Grid-enabled Spatial Data Infrastructure serving GEOSS, INSPIRE, and UNSDI

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Abstract:

This document aims to provide a technical overview of the grid-enabled Spatial Data Infrastructure developed to support the needs of enviroGRIDS partners, the different services that have been set up to share baseline data as well as outputs of the various models, and finally the main achievements in term of contribution to major initiatives such as the Global Earth Observation System of Systems, (GEOSS), the Infrastructure for Spatial Information in the European Community (INSPIRE), and the Unites Nations Spatial Data Infrastructure (UNSDI).

Executive Summary

EnviroGRIDS (Building Capacity for a Black Sea Catchment Observation and Assessment System supporting Sustainable Development) aims to develop a Spatial Data Infrastructure (SDI) targeting this region and link it to the EGEE (Enabling Grid for EScience in Europe) infrastructure. A large catalogue of environmental data sets (e.g. land use, hydrology, and climate) will be gathered and used to perform distributed spatially-explicit simulations to build scenarios of key environmental changes. EnviroGRIDS aims at building capacities in the Black Sea region to use new international standards to gather, store, distribute, analyze, visualize and disseminate crucial information on past, present and future states of this region, in order to assess its sustainability and vulnerability. To achieve its objectives, EnviroGRIDS will build a Grid-enabled Spatial Data Infrastructure (GSDI) becoming one of the integral systems in the Global Earth Observation System of Systems (GEOSS), and compatible with the new EU directive on Infrastructure for Spatial Information in the European Union (INSPIRE), as well as UNSDI developments. The aim is also to complement the existing database used by the BSC and ICPDR partner as they represent a perfect interface between scientific data and end users. The open source and possibly commercial parts of the EnviroGRIDS SDI will therefore be replicated within the BSC and/or ICPDR architecture.

In term of architecture, we plan to set up a scalable and a services-oriented architecture (SOA). The architecture solution will support high volume data processing demands, no matter how much the user community grows. The vision is to encourage existing observation systems in the Black Sea Catchment to register into GEOSS their institution as components, and their data and processing services as well. EnviroGRIDS will host the services of the institutions that wish to contribute without having the necessary infrastructure in place. The EnviroGRIDS BSC OS will therefore be built from its own services registered into GEOSS, from hosted services and from services already registered in GEOSS. 22 GEO data and processing services were already identified in the list of deliverables by adding a tag on Nature of Deliverables named S-GEOSS.

From a grid perspective, the BSC OS will integrate grid technology in various ways. First, SWAT model will be gridified to run on the EGEE and to store the results of the different scenarios. These results will be queries from web services built in the BSC OS. The gridified code of SWAT will become a geoprocessing service that can be called from various clients such as SWAT users or web clients. Finally, the possibility to store the other outputs of the EnviroGRIDS project (e.g. climate, demographic, land cover scenarios) on the EGEE will be explored and used if feasible and interesting.

Content

1. Introduction

1.1 Presentation of the enviroGRIDS project

The Black Sea Catchment is internationally known as one of ecologically unsustainable development and inadequate resource management, which has led to severe environmental, social and economic problems. The EnviroGRIDS @ Black Sea Catchment project addresses these issues by bringing several emerging information technologies that are revolutionizing the way we observe our planet. The Global Earth Observation System of Systems (GEOSS) is building a data-driven view of our planet that feeds into models and scenarios to explore our past, present and future. EnviroGRIDS aims at building the capacity of scientist to assemble such a system in the Black Sea Catchment, the capacity of decision-makers to use it, and the capacity of the general public to understand the important environmental, social and economic issues at stake.

