

## **A proposal for a thesaurus for web services in solar radiation**

Benoît Gschwind, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse

► **To cite this version:**

Benoît Gschwind, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse. A proposal for a thesaurus for web services in solar radiation. O. Hryniewicz, J. Studzinski and M. Romaniuk. EnviroInfo 2007, 2007, Varsovie, Poland. Shaker Verlag, 1, pp.135-142, 2007. <hal-00477645>

**HAL Id: hal-00477645**

**<https://hal-mines-paristech.archives-ouvertes.fr/hal-00477645>**

Submitted on 29 Apr 2010

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

## A Proposal for a Thesaurus for Web Services in Solar Radiation

Benoît Gschwind<sup>1</sup>, Lionel Ménard<sup>1</sup>, Thierry Ranchin<sup>1</sup>, Lucien Wald<sup>1</sup> and Paul Stackhouse<sup>2</sup>

### Abstract

Metadata are necessary to discover, describe and exchange any type of information, resource and service at a large scale. A significant amount of effort has been made in the field of geography and environment to establish standards. Efforts still remain to address more specific domains such as renewable energies. This communication focuses on solar energy and more specifically on aspects in solar radiation that relate to geography and meteorology. A thesaurus in solar radiation is proposed for the keys elements in solar radiation namely time, space and radiation types. The importance of time-series in solar radiation is outlined and attributes of the key elements are discussed. An XML schema for encoding metadata is proposed. The exploitation of such a schema in web services is discussed. This proposal is a first attempt at establishing a thesaurus for describing data and applications in solar radiation.

### 1. Introduction

Solar radiation is a domain where data are rare. The few providers are usually the National Meteorological Services which are geographically distributed. Such data are necessary to a large number of users (companies, consultants, researchers, students) in various business domains (energy, building engineering, health, agriculture, meteorology, climate...). Consequently, many exchanges of data occur. A recent survey conducted by the International Energy Agency (IEA) emphasises the heterogeneity observed in the data in various aspects (Cros et al. 2004). Access to data is complicated by the various types of data, various storage standards, various units, various time systems (coordinated universal time, mean solar time, true solar time, local time), diversity in information properties stored in databases: sampling support (e.g., pixel size or pin-point measurement), observational period, frequency of individual observations and averaging time intervals, etc. The survey identifies three major problems to solve in order to supply customers with information relevant to their requests: improved access to information, improved description and knowledge in space and time of the radiation field and related quantities, and improved matching to actual needs. It suggests that combining “measured or assessed data and physical models permits convenient access to the information. Co-operation between several sources of information provides fruitful results. Efforts made in integrated information systems and co-operative systems have to be supported to overcome the technical limits of measurements by using the information and communication technologies” (Cros et al. 2004).

We believe that an appropriate exploitation of metadata and web services within a collaborative system is an efficient means to solve these problems and to bring knowledge, applications and data when and where it is needed. The SoDa Service is such a collaborative information system and has been created to that aim. The success in exploitation since 2003 demonstrates that i) as foreseen by the IEA survey there is a real interest in improving access, ii) a collaborative system is an efficient solution, iii) the use of metadata permits to homogenise the graphical user interface, inputs from and outputs to users. The thesaurus of the SoDa Service is specific. An increase of capabilities in dissemination requires on the one hand, the adoption of standards and on the other hand, an extension of this thesaurus to better describe

---

<sup>1</sup> Ecole des Mines de Paris / Armines, BP 207, 06904 Sophia Antipolis cedex, France. Email: benoit.gschwind@ensmp.fr

<sup>2</sup> NASA Langley Research Center, Hampton, VA, USA

Gschwind Benoît, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse, 2007. A proposal for a thesaurus for web services in solar radiation. In Proceedings EnviroInfo 2007, O. Hryniewicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. 1, pp. 135-142.

specific terms in solar radiation. The projects IEA SHC #36 (2006) and EC-funded MESoR (project FP7 #038655 “management and exploitation of solar resource knowledge”) partly devoted to that goal.

