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Sitting of a solar power plant: Development of Web service based on GEOSS data and guidance

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Abstract – Renewable energy sources such as solar and wind energy offer a large untapped potential for electricity production. The exploitation of these energies requires accurate knowledge of the resources and of their availability (in space and time) as well as accurate forecasts in the different phases of an energy system life cycle. For instance, the site selection process for development of large solar systems, such as photovoltaic on open land, require data on time-averaged values of solar irradiance from which basic economic assessments of a plant concept can be made. The paper illustrates the exploitation of Earth Observation data in this context. It describes the approach of setting-up a series of Web services that implement key features in Earth Observation data exploitation and illustrate their use through a complex application in the sitting of a solar power plant. The scenario is built on GEOSS interoperability and standard guidance.

Keywords: Renewable Energy, Solar Radiation, Solar Power Plant, Web Service, GEO/GEOSS, Interoperability, Standard, AIP-2 Pilot

1. INTRODUCTION

Renewable energy (RE) sources such as solar and wind energy offer a large untapped potential for electricity production. In order to establish appropriate instruments and strategies for the introduction of RES in the market, well-founded information on demand, resources, technologies, and applications, is essential.

Figure 1 shows the necessary steps of a cascade for the successful development of investments in RE, that are themselves the seed for an efficient introduction of RE sources in market. The cascade starts with the analysis of the available resources. These are e.g. maps of wind speeds or annual solar irradiance. These results can be combined with data on available areas for the different technologies –e.g., roofs and land area for PV, land area with suitable irradiance levels or wind speed for concentrating solar power and wind power– to determine the technical feasible potential of the different technologies. The level of the available resources can then be used to calculate where these technologies become economically viable, in order to determine the economic potential.

It is beyond the scope of this communication to discuss further this figure; this may be found in Hoyer-Klick et al. (2009). What is underlined in this figure is the crucial role of the knowledge of resources and potentials. For example, the site selection process for development of large solar systems, such as photovoltaic (PV) on open land, require data on time-averaged values of solar irradiance from which basic economic assessments of a plant concept can be made. Accurate, easy accessible and affordable wind information is needed at different levels of detail before deciding the sitting of a wind park as well as during the life-cycle of a wind farm. An error of a few percent in wind resource evaluation may drastically affect the profitability of an offshore wind park. The importance of resources is supported by other articles (Cros, Wald, 2003; Dunlop et al., 2006; Hammer et al., 2003).

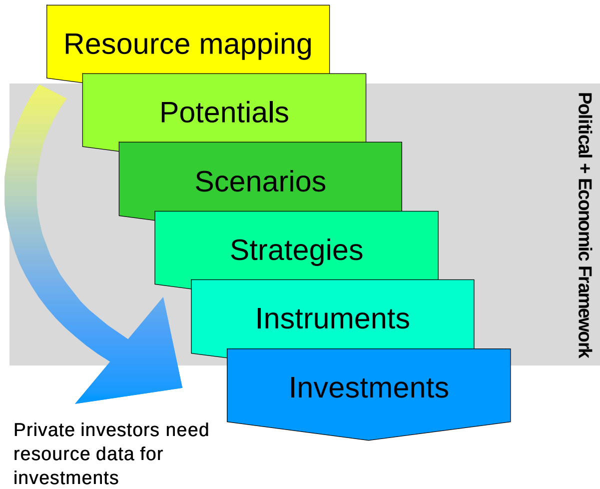

Figure 1: The cascade of market introduction of renewables (in Hoyer-Klick et al. 2009)

Resource for solar energy is hardly known in an accurate manner. There are a number of reasons (Cros et al., 2004; Dunlop et al., 2006; Gschwind et al., 2006). Among them are:

Improved access. The access to the relevant information is poor for many reasons. It is complicated by the various types of data, various storage standards, various units, various ways of expressing time (coordinated universal time, mean solar time, true solar time, local time) and diversity in information properties stored in databases: sampling support (pixel size versus or pin-point measurement), observational period of observation, frequency of individual observations and averaging time intervals, etc.