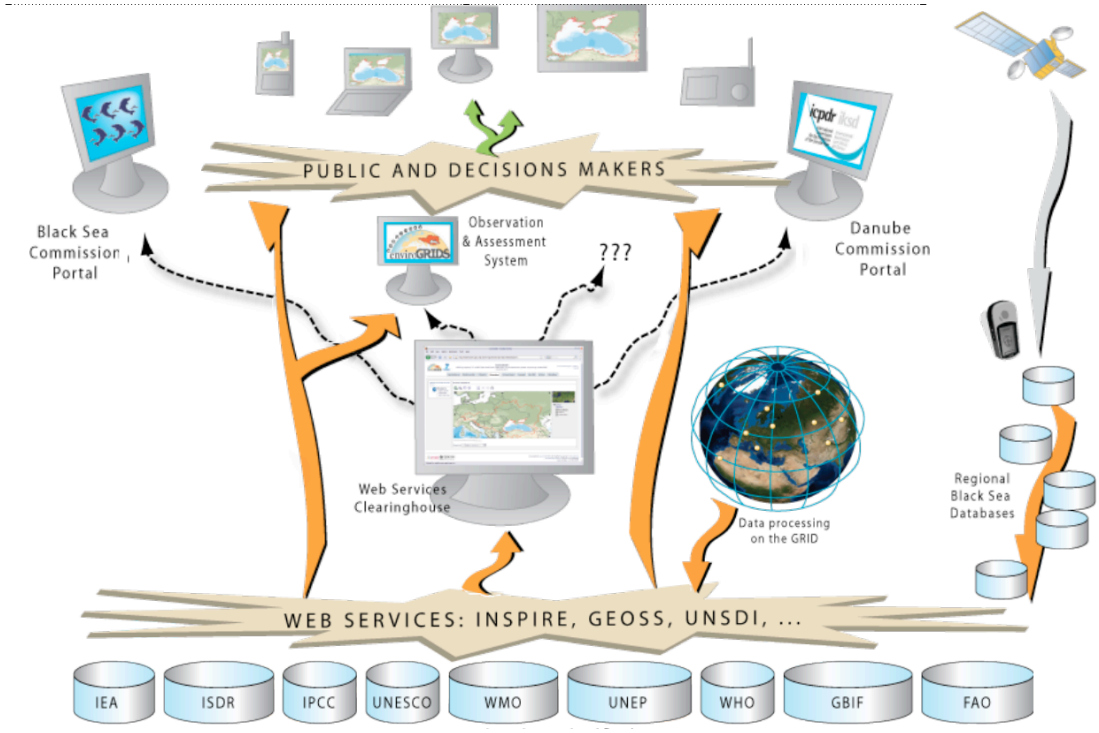

Figure 1: Project Vision and Goals.

EnviroGRIDS aims at building capacities in the Black Sea region to use new international standards to gather, store, distribute, analyze, visualize and disseminate crucial information on past, present and future states of this region, in order to assess its sustainability and vulnerability. To achieve its objectives, EnviroGRIDS will build a Grid-enabled Spatial Data Infrastructure (GSDI) becoming one of the integral systems in the GEOSS, and compatible with the new EU directive on Infrastructure for Spatial Information in the European Union (INSPIRE), as well as UNSDI developments.

The scientific aim of the EnviroGRIDS @ Black Sea Catchment project is to start building an Observation System that will address several GEO Societal Benefit Areas within a changing climate framework. This system will incorporate a shared information system that operates on the boundary of scientific/technical partners, stakeholders and the public.

It will contain an early warning system able to inform in advance decision-makers and the public about risks to human health, biodiversity and ecosystems integrity, agriculture production or energy supply caused by climatic, demographic and land cover changes on a 50-year time horizon (Lehmann, 2009).

1.2 Presentation of the Work package 2

The aim of this WP is to create a Grid enabled Spatial Data Infrastructure (GSDI) so that the data that are necessary for the assessment of GEO Societal Benefit Areas, as well as the data produced within the project to fulfill EnviroGRIDS specific objectives. This data can be gathered and stored in an organized form on the Grid infrastructure and distributed across the Grid in order to provide a high performance and reliable access through standardized interfaces. Using the standardized technologies of the Grid we can provide a Single Information Space for environmental data in the Black Sea Catchment.

First a gap analysis is undertaken by all partners to analyse the state of development of EO & SDI in the different countries within the Black Sea Catchment under the supervision of BSC PS and ICPDR partners. The recommendations derived from the gap analysis should aim at complementing the existing geographical information systems of the ICPDR and BSC. It will serve also to bring new partners from the Black Sea countries into the project in order to fill some thematic or technical gaps.

The proposed Grid-enabled system will require the creation of a Spatial Direct interface to load and download spatial data in different format and projections. Partners will therefore be able to make available existing sources of data more or less publicly available (e.g. historical climate data or geographic information), or newly collected data from sensors and satellites. This system will be fully compatible with developments made on interoperability standards such as INSPIRE, GEOSS, UNSDI, OGC, SensorML or TML. Grid services can be used to replicate and distribute the data from source sites to other data centres to improve availability but also access performance.