Metadata are necessary to ease data exchange at a large scale. A large amount of effort has been made in the field of geography and environment to establish standards. Efforts still remain to address more specific domains. This communication focuses on solar energy and more specifically on aspects in solar radiation that relate to geography and meteorology. It is a first attempt at establishing a thesaurus for describing data and applications in solar energy. A XML schema is proposed with focus on the exploitation of such a thesaurus in web services. The proposal exploits the standards available in time (ISO, W3C), geographic information (ISO, INSPIRE, GML) as well as the outcomes of several working groups for metadata in meteorology and related domains.

Users points of view are taken into account to draft this thesaurus. These views have been expressed when designing commercial products (ESRA, Meteororm), during projects in USA, Canada or EU where dissemination is an important issue (NASA-SSE, RETScreen, EU-Satellite, EU-SoDa, EU-MESoR) and works of the IEA and the Group on Earth Observation (GEO). In addition, surveys are periodically made by managers of information systems such as NASA-SSE, RETScreen and SoDa Service.

There are three different levels that metadata may be used for: “discovery metadata”, “exploration metadata” and “exploitation metadata”. Each of these purposes requires different levels of information. Users needs, low number of available services and attitude of the service providers show that presently, the emphasis should be put on “exploitation metadata”. These metadata describe those properties required to access, transfer, load, interpret and apply the data in the end application where it is exploited. This class of metadata often includes the details of a data dictionary, the data organisation, projection and geometric characteristics. The communication focuses on this level of metadata.

A major concern in our development and operation of the collaborative information system is the intellectual property rights (IPR). The attitude of the projects IEA SHC #36 and MESoR regarding these aspects is a respect of the IPR of the service provider with no obligation towards the collaborative information system, except those resulting from the commercial agreements if any. The “exploitation metadata” should include these aspects. However, this communication does not deal with details in IPR. The main reason is that we do not have enough experience to be able to elaborate efficiently details on IPR with service providers and customers. For example, no agreement was reached on payment schemes in a recent workshop gathering customers and service providers (EMP 2007). Metadata proposed by ISO 19115 in sections: Identification, Distribution, Citation and Responsible Party, are believed to cover our needs in a first phase. If necessary, extension may be possible for composition of services in the same way than discussed in this communication. The encoding process of these metadata may follow ISO 19118.

## **2. Thesaurus in solar radiation**

Gathering these standards, requirements and know-how gained in managing information systems, we propose a thesaurus for the main elements in solar radiation. Several thesauri exist in meteorology (AMS 2007; FAO 2007; UNESCO 2007; WMO 1966). None of them describes solar radiation accurately enough. Consequently, we establish a thesaurus that is specific to solar radiation. It comprises several elements, some of them relating to time and others to radiation. This thesaurus is based on the works of CIE (1970), Envisolar (2004) and Wald (2007).

Time is a very important matter in solar radiation. The daily rotation of the earth about itself determines a day which is divided in 24 h as an average. The time defined in this way is called the mean solar time (MST). The sun is approximately at zenith when the MST is equal to 12 h. However, because the orbit of the earth is an ellipse, the sun does not reach its highest position in the sky at 12 h MST every day. The highest position is called solar noon and is reached every day at 12 h in true solar time (TST). The difference between MST and TST differs each day and may reach up to 17 min. The time standard is

Coordinated Universal Time (UTC) and is the basis of the legal time. It differs by less than 1 s per day from the so-called Universal Time (UT), which is equal to the MST for longitude 0. Finally, legal time is the time legally used in one country. Several countries make use of daylight saving time, that adds 1 h to the winter legal time (summer in South hemisphere). All these times are used in solar radiation. Thus, the first elements of the thesaurus are:

- **Legal time, local time:** The time used legally in a given country;
- **Mean solar time:** The time determined locally by dividing the average duration of a rotation by 24 h. Mean solar time is equal to 12 h when the sun is at its zenith as an annual average;
- **True solar time:** The time for which the sun is actually at its zenith when it is 12 h. This depends on the day of the year and longitude of the site;
- **Universal Time (UT):** The mean solar time for the longitude 0.