Improved knowledge on space and time structures. Space and time characteristics of presently available data are unsatisfactory. Interpolation/extrapolation techniques can be employed to gain knowledge at any geographical location and time, but the present techniques approaches lead to poor quality estimates.

Improved matching to actual users needs. Raw measurements are stored in and supplied by the current databases. Most often, they are not what are is really needed by the user. More advanced information should be supplied to the user.

The GEOSS initiative reveals its usefulness in bringing solutions to these three main concerns expressed by users as it will be detailed in subsequent sections. Standards for exchange and supply of data, interoperability are a means to improve access to data as well as extensive use of Internet and geographically-distributed services that can be exploited by a collaborative information system (Gschwind et al., 2006). Images from meteorological satellites together with appropriate processing methods are a means to improve knowledge on space and time structures as they offer every hour a synoptic view of the clouds and more generally of the optical state of the atmosphere (Hammer et al., 2003; Perez et al., 2002; Rigollier et al., 2004). Finally, availability of data of various types from various sources is enabled by the GEOSS, especially interoperability capabilities, which improve the matching of service supply to actual users needs.

2. GEOSS APPROACH

2.1 GEO, the Group on Earth Observation

The Group on Earth Observations (GEO) is an intergovernmental organization with 76 members plus the European Commission and 56 participating organization. GEO is coordinating efforts to build a Global Earth Observation System of Systems called GEOSS.

2.2 GEOSS, the Global Earth Observation System of Systems

The Global Earth Observation System of Systems (GEOSS) aims at promoting a global synergy of Earth observation. It intends to provide a more easy and open access to Earth observation data, to coordinate and sustain observation systems and to foster the use of such systems in all applicable domains. Nine areas of critical importance to people and society called Societal Benefit Area (SBA) are being addressed: disasters, health, energy, climate, water, weather, ecosystems, agriculture and biodiversity as shown in Figure 2.

Figure 2: The Global Earth Observation System of Systems.

2.3 GCI, the GEOSS Common Infrastructure

The GEOSS Common Infrastructure (GCI) comprises four main elements (Fig. 3):

1. the GEO Portal allows the user to directly search for information and services available in GEOSS;
2. the GEOSS Clearinghouse is the element that collects search and presents the various existing GEOSS components to the users via the GEO Portal;
3. the GEOSS Component and Service Registry allows GEOSS organizations to contribute components and services to the community;
4. the Standards Registry enables contributors to GEOSS to configure their own systems to be compatible and interoperable with others systems. A Standards and Interoperability Forum (SIF) has been created to allow contributors to share experiences, ideas and initiate new standards proposals.

These four elements are intended to provide the users of Earth observation a mean to search, discover and access information, tools and services available in GEOSS.

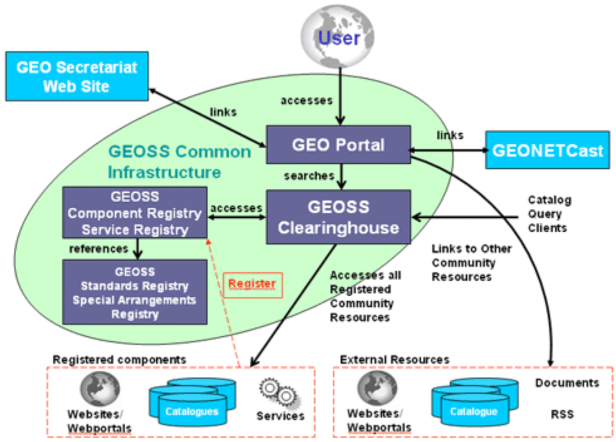

Figure 3: The GEOSS Common Infrastructure (GCI)

