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Environmental Services Infrastructure with Ontologies – A Decision Support Framework

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Abstract

An important challenge for today's environmental applications is to support the migration of environmental models to be provided as a service on the Web, and to be able to use other services, in the context of a potential wider environmental user community of service providers and service consumers. We refer to this shift in the way environmental modes are provided as Model-as-a-Service (MaaS). This paper briefly presents MaaS and introduces ENVISION – an easy-to-use framework to support the emerging MaaS paradigm. We propose a general architecture (comprising components ranging from environmental Web portals to semantic service annotations to adaptive service chains execution) for ENVISION. Our architectural choices are motivated and validated by two scenarios (one from oils spill and the other from landslide monitoring and analysis), which we present in this paper. Finally, we identify a set of general scenarios supported by the ENVISION framework.

Keywords: *decision support framework, service infrastructures, environmental modelling, case studies*

1. Introduction

Together with the Single Information Space in Europe for the Environment (SISE) (Weets 2006), the Shared Environmental Information System (SEIS)1 is one of three major initiatives, jointly with the INSPIRE Directive2 and the Global Monitoring for Environment and Security (GMES) initiative,3 undertaken by Europe to collect and share environmental information for the benefit of the global society. Major SEIS aims are: to improve information availability and quality for a better design and implementation of Community environment policies, to reduce the administrative burden on Member States and EU Institutions and to modernize reporting, to develop information services and applications that all of us can use and benefit from.

Many current environmental models are provided through monolithic and isolated applications, only linked by manual handling of input and output files and interactive data entry. In the evolution towards SISE/SEIS it as a goal that not only data become available, but also a large number of environmental models become available as services. We refer to this shift in the way environmental models are provided as Model-as-a-Service (MaaS), and to the concrete framework we propose in this paper to realize the MaaS paradigm shift as ENVISION. In Subsection 1.1 we briefly present MaaS and in Subsection 1.2 we provide the overall objectives of ENVISION, summarizing the contributions and structure of this paper.

1 http://ec.europa.eu/environment/seis/
2 http://inspire.jrc.ec.europa.eu/
3 http://www.gmes.info/

1.1 Model-as-a-Service (MaaS)

The *Model-as-a-service (MaaS)* (Roman et al, 2009) concept has evolved as a merge of *Model Web* (Geller and Turner, 2007, Geller and Melton, 2008) and *Software as a Service (SaaS)*,[1] in the context of the current *Everything as a service*,[2] as a concept of being able to call up re-usable, fine-grained software components across a network. The aim of MaaS is to provide access for a wider user community to relevant analysis models (e.g. spatial models, ecological models) through an automated request system for model runs, with online visualization and analysis tools and through standard data formats for simulation data interoperability. In the context of SaaS, MaaS, from a technical perspective combines technologies from Cloud and Grid computing with principles from Semantically Enabled Service Architectures (SESA) (Brodie et al, 2005) and Service-Oriented Knowledge Utilities (SOKU) (De Roure, 2006). This combination will potentially enable the provision of computing, data, information and knowledge capabilities such as utility-like services in the future, including services which intersect with the physical world through a wide range of computing devices.

Any framework realizing MaaS will have to implement a set of components that will enable easier use of environmental models by non ICT-skilled users and with advanced semantic technology support. Specifically, we envision: tools and components for portals with a pluggable decision support framework, support for visual service chaining, migration of existing environmental modeling applications to MaaS, semantic annotation infrastructures to support visual semantic annotation mechanisms and multilingual ontology management, an execution space that comprises a semantic discovery catalogue and semantic service mediator, and adaptive service chaining execution.

In ENVISION – the framework we propose in this paper to realize MaaS – we focus initially on the basic infrastructure for semantic service discovery and service chaining. Future extensions will include support for security and payments, for example.

By realizing the MaaS vision in domains such as the environmental domain, several benefits can be envisioned, including publication and high-level, multi-lingual re-use of models, different levels of access to models, interoperability between models, e.g. in service chains, easy formation of user communities, a faster/real-time decision making process, and a shared modeling infrastructure.