The amount of power received by a surface depends on its geographical location. Thus, space is an important matter. This is well described in several thesauri and there is no need to address it in a specific way in solar radiation.

Two radiation types are used to describe radiation. **Irradiance** is defined as a power received per area or expressed differently as radiant flux of any origin incident onto an area. **Irradiation** is the energy received per area; it is an irradiance integrated over a certain period of time.

The radiation at ground, whether it is expressed as irradiance or irradiation, consists of several components: direct, diffuse and reflected. This decomposition may be of importance for several solar energy conversion systems. For convenience, one may add to these components the DNI (direct normal irradiance, or irradiation). The definitions are the following:

- **Diffuse** component: The downward scattered shortwave radiation coming from the whole hemisphere, with the exception of the solid angle of the sun disc and of the part of the radiation reflected by the ground in the case of an inclined receiving plane;
- **Direct** radiation: The shortwave radiation coming from the solid angle of the sun disc;
- **Reflected** radiation: The radiation reflected by the ground and received on an inclined plane;
- **Global** radiation: The shortwave radiation received at ground level; it is the sum of the direct, diffuse and reflected radiations;
- **Direct normal radiation (DNI):** The direct radiation received by a plane normal to the direction of the solar rays.

The spectral distribution of the radiation, i.e. the distribution of radiation as a function of the wavelength, varies in time and space. Its knowledge is requested for a better knowledge of the daylight, or UV radiation or any photo-energy system. Thus, we can define **spectral irradiance**, respectively **spectral irradiation**, as the spectral distribution of the irradiance, respectively irradiation, or the irradiance, respectively irradiation, integrated over a spectral window. This spectral property can be combined with the component, e.g., the spectral direct irradiance. If the spectral property is not mentioned, then it is understood that the radiation is considered as being the total, or broadband, radiation. This corresponds to an integration over the whole spectrum.

### 3. Description and attributes

How important are time-series in our activity should be underlined. Most of the information exchanged is presently under this form. We choose to focus on time-series and to use them as a basis for the description of information. A time-series is associated to a geographical site and to a period of time. In fact there are several attributes, some of them being constant in time, such as space or IPR, and others not, such as radiation values. We choose the description of a time-series as consisting of a series of constant attributes and a time-varying sequence of other time-varying attributes.

The first constant attribute is the unit in which the radiation value is expressed. The second is the type of radiation component, which is an enumeration: diffuse, direct, reflected, global, DNI. The third set of constant attributes deals with the IPR. It comprises the name of the provider and the relevant URL. An attribute conveys the name of the time-series given by the provider and another one the copyright text. Other attributes will convey information of dissemination issues. For example, data may be used freely or are of restricted access. We have chosen to attach these IPR attributes to the time-series and not only to the web services because of the composition of services that is foreseen. During composition, data flow are exchanged between services under the control of the collaborative information system and we believe that the controlling task is easier if IPR attributes are in the data flow. For the time being, we have not defined all these attributes; this should be done in close cooperation with service providers.

The next set of constant attributes deals with geographical location. Following BOM (2004), this set comprises the geographical coordinates and the time period of measurement which is called summarization in BOM. The associated enumeration in summarization differs slightly from WMO (2004) and BOM: 1 min, 5 min, 15 min, 1 h, 1 day, 1 week, 1 month, 1 year.

Finally, three constant attributes describe the spectral distribution. They are the two begin and end wavelengths depicting the wavelength interval over which the radiation is integrated and the unit in which these wavelengths are expressed.

It may be possible to define two other constant attributes: a scale and an offset that apply to the value as expressed in ISO 19103. We do not feel the need for these two attributes presently.