2.4 The GEOSS Interoperability Process Pilot Projects

GEOSS aims at integrating existing systems keeping in mind synergies among GEOSS components for the benefit of the nine SBAs. Interoperability is the key concept of GEOSS. The GEOSS Architecture & Data Committee (ADC) is in charge of developing and implementing this concept in several phases. The GEOSS Architecture Implementation Pilot task aims to incorporate contributed components consistent with the GEOSS Architecture, using a GEOSS Web Portal and a GEOSS Clearinghouse search facility, in order to access services (Fig. 3). Within the current Architecture Implementation Pilot Phase 2 (AIP-2), initiatives, called Process Pilot Projects, have been issued not only to address conceptual design but to demonstrate interoperability through real and persistent use cases. In that respect, a call for participation was released in June 2008 in close collaboration between the ADC and the GEOSS User Interface Committee (UIC).

2.5 Renewable Energy Scenario: an answer to the AIP-2 Call

Mines ParisTech and its associates: DLR (Deutsches Zentrum für Luft- und Raumfahrt), Joint Research Center – European Commission, Meteotest, NASA (Langley Research Center), Rutherford Appleton Laboratory, answered theAIP-2 call. Thereby, they express the global concern of a large community of users covering a broad spectrum: researchers, investors, producers, utilities, consulting companies, in the field of renewable energy looking mainly for solar radiation data but having also needs to access other various data sets to fulfill their objectives. The needs for Earth observation data in RE has been addressed by the Community of Practice “Energy” (GEOSS-ECP). A scenario divided in two main consecutive phases has been proposed. It intends to federate the RE community towards GEOSS interoperability concepts in order to provide as much as possible standard access to energy related catalogues and resources. Then it plans to demonstrate interoperability concepts through a real use case for “Sitting Solar Power Plants”.

3. FEDERATE THE RE COMMUNITY TOWARDS GEOSS INTEROPERABILITY CONCEPTS

3.1 Identify, check and validate, candidate resources for the RE SBA & Scenario

The first action undertaken has been to provide the most large and thorough list of already existing available resources addressing concerns of the RE. These resources must implement interoperability arrangements in order to comply with the AIP-2.
This living list is available at the dedicated section for the RE scenario within the collaborative development site for the GEOSS AIP-2. Emphasis has been put on identifying the interoperable arrangement proposed by each resource. Various interoperable standards stand together (OGC/WMS, W3C/WSDL, JSR6168,…) in this list; each of them addresses specific concerns of the RE community. An excerpt of this list is given in Table 1.

Provider	Resource Desc.	Interop. Arrangement	Spatial and Time Coverage
Mines ParisTech	HelioClim3: Database of Solar Radiation	W3C WSDL	Europe – Africa. Time series - Minute to Month
DLR	SOLEMI: Database of Solar Radiation	JSR-168 Compatible Portlet	Europe, Africa, Western Asia - Time series of hourly values
CIESIN	Hazards, Population Density, Natural Disaster, Human Footprint,... layers	OGC WMS and WFS Compliant Mapping Services	World
Mines ParisTech	RE Community portal	ISO-19119 Metadata WAF	N/A

Table 1: Resources listing details excerpt

3.2 Renewable energy community portal

Community portal as a whole is a recognized component of the architecture of the GEOSS Common Infrastructure. The scenario intends to provide access to interoperable resources as shown in Table 1. However, several of them necessary for the scenario were not practically implemented as such. For the purpose of the scenario and also as a strategic move to support interoperability for the sake of the RE community, Mines ParisTech has developed a community portal (www.webservice-energy.org) for deploying, hosting, promoting and allowing access to W3C Web services useful in this community. It acts a repository where providers may deploy their services that can be launched in an automatic manner by interested, and possibly authorized, users. Mines ParisTech has deployed several of such services, providing a standard access to several well-used data sets in solar radiation. For example, the services for databases HelioClim3 and SOLEMI (Table 1) are hosted by this portal.
This dedicated platform comprises in the back-end a Red-Hat JBoss application server for deploying and hosting W3C Web services. In the front-end an Apache Web server has been installed for human description of the Web services, to host the INSPIRE metadata of these Web Services and to act as a catalogue component thanks to the WAF (see later). The WAF URL has been provided to the GEOSS Registry as the end point for harvesting purpose.