1.2 Objectives, Contributions, and Paper Organization

The ENVISION framework presented in this paper aims to address the SISE/SEIS and MaaS challenges, with a specific focus on providing the environmental community with better Web-based accessibility to environmental modeling tools and greater flexibility for designing environmental Web applications, through improved connections to distributed sources of information and services.

Based on earlier results from the EU FP6 SWING project[3] which developed a semantic Web services framework for geospatial decision making, we propose an ENVironmental Services Infrastructure with ONtologies (ENVISION framework) for semantically-enhanced multilingual discovery and adaptive composition of environmental models as services for non ICT-skilled users. The core objectives of ENVISION are to:

(1) Develop an Environmental Decision Support Portal based on a pluggable framework for non ICT-skilled users for on-demand semantic discovery and visual chaining of environmental services;

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1 http://en.wikipedia.org/wiki/Software_as_a_service

2 http://en.wikipedia.org/wiki/Everything_as_a_service

3 Semantic Web services Interoperability for Geospatial decision-making; http://www.swing-project.org/.

(2) Develop a Model-as-a-Service (MaaS) composition portal for making existing and new environmental models available as services;

(3) Develop an ontology infrastructure with tools for a non ICT-skilled user to interface with ontologies and multilingual semantic annotations of environmental resources and data streams;

(4) Develop an execution infrastructure with a semantic discovery catalogue and support for service mediation and adaptive service chaining;

(5) Develop and validate the tools and infrastructure based on pilots and scenarios in the areas of landslide and oil spill decision support, through contact with other environmental communities.

In this paper, we aim to set the foundation of ENVISION by identifying the core components and developing the underlying architecture, and providing examples of scenarios where the ENVISON framework could be applied. Besides introducing and discussing the emerging paradigm of MaaS, key contributions of this paper include the development of the ENVISION architecture and the identification of a set of common requirements for environmental applications supported by ENVISION, based on the analysis of two key environmental use cases (oil spill and landslide risk assessments).
The rest of this paper is organized as follows. Section 2 presents the general approach and the general building blocks. Section 3 presents the ENVISION architecture and its components. Section 4 exemplifies the application areas of ENVISION using two scenarios and extracting a general set of requirements for targeted application domains. Section 5 presents relevant related work and concludes this paper.

2. Overall Approach

To address the objectives, we identified a set of components that together have the potential to significantly improve the usability of environmental services. The components (planned to be provided as open source components) are grouped as follows:

(1) Portal with a pluggable decision support framework, support for visual service chaining, and migration of existing environmental modeling applications to MaaS;

(2) Semantic annotation infrastructure to support visual semantic annotation mechanism and a multilanguage ontology management;

(3) Execution space that comprises a semantic discovery catalogue and semantic service mediator, and adaptive service chaining execution.

The ENVISION framework combines and extends existing tools and components with functionality for easier use by non ICT-skilled users and with increased semantic technology support in an incremental development approach. The figure to the right shows the focus areas of ENVISION.

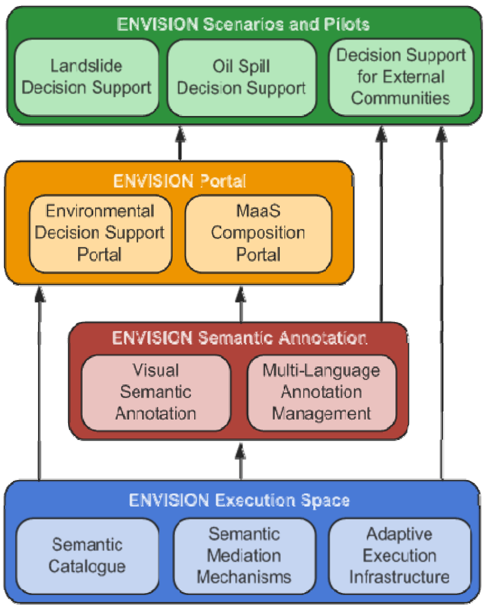

Figure 1: Central building blocks for ENVISION.