The sequence is made of a series of four time-varying attributes. One is the time corresponding to the measurement, the second is the radiation value, the third is the accuracy and the fourth one the reliability. The two latter attributes are not present in the thesaurus as there is no consensus reached up to now on that matter. This is one of the objectives of the projects IA SHC #36 and MESoR; it should be attained by the end of 2007. Though loosely defined, these attributes are present in the proposed XML schema.

Description of time is well covered by the ISO 19103, 19115 and 19118. There is no necessity for extension. Description of a date (year YYYY, month MM and day DD) and time (hour hh, minute mm and second ss) is in the form YYYY-MM-DDThh:mm:ss. Obviously, it would be better to have time expressed in decimal hour from a computational point of view. Nevertheless, we prefer to adopt this description rather than defining an extension though this would oblige most of the service providers to perform a conversion from sexagesimal system into decimal one and reciprocally.

The various systems for time may be accounted for in the ISO description. If one writes a time as hh:mm:ss±hh:mm (e.g., 18:30:43+01:00), the latter value hh:mm denotes the offset between the time used and the UT time. The offset is calculated as "local time minus UT". In the example above, 18:30:43+01:00 is the same time than 17:30:43Z where Z (or z) is the symbol used to depict UT time. As discussed before, measurements are made sometimes in TST. Using the offset permits to provide the means to represent these data in UT time. Note that the offset between TST and UT varies every day. Thus it should be computed every day. In addition, this offset should be rounded to the minute in order to conform to ISO. This may affect measurements that are made every minute or more frequently. These cases are not the most frequent presently and we believe that we can use this representation for the time being. If necessary, an extension may be performed that may include the use of decimal hours.

A limitation of this representation is encountered for data that are aggregated for, e.g., a given month over several years. For example, customers may request mean values of irradiance for each of the 12 months of a year but integrated over 10 years or more. The ISO description or that from W3C (2004) with the extension defining part of date, e.g. a full month within a year or a full year, does not cope with this case. An extension will be necessary.

One may note that we use only one time to describe the time range in which the measurement was made. An instant combined with a duration given by the constant attribute on summarization is sufficient. However, this assumes that all providers follow the same rule in meteorological measurements: the time

given is that of the end of the measuring period. Another hypothesis is that the duration of the measurement is the same than the sampling time, which is usually the case.

We thought about another possibility to describe the instant in the time-series. We can describe the instant at which the sequence begins as a constant attribute and exploit the summarization attribute and the rank of the radiation value in the sequence to compute the measuring instant. This solution reduces the size of the message to exchange. One of the disadvantages is that it requests to have data for each instant, even if empty flag. The method for composition of services in order to detect gaps in a time-series and to fill in these gaps by invoking another web service is more difficult than if instants are provided in the sequence, even at irregular spacing. A third disadvantage is that it is more difficult to describe instant in true solar time. As already said, the difference in time between UT, or MST, and TST depends on the day; it is not constant. The only solution would be to express time only in true solar time. Experience in the SoDa Service demonstrates clearly that though physically sound and recommended by WMO in measuring solar radiation, it was not a sustainable solution as it is conflicting with the current practices.

#### 4. XML schema

There are several possible ways for encoding metadata. The choice determines how efficiently the collaborative system may exploit and compose web services. Tendency in composition is to define very exhaustive and precise XML schema to increase the capabilities and accuracy in composition. Reversely, a too verbose schema will discourage the services providers of using it. A trade-off should be found.

Defining an encoding is not an easy task. Obviously, it comprises an arbitrary part that depends on the choices made in implementation and exploitation. Besides the XML schema of W3C (2004) dealing with time, several XML schemas exist that are relating to meteorology and to the attributes listed above (BOM 2004; GML 2005; NOAA 2007). To our surprise, only a little of these can be exploited in our application. We believe that this is due to the fact that we are very orientated to web services and their composition and that we are dealing presently only with time-series. Description of input and output messages is of paramount importance on the efficiency of methods for adaptative composition of web services (Ponnekanti/Fox 2002; Medjahed et al. 2003). Besides the input and output messages, the web service description language (WSDL) (W3C 2001) does not comprise efficient means to describe the service in a more semantic way, i.e., what does this service. One way to overcome this limitation is to increase the semantics of the input and output messages by defining types that convey part of the semantics of the service. For example, if we define a type *irradiance*, the message does not tell much whether the data are global or direct irradiance. Defining two types *globalIrradiance* and *directIrradiance* provides a means to distinguish between two services by their messages. This is the track we are following.

