structure of the information was discarded and the database was shaped to facilitate the search for time-series for a given location. This was our first step to ease the access to data.

The processing of Meteosat images into SSI was made for each pixel of each image. Then, the computation considers each pixel as a time-series of hourly values in a day to compute daily means. This implies an increasing processing time due to the handling of several large files. The structure adopted for storing the daily means of the SSI is shown in Fig. 2.

<table>
<tr><th rowspan="2">Pixel identifiers</th><th colspan="5">Julian days</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>…</th><th>366</th></tr>
<tr><td>1</td><td colspan="5" rowspan="5">For each day, daily mean of irradiance</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>…</td></tr>
<tr><td>N</td></tr>
</table>

Figure 2.
Scheme of a yearly file of data, each daily mean of SSI is stored in a cell identifiable by the pixel identifier and the julian day

There is one file per year. Within, each file, an image pixel is identified by the pixel identifier and the daily means are stored consecutively for the 366 days contained in a year. Storing a new result into the yearly file for a given day requests reading the whole file and writing in one cell at a time, for all cells for this day. These operations are very lengthy and cost a lot of computer time. However, they are done only once. The advantages are of this structure is that time-series are already constructed for a given location and therefore can be delivered very rapidly.

The next step to facilitate access was to adopt the Web as a means to disseminate the time-series. Rather than developing a new Web site specific to HC-1, the SoDa Service (www.soda-is.com) was selected as a main means to disseminate HC-1. The SoDa Service has been presented in several occasions in the EnviroInfo series of conferences (Gschwind et al. 2005; Wald et al. 2002). This Web portal was established by MINES ParisTech in 2003 and is managed by the company Transvalor since 2009 for the common good. The service is widely used by communities interested in solar radiation. There were approximately 40000 unique visitors to the Web site in 2011. Therefore, HC-1 benefits from the notoriety of the SoDa Service. Transvalor is providing a helpdesk for all resources available in the SoDa Service, including HC-1.

Together with Transvalor, an effort was made for a fast access to the databases of SSI available through the SoDa Service. Whether the user is registered or not, he may access the HC-1 interface for ordering a time-series spanning 21 years of data in two clicks, and after selection, get it with a final click. This was another effort to make access to data more efficient.

Data can be retrieved by users using a standard internet browser, freely without registration. The graphical user interface allows for selection of a given location on a map, or by entering geographical coordinates or name of a place, e.g. Nice, France. Other inputs are the period (dates begin and end) and the period of integration (summarization): day, week, and month. Outputs may be either displayed on the screen in HTML format or returned in a CSV file in ASCII format. Outputs comprise the SSI, the corresponding irradiation, the irradiance at the top-of-the-atmosphere and the SSI that would be observed if the sky were clear. As requested by users (Espinar et al. 2013; Schroedter-Homscheidt et al. 2006), the uncertainty in SSI is delivered for each daily mean equivalent to a RMSE (root mean square error). This uncertainty is provided by a combination of web services (Wald et al. 2011).

5. Designing an OGC Web Processing Service for HC-1

The Global Earth Observation System of Systems (GEOSS) has created the GEOSS Data Collection of Open Resources for Everyone (GEOSS Data-CORE) effective in November 2010. The GEOSS Data-CORE is a distributed pool of documented data sets with full, open and unrestricted access at no more than the cost of reproduction and distribution.

Efforts were then made to promote HC-1 as a Data-CORE. It was recognized as such by the GEOSS in November 2011. In the wake of this recognition, efforts were recently made to offer access through an OGC (Open Geospatial Consortium) standard Web processing service (WPS) taking benefit from the interoperability promoted by GEOSS (Ménard et al. 2012). This WPS is a means to access the HC-1 database by a computer without human interaction (Percivall et al. 2011).

The WPS is located in the GEOSS energy community portal: www.webservice-energy.org, and is published in the geo-catalog of this portal (geocatalog.webservice-energy.org). A set of ISO 19139 metadata describes the WPS. The following keywords recommended by GEOSS: *GEOSS Data CORE*, *geossDataCore*, and *geossNoMonetaryCharge* have been written in one of these metadata fields, thus providing the necessary information related to the use and constrains attached to this service. During the 4th phase of the GEOSS Architecture Implementation Pilot whose results were presented at Istanbul in 2011, an application has been devised and set up temporarily on the web site of the European-funded GENESIS project exploiting this WPS in order to deliver SSI time-series for up to five locations at the same time (Ménard 2011).

Beyond another means of dissemination with an expected increase of use of HC-1, this WPS offers a main advantage. Being interoperable, it can be invoked in operational routines.

One example is its integration into the MACC-RAD service. MACC-II (Monitoring Atmosphere Composition and Climate) is a European FP7 project led by ECMWF, and is the current pre-operational Copernicus Atmosphere Service. MACC-II provides data records on atmospheric composition for recent years, data for monitoring present conditions and forecasts of the distribution of key constituents for a few days ahead. Within MACC, the MACC-RAD service will deliver SSI data for past days. The HC-1 WPS will be part of the monitoring procedure of the service (Espinar et al. 2013). The monitoring procedure will take advantage of the easy access to the 21 years of data to compute statistics which will be compared to the current outputs of the MACC-RAD service to detect trends and other suspicious values.

Another example deals with the fusion of the HC-1 and HC-3 data sets. HC-3 is a more recent database that began in 2004 and is updated daily. Combining HC-1 and HC-3 yields time-series of 29 years of data of high statistical significance (Blanc et al. 2012). Currently, this combination cannot be achieved in a simple way and requests a specific processing by the user himself. The HC-1 WPS is a first step towards an automatic combination of both data sets on the Web. Once an equivalent HC-3 WPS set up, a third WPS will be realized that will automatically blend the outputs of the two WPS.

6. Conclusion

HC-1 is a full GEOSS Data-CORE and supports research and business by providing data of known quality on surface solar irradiance. HC-1 is of free access at no cost and without registration. Therefore, the exact uses and users of HC-1 are unknown. A few testimonies have been left in the SoDa web site where HC-1 data can be downloaded. There is a testimony from a company studying the maximum SSI impinging on their gas tanks in a risk analysis, and others from MSc and PhD students in renewable energy, climate or architecture. Several examples of use of HC-1 were found in scientific journals in various domains: oceanography, climate, energy production, life cycle analysis, agriculture, ecology, human health, and air quality.

Not accounting for requests made by MINES ParisTech and Transvalor, approximately 104000 requests were made in 2012 to the HC-1 database by users. This makes an average of 400 requests per workday and demonstrates the usefulness of the HC-1 database. Furthermore this number of access in 2012 is ten times more than before HC-1 was declared a GEOSS Data-CORE. This demonstrates the benefit of a data set to become a GEOSS Data-CORE.

The success of the uses of the HC-1 database is rewarding for MINES ParisTech. It demonstrates the soundness of the approach adopted here, where expectations of users were carefully analyzed, especially regarding dissemination of and access to data, and were taken into account in the design of the database.

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