The *Execution Space* provides the basis for resource discovery and service chaining. Semantic interoperability is facilitated by the *Semantic Annotation* area, which contains ontologies, resource descriptions, and supporting tools. Both mentioned components provide input to the *Portal*. This area is also responsible for providing client components mechanisms for interfacing with the ontology and execution infrastructure. All areas in conjunction are applied to the *Scenarios and Pilots*. Concrete scenarios and pilots require application-specific decision support portals, and the overall framework provides means to generate such portals. To prove the ENVISION concept, we refer to two customized portals for two pilot cases (landslides and oil spills).

3. Architecture

The ENVISION architecture (Figure 2) shows details of the components, tools and infrastructure parts, and how they are used at design time and runtime. The color-coding is re-used from the previous figure.
At design time, the *Design Components* provide access to tools for building application-specific portals (for specific communities). Annotation and ontology clients provide easy access to available ontologies and semantic descriptions of resources. The *Environmental Decision Support Portal* provides interfaces for generating application-specific portal while the *MaaS Composition Portal* offers functionality for visual composition of service chains. A catalogue client can be used for discovery of candidate services of a specific composition task. The *Semantic Annotation Components* provide functionality to the annotation and ontology clients, as well as to the *Semantic Catalogue*. It comprises tools which support ontology creation and the annotation of resources, and a component for multi-language annotation management. The management of semantic annotations requires repositories for ontologies and for related metadata.

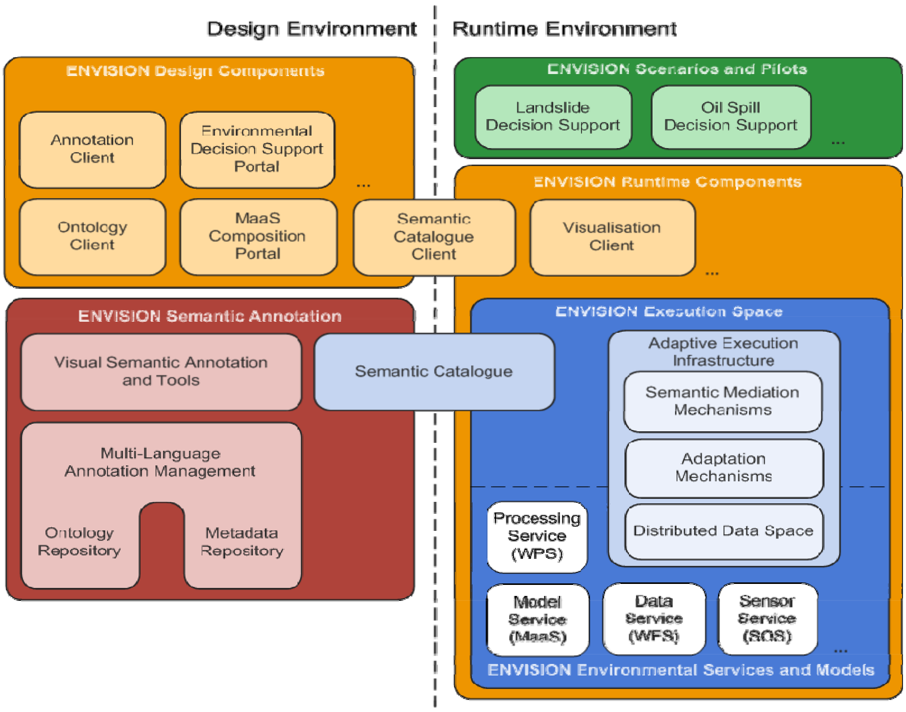

Figure 2. ENVISION Architecture.