Three types of attributes should be represented as types in the schema:

- the radiation parameter: irradiance, irradiation;
- the radiation component: global, direct, DNI, diffuse, reflected;
- the summarization: 1min, 5min, 15min, hourly, daily, weekly, monthly, yearly.

Our approach is to define a generic type for a time-series of radiation data *sequenceOfRadiationValues*, depicted in Fig. 1. Then this type is extended to describe the three levels (Fig. 2). An example is given by *sequenceOfHourlyGlobalIrradiance* that inherits from *sequenceOfGlobalIrradiance* that inherits from *sequenceOfIrradiance* that inherits itself from the generic type. Rather than this 3-levels cascade, it would have been more efficient to define a generic type for each of the three types of attributes and to create a new type describing a specific time-series by inheritance of three types. However, as discussed in the next section, the XML schema will be used in a certain environment in which Java is the preferred language. Java does not accept simultaneous inheritance and this solution cannot be retained.

Once the XML schema established, one possible approach to its exploitation for web services is as follows. We choose Java because we believe that it is the most appropriate tool for our development.

Gschwind Benoît, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse, 2007. A proposal for a thesaurus for web services in solar radiation. In Proceedings EnviroInfo 2007, O. Hryniewicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. 1, pp. 135-142.

Firstly, the XML schema is written down with Eclipse as illustrated in the previous section. For a given service, one should define the inputs and outputs as well as the operations using the types present in the XML schema. From that, we create a WSDL file that imports the XML schema. Then, we generate the skeleton of the service in Java. Functions are implemented to complete the service. Then, it is deployed and finally, the WSDL is published for the use of the service by the collaborative information system.

## 5. Discussion

From 2000 to 2002, the partners in the SoDa consortium spent approximately 2.5 Meuro to build a working prototype of the SoDa Service. Then our team spent approximately 150 Keuro to make a truly operational SoDa Service with more than 20 000 users, a dozen of services providers and approximately 60 services, 10 among them being for pay. As a whole, the effort was very important (Gschwind et al. 2006). The SoDa Intelligent System (SoDa-IS) was developed to handle messages from and to web services and to invoke them (Wald et al. 2002, 2004). For that purpose, a SoDa XML schema was developed, comprising a very limited number of metadata. Each service is described by a descriptor using this schema. For example, it contains the temporal and geographical coverage of the service. The SoDa-IS has also the capability of dynamically building the GUI for each service by exploiting the service descriptor. The current applications for web services invocation, like Eclipse, do not permit to construct easily such a GUI-builder and we should spend efforts to create that application that may reach the current state of the SoDa-IS. In addition, the SoDa-IS permits to compose services in an easy way, where plans are manually built a priori in the same manner than BPEL (Van der Aalst et al. 2005). Finally, the SoDa-IS understands a set of metadata that are devoted to the presentation of the results, e.g., tables or graphs. These metadata are not part of the service descriptor; they are in the output flow from the service. That means that though all SoDa results exhibit the same SoDa frame, some arrangements are possible at the will of each provider. This possibility is very convenient but is not included in the web services description by W3C.

This discussion shows that metadata and their encoding are a major element in the SoDa-IS. Changing them will result in a in-depth re-engineering of the SoDa-IS, of message exchanges and on services provided by tiers. We are at the very beginning of this re-engineering process with many unknowns and little guidance. One of the many concerns is the relation with providers since it is the key to success for a collaborative information system. Are they ready to spend a large amount of effort to re-engineer their services? On the contrary, should we make efforts to create an interface between the legacy SoDa XML and the new one so that legacy services can be operated in the same way than before? We believe that the answer will depend upon the provider. Some of them will re-engineer their services. For the others, we may build pseudo-services, each of them encapsulating a legacy service.