We intend to base our work firmly on the experience that the EGEE project (and in particular our partner CERN) has acquired in similar projects, but with non-geographic data (e.g. biomedical data). CERN also collaborated with UNOSAT to store satellite images and geographic metadata on the Grid. In particular, CERN has been providing the AMGA metadata service as part of the gLite middleware of the EGEE project that allows access on the Grid to databases storing GIS information. We intend to adapt this catalogue and its extensive replication and federation features to provide a unified view of all available metadata. EnviroGRIDS GSDI will also allow distributing intensive calculations such as those needed for hydrological modelling and calibrations.

1.3 Scope and purpose of the Task 2.7

This task is about building a Spatial Data Infrastructure connected to the grid infrastructure in various ways to store and analyse data. This SDI will allow partners to exchange data in various format and projections within the Black Sea catchment. It will also serve data to international and national initiatives as INSPIRE, GEOSS or UNSDI through web services.

In order to set up and provide these functionalities, we have planned to use a combination of open source (Postgres SQL, PostGIS, MapServer) and commercial software (ArcGIS server, FME), and to customize it with software development. Here are some of the features that will be developed to reach the needs of the Black Sea Catchment Observation System:

- View vector and raster data directly from the spatial databases
- Perform simple mapping operations such as pan and zoom
- Visualize the data to extract/download (like a Self-service portal to the spatial data)
    - Select themes and the format of the delivered data
    - Select the projection for the delivered data
    - Specify the geographic extent of the delivered data

- Serve data through WMS, WFS, WCS services
- Serve geoprocessing services with WPS standards

The aim is also to complement the existing database used by the BSC and ICPDR partners as these two institutions represent a privileged interface between scientific data and end users. The open source and possibly commercial parts of the EnviroGRIDS SDI will therefore be replicated within the BSC and/or ICPDR architecture.

In term of architecture, we plan to set up a scalable and a services-oriented architecture (SOA). The architecture solution will support high volume data processing demands, no matter how much the user community grows. The vision is to encourage existing observation systems in the Black Sea Catchment to register into GEOSS their institution as components, and their data and processing services as well. EnviroGRIDS will host the services of the institutions that wish to contribute without having the necessary infrastructure in place. The EnviroGRIDS BSC OS will therefore be built from its own services registered into GEOSS, from hosted services and from services already registered in GEOSS. 22 GEO data and processing services were already identified in the list of deliverables by adding a tag on Nature of Deliverables named S-GEOSS.

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1.4 Scope and Purpose of Deliverable 2.10

This document aims to provide a technical overview of the grid-enabled Spatial Data Infrastructure developed to support the needs of enviroGRIDS partners, the different services that have been set up to share baseline data as well as outputs of the various models, and finally the main achievements in term of contribution to major initiatives such as the Global Earth Observation System of Systems, (GEOSS), the Infrastructure for Spatial Information in the European Community (INSPIRE), and the Unites Nations Spatial Data Infrastructure (UNSDI).

The different chapters of the deliverable cover the following points:

- Chapter 2: Architecture of the enviroGRIDS grid-enabled SDI
- Chapter 3: Contribution to GEOSS
- Chapter 4: INSPIRE compliance
- Chapter 5:Contribution to other initiatives. UNSDI, Eye on Earth
- Chapter 6: Data policy, capacity building, etc..
- Chapter 7: BSC and ICPDR

We conclude with some conclusions, lessons learnt, and recommendations (chapter 8).

This report is linked with other enviroGRIDS deliverables:

- D2.1 EnviroGRIDS interoperability guideline
- D2.2 EnviroGRIDS data storage guideline
- D2.3 EnviroGRIDS sensor data use and integration guideline
- D2.4 EnviroGRIDS remote sensing data use and integration guideline
- D2.5 GRID infrastructure sustainability for environmental sciences
- D2.6 Report on Gap Analysis (12,24)

- D2.7 Report and Software package of grid services supporting massive data management
- D2.8 Gridified code, report
- D2.9 Software package of grid services supporting CWE Portal
- D2.11 Remote sensing data services
- D2.12 Sensor web services

1.5 Contributors to the Deliverable

Dr. Gregory Giuliani:

After obtaining a degree in Earth Sciences, he went on to complete a master in Environmental Sciences, specializing in remote sensing and GIS. He previously worked as a GIS Consultant for the World Health Organization, as a University tutor in remote sensing and GIS and as a GIS developer in a local Swiss GIS company. He works at UNEP/GRID-Geneva since 2001 and is the focal point for Spatial Data Infrastructure (SDI). In 2008, he also started to collaborate closely with the enviroSPACE laboratory where he completed a Ph.D thesis and works also for the FP7 ACQWA and AfroMaison projects. In EnviroGRIDS, he is involved as WP2 leader where his objective is to coordinate SDI and Grid technology researches.