At runtime, community specific decision support is illustrated by a landslide and an oil spill scenario and pilot. They will directly apply the catalogue client and visualization clients, which are both provided by the *Runtime Components*. Underneath, the *Execution Space* provides the *Adaptive Execution Infrastructure*. This incorporates mechanisms for data mediation and adaptation of service compositions. It hosts a *Distributed Data Space*, which is fed by classical data services, such as OGC WFS (OGC 2005) or SOS, Sensor Observation Service. Further resources, like processing functionality and environmental models are also provided as services. We call this part of the *Execution Space*, which includes the later four components, the *Environmental Services and Models*. A *Semantic Catalogue* supports registration and discovery of resources, providing the bridge between executable components and the ontology infrastructure.

4. Scenarios and Pilots

The above overall approach and architecture have been derived from a detailed and careful analysis of several large-scale use cases in the environmental domain. In the following subsections we briefly introduce two of these use case: one in the area of landslide hazard and risk assessment (Subsection 4.1) and the other one in the area of oil spill risk analysis (Subsection 4.2). By analyzing these use cases in relation to the ENVISION architecture and components, we extracted a set of general operations that the ENVISION framework aims to support (Subsection 4.3).

4.1 Landslide Hazard and Risk Assessment

Global warming is thought to have an increasing influence on natural events and the occurrence of natural dangerous phenomena such as hurricanes, storms and depressions responsible for damage to the environment through: floods, cyclonic swell, storm tides and coastal erosion. Heavy rainfall can also create or trigger potentially-damaging events such as mud flows, landslides and ground failure. As an example of a geographical area where these events are common and where data and sensors are available, we have chosen a French department (Guadeloupe) as a pilot area (although many of the problems addressed in this pilot use case are general) to point out some of the problems ENVISION is targeting (
Figure).

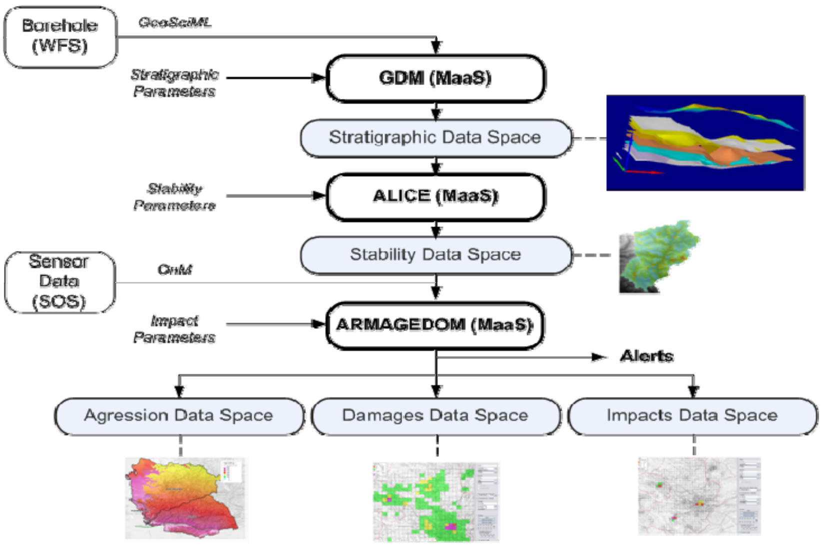

Figure 3. Landslides in Guadeloupe: Service based modeling.

The aim of the ENVISION use case for Guadeloupe is to set up Web services that can be manipulated by non-technical operators and can simulate damage under different climatic and/or earthquake (another potential trigger for landslides) scenarios. The French Geological Survey (BRGM) has a regional office on Guadeloupe, at which there are many databases available concerning landslides and earthquakes. In addition, this regional office has installed many *in-situ* sensors in the pilot area.

With the help of the ENVISION framework, standalone applications, such as GDM, ALICE, ARMAGEDOM, initially with restricted connection to limited data format and no interoperability, will be provided to a much wider community in a very flexible way, allowing the different components to be reused in many ways, and connected to various data sources, such as WFS or SOS.