The effort in re-engineering the SoDa-IS and making a new IS that is built on Open Source software, that uses known XML schemas and WSDL and is at least equivalent in functionalities to the current SoDa-IS overpasses what has been already done for the SoDa-IS in the past years. Nevertheless, it is worth making it. As the SoDa Service brings answers that are appreciated by a large number of professionals, it must evolve to survive and continue to serve efficiently the community.

## Bibliography

AMS (2007) Glossary of meteorology, American Meteorology Society. Available at [amsglossary.allenpress.com/glossary](http://amsglossary.allenpress.com/glossary).

- Gschwind Benoît, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse, 2007. A proposal for a thesaurus for web services in solar radiation. In Proceedings EnviroInfo 2007, O. Hryniewicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. 1, pp. 135-142.
- BOM (2004) XML schema for WxML markup language (weather XML), Australian Bureau of Meteorology. Available at [www.bom.gov.au/bmrc/wefor/projects/b08fdp/WxML/definitions.xsd](http://www.bom.gov.au/bmrc/wefor/projects/b08fdp/WxML/definitions.xsd) and [location.xsd](http://www.bom.gov.au/bmrc/wefor/projects/b08fdp/WxML/location.xsd)
- CIE (1970). International Lighting Vocabulary, CIE-no 45-05-160, 1970.
- Cros, S., Mayer, D., and Wald, L. (2004) *The Availability of Irradiation Data*. Report IEA-PVPS T2-04: 2004, International Energy Agency, Vienna, Austria, 29 p.
- Eclipse, an open development platform. The Eclipse Foundation. Available at [www.eclipse.org](http://www.eclipse.org), with plugins from Lomboz distribution, available at [lomboz.objectweb.org](http://lomboz.objectweb.org)
- EMP (2007). Summary of the workshop “Strategic Data for Financing Solar and Wind Power Projects”, held at Ecole des Mines de Paris, Paris, France, March 16, 2007. Available at [eod4invest.cma.fr/documents\\_en.php](http://eod4invest.cma.fr/documents_en.php).
- Envisolar (2004). Envisolar Project “Environmental Information for Solar Energy Industries”. European Space Agency project # AO/1-4364/03/I-IW. Deliverable D1 “Integrated Service Chain Specification”. Deutsches Zentrum für Luft- und Raumfahrt (DLR), Wessling, Germany.
- GML (2005) Geography Markup Language, Open Geospatial Consortium. Available at [schemas.opengis.net/gml/3.1.1/base](http://schemas.opengis.net/gml/3.1.1/base).
- Gschwind, B., Ménard, L., Albuissou, M., and Wald, L. (2006) Converting a successful research project into a sustainable service: the case of the SoDa Web service. *Environmental Modelling and Software*, 21, 1555-1561.
- FAO (2007) Thesaurus, Aquatic Sciences and Fisheries Abstracts. Food and Agriculture Organization of the United Nations. Available at [www4.fao.org/asfa/asfa.htm](http://www4.fao.org/asfa/asfa.htm)
- INSPIRE Infrastructure for Spatial Information in the European Community. Web site: [inspire.jrc.it/](http://inspire.jrc.it/)
- IEA (2006). International Energy Agency, Solar Heating and Cooling Programme Implementing Agreement, Task 36 - Solar Resource Knowledge Management. Available at [www.iea-shc.org/task36/index.html](http://www.iea-shc.org/task36/index.html)
- ISO 19115 (2003): International standard. Geographic information – Metadata. First edition, ISO, Geneva, Switzerland, 140 p. Technical Corrigendum 1 (2006), 33 p.
- ISO 19103 (2005): Technical Specification. Geographic information – Conceptual schema language. First edition, ISO, Geneva, Switzerland, 67 p.
- ISO 19118 (2005): International standard. Geographic information – Encoding. First edition, ISO, Geneva, Switzerland, 104 p.
- Medjahed, B., Bouguettaya, A., and Elmagarmid, A. K. (2003) Composing web services on the semantic web. *VLDB Journal*, vol. 12, pp. 333-351.
- NASA (2007) Surface meteorology and solar energy (SSE). Available at [eosweb.larc.nasa.gov/sse/](http://eosweb.larc.nasa.gov/sse/)
- NOAA (2007) XML schema for MADIS hydrological surface data. Available at [madis-fsl.org/hydro\\_sfc\\_schema.html](http://madis-fsl.org/hydro_sfc_schema.html).
- Ponnekanti S. R., Fox A. (2002) SWORD: A developer toolkit for web service composition. In Proceedings of The Eleventh World Wide Web Conference (Web Engineering Track), Honolulu, Hawaii, USA, May 7-11, pp. 83-107, 2002.
- RETSscreen (2007) RETScreen International. Available at [www.retscreen.net/](http://www.retscreen.net/)
- SoDa (2007) The SoDa service for knowledge in solar radiation. Available at [www.soda-is.com](http://www.soda-is.com). European Commission-funded project IST-1999-12245 “SoDa. Integration and exploitation of networked Solar radiation Databases for environment monitoring”.
- UNESCO (2007) Thesaurus. Available at [www2.ulcc.ac.uk/unesco](http://www2.ulcc.ac.uk/unesco).
- Van der Aalst, W. M. M., Dumas, M., Ter Hofstede, A. H. M., Russel, N., Verbeek, H. M. W., and Wohed, P. (2005) Life after BPEL? *Lecture Notes In Computer Science*, 3670:35-50.
- Wald, L. (2007) Solar Radiation Energy (Fundamentals). In UNESCO EOLSS (Encyclopedia of Life Support System). On-line encyclopedia available at [www.eolss.net](http://www.eolss.net).