Dr. Nicolas Ray:

Dr. Nicolas Ray is the EnviroGRIDS project manager. He holds a Master in Environmental Sciences, a PhD in Biology from University of Geneva in the field of Human Population Genetics, and a postgraduate certificate in Computer Sciences. Nicolas' research activities focused on the modeling of animal movement and habitat, with the development of several spatial and statistical analysis tools to integrate various data types (genetic, environmental, demographic). Through his research and various consultancy works, Nicolas acquired solid competencies in GIS, spatial analysis, software development, and grid computing integration. After six years of postdoctoral research in Australia, UK and University of Bern, he recently joined the Institute of Environmental Science at University of Geneva and UNEP/GRID-Europe to dedicate his time to the enviroGRIDS project. In addition to managing the daily activities of the project and ensuring high quality deliverables, he will take an active part in WP2 with all tasks related to the integration of grid computing and SDI.

Prof. Anthony Lehmann:

Dr. Anthony Lehmann is the EnviroGRIDS project initiator and coordinator. He holds a Masters Degree and a PhD in Aquatic Biology from the University of Geneva, and a Postgraduate Master in Statistics from the University of Neuchâtel. He specialized during his career in combining GIS analyses with statistical models. At the University of Geneva he is in charge of the enviroSPACE laboratory exploring Spatial Predictions and Analyses in Complex Environments. He is sharing is working time at a 50% rate with the United Nations Environment Programme (UNEP) Global Resource Information Database (GRID) under a special agreement between the University of Geneva and UNEP. At GRID, Dr. Lehmann is responsible for organizing research activities by leading the "environmental monitoring and modelling" unit. With the EnviroGRIDS project, his personal objective is to motivate all the partners to give their best in order to create a great observation system for the Black Sea Catchment. He will be specially involved in WP3 and WP5.

Dr. Karel Charvat:

Dr. Karel Charvat has a PhD in theoretical cybernetics from Charles University in Prague and currently works for Czech Centre for Science and Society.

Jean-Philippe Pôt & Florent Krin

Jean-Philippe Pôt is a manager at arxIT, specialized in GIS and ESRI products.

Florent Krin is a GIS expert at arxIT.

2. Architecture of the enviroGRIDS grid-enabled SDI

2.1 Components, tools, and functionalities

EnviroGRIDS is a distributed system built on a Service Oriented Architecture (SOA) that allows a flexible use of services over heterogeneous architectural components and technologies. The functionality provided by services could be used anywhere over the computing infrastructure by open standards and communication protocols.

The functionality and the layered architecture of the enviroGRIDS system are presented in Figure 1. The lower level is the data level. The following levels are Grid Infrastructure and Middleware. The Grid infrastructure is provided by the EGEE network, on which the gLite middleware is running. The upper levels consist of a Web portal hosting various services.