4.2 Oil Spill Risk Analysis

Accidental oil discharges can happen and they may potentially severely harm the natural environment. Oil spills at sea call for a quick and appropriate response to minimize their biological consequences. Knowledge about the behaviour and fate of oil spills is crucial for preparedness and for taking adequate response actions. The Oil Spill Contingency and Response (OSCAR) model is designed for strategic analysis of alternative spill response options to oil spill events. The Oil Weathering Model (OWM) also operates as a stand-alone tool providing information to responders on windows of opportunity for alternate response strategies, including dispersant application and mechanical recovery operations. ENVISION provides the MaaS composition tool for making existing environmental models available as services. Also, ENVISION provides portal-based tools for visual chaining of environmental services. In the Oil spill pilot case in a Norwegian context, we can envision the following providers and services (
Figure 4). We use the same graphical elements as in
Figure 3.

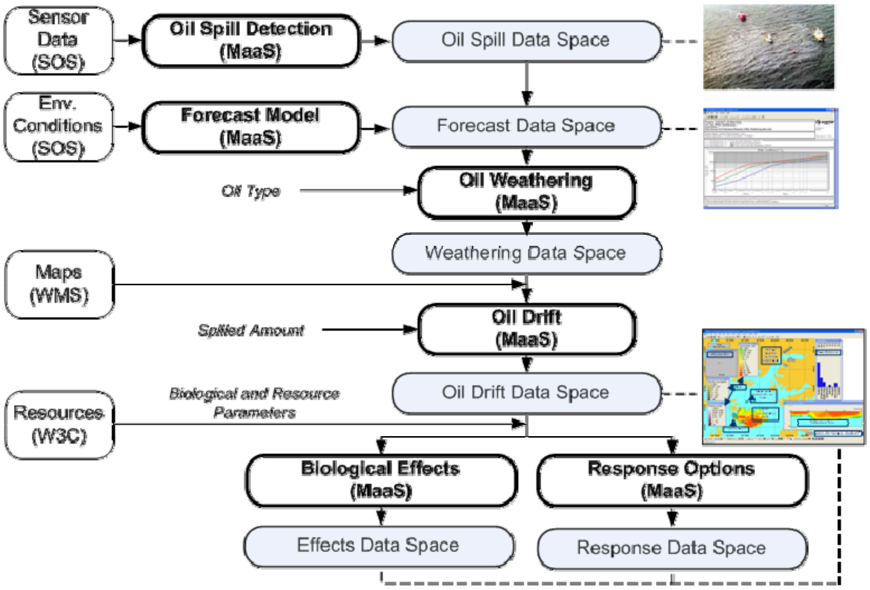

Figure 4. Oil spills in Norway: Service-based modeling.

The aim of this use case is the projection of the ENVISION framework to a second application area of environmental modeling. Again, the framework provides the means for encapsulating environmental models as services and for the connection of data services, such as OGC WFS, SOS, WMS (OGC 2006), and traditional Web services. The experience gained will allow for testing of the ability to generalize.

4.3 General Scenario

The use of the ENVISION architecture can be illustrated in the following scenario through a general set of patterns extracted from a thorough analysis of the use cases briefly introduced in the previous two subsections. These patterns are materialized through a set of operations the user can perform when interacting with a platform implementing ENVISION. Depending on the users' profiles, the different actors may interact in different ways: at *design time*, to provide off-the-shelf modeling solutions, at *set up time*, to connect the appropriate sources of information to feed the ad-hoc modeling service, and at *run time* to interact with the information provided by the models and to monitor the system. In this section we follow the same generic pattern of resource discovery, selection and execution during each phase, and highlight specific actions for both case studies, Landslide (LS) and Oil Spill (OS). The resulting modeling services for both use cases are illustrated in the figures in the previous two subsections.

Design time user operations

Discover existing re-sources: Iteratively, the user formulates semantic queries using the graphical interface, to find appropriate services (LS: Stratigraphic modeling services; Stability modeling services; Landslides hazard modeling services; Impact assessment modeling services. OS: Oil weathering modeling services; Oil drift modeling services; Biological effects modeling services; Response options modeling services). These queries are sent to the catalogue. The catalogue sends back all the resources matching the queries (for LS: GDM services; ALICE services; ARMAGEDOM services, and for OS: OWM services; OSCAR services).