Gschwind Benoît, Lionel Ménard, Thierry Ranchin, Lucien Wald, Paul Stackhouse, 2007. A proposal for a thesaurus for web services in solar radiation. In Proceedings EnviroInfo 2007, O. Hryniewicz, J. Studzinski and M. Romaniuk (Eds), Shaker Verlag, vol. 1, pp. 135-142.

Wald, L., Albuisson, M., Best, C., Delamare, C., Dumortier, D., Gaboardi, E., Hammer, A., Heinemann, D., Kift, R., Kunz, S., Lefèvre, M., Leroy, S., Martinoli, M., Ménard, L., Page, J., Prager, T., Ratto, C., Reise, C., Remund, J., Rimoczi-Paal, A., Van der Goot, E., Vanroy, F., and Webb, A. (2002) SoDa: a project for the integration and exploitation of networked solar radiation databases. In: Environmental Communication in the Information Society, W. Pillmann, K. Tochtermann Eds, Part 2, pp. 713-720. Published by the International Society for Environmental Protection, Vienna, Austria.

WMO (1966). International meteorology vocabulary. WMO no 182, TP 91, World Meteorological Organization, Geneva, Switzerland.

WMO Core Profile (2004). Proposal for an XML representation of the version 0.2 of the draft WMO core profile of the ISO metadata standard, September 2004.

W3C (2001). Web Services Description Language (WSDL). Available at [www.w3.org/TR/wsdll](http://www.w3.org/TR/wsdll).