3.3 Metadata and catalogue for resources

Implementing interoperability arrangement implies the provision of key components to ease mechanisms for search and discovery of resources. These two key components are metadata and catalogue. Various standards exists but selecting the one that best suits specific need can sometimes be difficult. As the RE community has developed already several W3C Web services, this implies the ability of the GEOSS to build metadata and catalogue upon W3C WSDL Web services. Though UDDI catalogue exists, its implementation requires a considerable infrastructure to operate and is not worth the effort when only tens of services are considered. Existing UDDI hosting facilities have not revealed appropriate to our case. We have therefore considered a new approach that is by far simplest but is perfectly compliant with GEOSS interoperable arrangements. This approach exploits INSPIRE ISO-19119 metadata for resources description and Web Accessible Folder (WAF) for cataloguing purpose. The INSPIRE metadata have been generated thanks to the INSPIRE metadata editor available on-line at the INSPIRE web site. This easy-to-use editor allows to generate ISO 19119 compliant metadata that describe W3C Web services through simple forms displayed in various tabs. Once the metadata are ready, they can be saved on the computer of the user. In order to provide a repository for those metadata in the community portal, a new component was designed: the Web Accessible Folder (WAF). The WAF is a basic directory where all the metadata XML files are stored. It is registered as a GEOSS standard component within the GEOSS component registry in order to offer search and discovery capabilities. This registry in then harvested by the GEOSS crawlers of the GEOSS Clearinghouse to allow the search and discovery actions of Web services in the GEOSS portal. Valid requests for searching and discovering W3C Web Service parameters have been successfully achieved and demonstrate the usefulness of such an approach.

4. "SITTING A SOLAR POWER PLANT" SCENARIO USE CASE IMPLEMENTATION

4.1 Scenario summary

The purpose of the second part of the response of Mines ParisTech and associates is to demonstrate interoperability concepts through a real use case for "Sitting Solar Power Plants". The scenario summary comes from a real business case encountered by various solar energy stakeholders. It is presented as the following steps:

- investors and electricity producers willing to invest in solar plants need precise and thorough information to support decision-making;
- on their behalf, consulting companies perform feasibility studies in order to decide where to sit power plants and which technology to use ensuring a profitable return on investment;
- to reach that goal, consultants need an easy and unified access to data sets. Such data sets include meteorological, geographical and environmental parameters.

4.2 Defining inputs and outputs

An overview of the inputs and outputs implementing this scenario can be summarized as follows:

As inputs it is mandatory to enter the AOI (Area Of Interest), the time period and the output scale. This will trigger the request for “core” layers. “Optional” layers can be selected on purpose. The output is a downloadable ZIP archive containing “core” and “optional” layers.

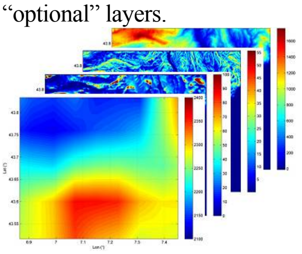

Figure 4: "Core" layers

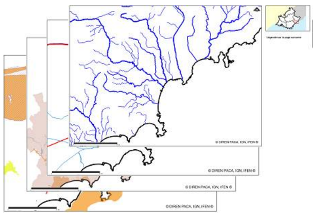

Figure 5: "Optional" layers

4.3 Resources description

The scenario addresses two kinds of resources.