Build the modeling workflow: The user graphically composes a service workflow based on the identified resources. For our use cases, this sequence is composed as follows. For LS: Using GDM services to apply geology modeling services to obtain a stratigraphic model; Using ALICE services to apply geophysical modeling services to obtain the stability model; Using ALICE services to apply the landslides hazard model; Using ARMAGEDOM services to apply impact assessment model. For OS: Using OWM services to apply oil weathering modeling services to obtain a weathering model; Using OSCAR services to apply modeling services to obtain: oil drift model, biological effects model and response options model. This model can be connected either with full static information from databases for simulation purposes; or real-time sensors.

Register/Annotate the new Service: The resulting service is deployed and registered in the catalogue and annotated using the relevant ontologies.

Set-up time user operations

Discover existing Modeling Services: The user query the catalogue for existing modeling services. The catalogue sends back all modeling services available. The user selects the LS or OS.

Select a region of interest (ROI): The region of interest is graphically selected.

Discover existing data sources: The catalogue sends back all data sources in compliance with the modeling service input parameters. In our case, data sources related to Geology and Geophysical parameters for LS, and for OS to Weather, sea forecasts; Map data; Biological resources data; Response resources.

Select the data sources: The user selects data relating to boreholes (or oil spill).

Set the parameters: The user sets the stratigraphic parameters and the stability parameters (or oil type and volume of spill).

Play the scenario: The user runs the scenario and retrieves a stability modeling data space.

Execution time user operations

Discover existing Modeling Services: The user queries the catalogue for existing modeling services. The catalogue sends back all modeling services available. The user selects LS or OS.

Select a region of interest (ROI): The region of interest is graphically selected.

Discover existing data sources: The catalogue sends back all data sources in compliance with the modeling service input parameters. In our case, some sensors are discovered.

Select the appropriate sensors data streams: The available sensors are connected to the MaaS.

Select functional parameters for the alerting system: The user selects the parameters to be triggered and threshold. The alerting mechanism is defined (e.g. send an e-mail to X when Y).

5. Related Work, Conclusions and Outlook

The MaaS paradigm shift proposed in this paper, together with the ENVISION framework as a concrete means to realize MaaS, are novel concepts that have the potential to significantly improve the access and usability of environmental services. ENVISION touches several research areas, the most important being environmental decision support portals, multi-language semantic annotation, multi-language annotation management, semantic discovery catalogues, service chaining, and adaptive service chaining execution. Although there has been significant work done in these areas individually, there is no unifying framework to glue together all these aspects and support the emerging paradigm of MaaS.

One relevant work is the semantic Web services framework developed in the context of the SWING project (SWING 2009). SWING provides a set of techniques and tools for annotation, discovery, composition, and invocation of geospatial Web services. Whereas SWING is seen as a foundation for ENVISION in terms of techniques and tools, the scope of ENVISION is much broader in the sense that it aims at providing a general-purpose decision support portal for various user communities, including non ICT-skilled users, in the environmental domain. Nevertheless, the tools and techniques developed in SWING provide a foundation for ENVISION and the implementation of ENVISION will reuse and further enhance SWING results.

The importance of environmental models interoperability has been recently emphasized in the context of the *Model Web* vision (Geller and Turner, 2007, Geller and Melton, 2008). The MaaS concept goes in the same direction but with a stronger emphasis on the service aspect. The Model Web does not come with any concrete platform for realizing models interoperability. With ENVISION we proposed a specific infrastructure combining various components and tools that could serve as an implementation for the Model Web vision as well.

It is also worth mentioning related work by Villa et al (2009), where a review of emerging semantic approaches to environmental modeling is presented. This work is complementary to the work presented in this paper. However the various approaches to environmental modeling could be considered in the context of ENVISION.