W3C (2004). XML Schema Part 2: Datatypes. Available at [www.w3.org/TR/xmlschema-2/](http://www.w3.org/TR/xmlschema-2/)

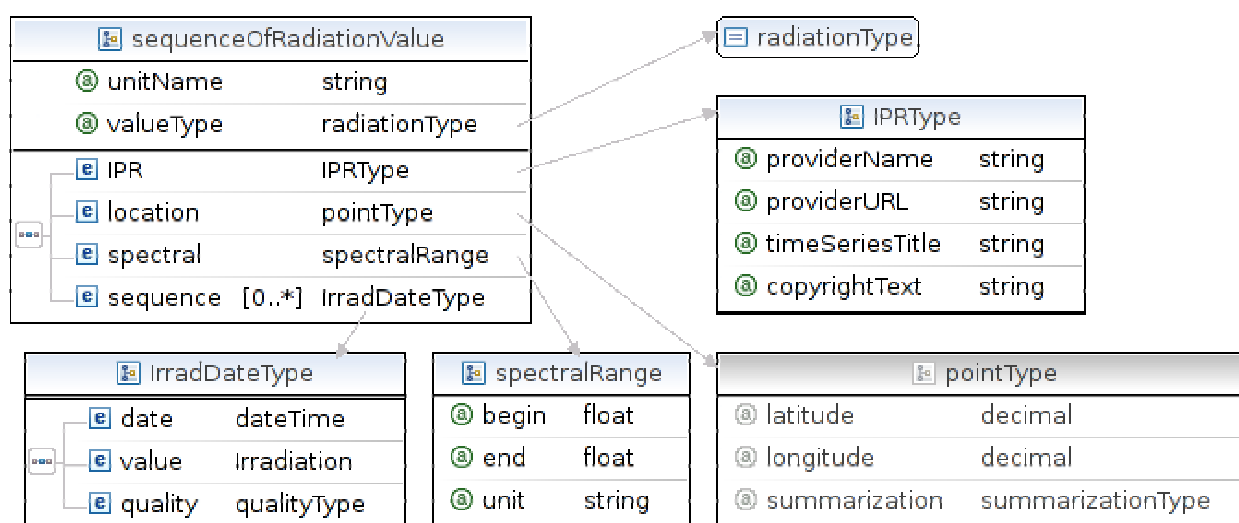


Figure 1. Schema of the generic type *sequenceOfRadiationValues*. Relations between attributes and types are shown.

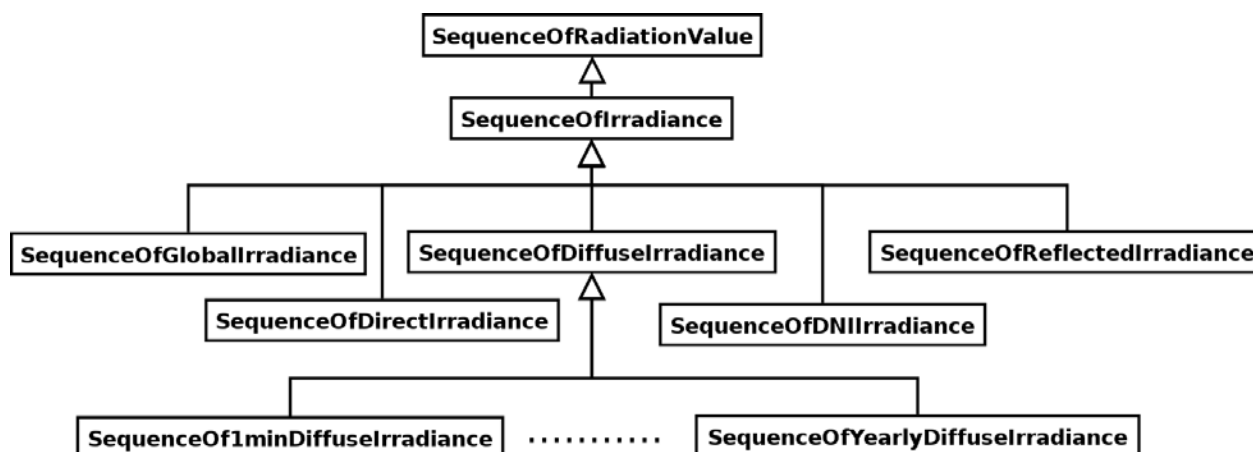


Figure 2. Diagram of inheritance of types describing the time-series of irradiance