1. The “core” layers systematically provided in the output archive.
   The “core” layers are built and added to the archive by internal processing of Mines ParisTech resources. These resources are made of meteorological data such as map of annual irradiation (kWh m^{-2}) extracted from the HelioClim database. Other “core” layers include shadows (%), terrain elevation (m) and local max slope (in degree) derived by an appropriate processing of terrain data from the SRTM database.
2. “Optional” layers which are optional but valuable for the renewable energy planner may be provided upon user selection.
   These layers will be triggered and added to the archive from already known and identified interoperable resources of GEOSS partners. A first list of such layers has been identified. It includes geographical data layers providing information on hydrological features (rivers, lake, channels), gazetteer and land use, environmental data like protected area, risks and hazards.

As previously discussed in this document, a work to identify operational and persistent resources to ease the scenario rolls out has been conducted (Table 1). These resources include the Web services deployed on the RE community portal and the CEISIN Columbia University resources on hazard, risks, population density resources, implementing OGC/WMS-compliant Web map services.

4.4 Web services chaining

In order to provide users with the map layers archives, specific software developments need to be carried out. Beside having all the resources available in an GEOSS compatible interoperable format, an orchestration of request, access, retrieve actions need to be performed. Some platforms such as SSE from ESA provide a workflow framework for Web service orchestration. The use of this tool has not been considered given the time frame of the scenario with respect to the efforts that it would have requested. Our approach uses a simple daisy chain mechanism by sequentially request the optional selected resources beside the always included core ones. As stated previously, it is admitted that the resources are already known and are permanently and persistently operating. Classical time-out access parameters will be use in the programming approach to encompass possible data failure.

As this approach might sound simplistic, it nevertheless illustrates data sets interoperable approach; it will underline the benefit of bringing resources alive complying to GEOSS standards and at least it will provide a valuable outcomes to renewable energy practitioners.

4.5 Client development

Bringing the above mentioned concept alive from the user perspective implies a design of a graphical user interface (GUI). By taking advantage of previous experience gained in an on-going project called MESoR and funded by the European Commission, we are working towards the provision of the GUI in a form of a JSR-168 compatible Portlet. According to JBoss terminology a Portlet is a *Java technology based web component, managed by a Portlet container, that processes requests and generates dynamic content.* This Portlet is deployed on a Liferay portal on the top of a JBoss platform. It is worth noticing that the Liferay portal that we are using within this scenario has been chosen by two of the current portal candidates in GEOSS.

The GUI elements within this Portlet will include Google Map API for Area Of Iterest (AOI) selection and a set of HTML forms for the other parameters. It will provide the coverage of the data resources as a KML file. Similarly to what has been developed within the MESoR project we want to provide the users with meta information about the application. Such meta information can include Web service overall description, reference to IPR (Intellectual Property Rights) and credits, and description of inputs and outputs. To provide a more interactive GUI, the meta information is embedded in tabs developed with AJAX technology for asynchronous browsing and querying approach.

Figure 6 provides an example of a Portlet, by which the above mentioned GUI elements trigger the HelioClim database through the corresponding Web service deployed at the RE community portal. This example fully addresses the GEOSS interoperable approach promoted in the renewable energy scenario and will be used as a template to implement the client.

5. CONCLUSIONS

Though the work has not yet been fully completed, it illustrates the exploitation of Earth observation data for the benefit of the development and integration of renewable energy in energy production. Within the framework of the AIP-2 initiative, a series of services has been developed that are compliant to the standards and interoperability requirements. As the RE community has more than 10-years experience in Web services, these services were developed using W3C standards such as WSDL and SOAP. The present study demonstrates the capability of the ADC to develop interoperability arrangements that accommodates various standards: W3C, ISO, INSPIRE and OGC. One of the benefits of this collaboration between the architects (ADC) and the users (UIC) is the development of the Web Accessible Folder (WAF), which is a new type of catalog.

As practitioners in RE, we have been able to achieve a more easy and open access to Earth observation data and services and to propose user-oriented services specific to RE that are compliant to GEOSS requirements.

Figure 6: HelioClim3 Portlet at MESoR prototype

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