The core challenge ENVISION is tackling is on the Web-enabling and packaging of technologies for use by non ICT-skilled users in various domains, the support for migrating existing environmental models to MaaS on the Web, and the use of data streaming information for harvesting information for dynamic building of ontologies and adapting service execution. In this paper we briefly presented the concept of MaaS, set the architectural foundations for ENVISION, and identified general scenarios in the environmental domain where the ENVISION framework can be applied with significant gains. However, to realize MaaS and have a fully functional platform for ENVISION much remains to be done and new techniques such as portals, adaptive service chaining, sensor services, and annotation of data streams need to be developed and integrated in the ENVISION framework. Nevertheless, the work presented in this paper opens up new challenges and opportunities in the environmental domain, and set up new directions for further research in this area.

The impact of ENVISION is planned to be ensured through strong participation and leadership in relevant standardisation communities (e.g. INSPIRE, OGC, ISO/TC211), in user communities like SEISnet[1] and EuroGeoSurveys[2] and through the development of open-source software and reference implementations supporting open standards. ENVISION will potentially contribute to both SEIS, SISE and the INSPIRE Directive, different important initiatives taken by the European Commission to collect and share environmental information for the benefit of global society.

References

Brodie, M. L.; Bussler, C.; de Bruijn, J.; Fahringer, T.; Fensel, D.; Hepp, M.; Lausen, H.; Roman, D.; Strang, T.; Werthner, H.; and Zaremba, M. (2005). *Semantically Enabled Service-Oriented Architectures: A Manifesto and a Paradigm Shift in Computer Science*. Technical Report TR-2005-12-26, 2005. Available at http://www.deri.at/fileadmin/documents/DERI-TR-2005-12-26.pdf.

D. De Roure (editor) (2006). *Vision and research directions 2010 and beyond Future for European Grids: Grids and Service-Oriented Knowledge Utilities*. Next Generation Grids Expert Group report 3, 2006. Available at ftp://ftp.cordis.europa.eu/pub/ist/docs/grids/ngg3-report_en.pdf.

Geller, G.N. and Turner, W. (2007): *The Model Web: A concept for ecological forecasting*. In: IEEE International Geoscience and Remote Sensing Symposium, ISBN: 978-1-4244-1211-2, pages 2469-2472, Barcelona, Spain, July 2007.

Geller, G. N. and Melton, F. (2008): Looking Forward: Applying an Ecological Model Web to assess impacts of climate change. In *Biodiversity 9(3 & 4):79-83*. 2008. Special: Climate Change. ISSN 1488-8386.

OGC (2005). Open Geospatial Consortium Inc. *Web Feature Service Implementation Specification 1.1*. Available via http://www.opengeospatial.org/standards/wfs.

OGC (2006) Open Geospatial Consortium Inc. *OpenGIS Web Map Service (WMS) Implementation Specification, Version 1.3.0.* Available via http://www.opengeospatial.org/standards/wms.

Roman, D; Schade S.; Berre, A. J.; Bodsberg, N. R.; Langlois, J. (2009). *Model as a Service (MaaS)*. In Grid Technologies for Geospatial Applications Workshop, Hannover, Germany, 2009. Available at http://ifgi.uni-muenster.de/0/agile/submissions/AGILE-GridWorkshop-Roman.pdf.

SWING (2009) Semantic Web services Interoperability for Geospatial decision-making Project. Information available at http://www.swing-project.org/.

Villa, F.; Athanasiadis, I. N.; Rizzoli, A. E. (2009): Modelling with knowledge: A review of emerging semantic approaches to environmental modelling, Environmental Modelling & Software (24)5:577-587, ISSN 1364-8152.

Weets, G. (2006). *Toward a Single European Information Space for Environment*. ESA - DG INFSO Interoperability workshop: Architecture workshop in support of GEO and GMES. Frascati, Italy.

[1] http://www.epractice.eu/community/seisnet

[2] http://www.eurogeosurveys.org/