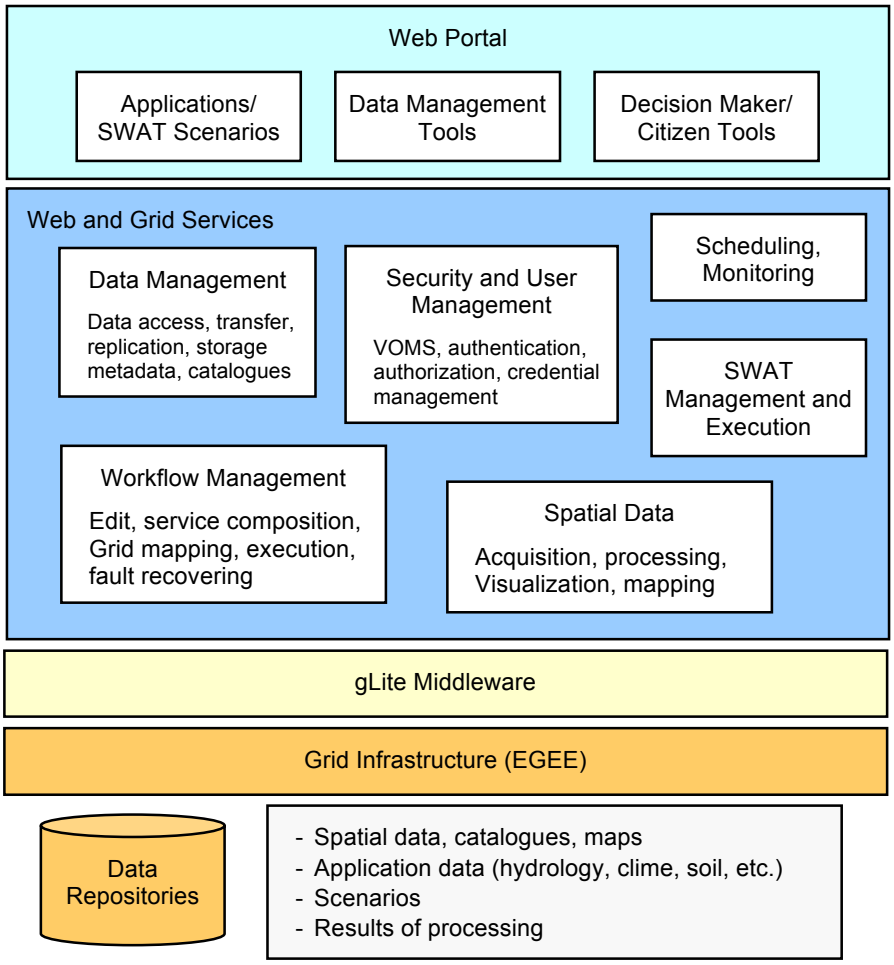


Figure 1: EnviroGRIDS functional Layers (from Dorian Gorgan). The lower level is the data level. The following levels are Grid Infrastructure and Middleware. The Grid infrastructure is provided by the EGEE infrastructure, on which the gLite middleware is running. The upper levels consist of a Web portal hosting various services.

Data repositories

Data Repositories consist of stored data and associated functionalities required to manage the repository. The repository stores raw data (e.g. spatial data) as well as processed data (e.g. maps, tables). They store application data, which are specific for each application type and instance (e.g. hydrology, climate, soil, etc). The register stores metadata catalogues that support the search, discovery and use of distributed data by the user applications, and processing services.

Resource Management and Data Processing Services

This level provides the basic services available over the Grid as secure and persistent services, and over the Web as stateless services. The services encapsulate the basic functionality provided to user applications. Such service categories are:

- Data Management: provides the basic operation on data repositories (e.g. data access, transfer, replication, storage metadata). The catalogues oriented operations are supported by AMGA Metadata Catalogue [25], which is the metadata service used in the gLite middleware.
- Security and User Management: provides the user the functionality needed to work with VOMS database, in order to support user authentication, authorization, and credential management. VOMS support the implementation of particular policies for data access and use.
- Scheduling: provide optimal resource allocation and sharing. Static or dynamic load balancing provide the best efficiency, costs, and use of available resources.
- Monitoring: support evaluation of the execution performance, and statistical analysis.
- SWAT Management and Execution: provide the functionality to control the execution over the Grid of the SWAT modules and related data.
- Workflow Management: supports the graph description of the processing, service composition, Grid mapping, workflow interpretation and execution, and fault recovering.
- Spatial Data Acquisition: support the working with sensors. They supervise the sensor status, data acquisition and transformation, store, and processing.
- Visualization and GIS Mapping: support data visualization in graphical user interfaces of the interactive applications, and maps generation and visualization.

EnviroGRIDS Applications

The enviroGRIDS Portal exposes to the user a set of tools and applications of which functionality is composed of the services provided by the underlying level. There are four types of interactive applications and tools available through the enviroGRIDS Portal:

1. Applications/ SWAT Scenarios Development Tools: the user may develop various scenarios for natural phenomena (e.g. through a graph based language) and use cases, and perform their execution over the Grid. The user may visualize the results and analyze statistical data.
2. Data Management Tools: data administrators and data provider may access, upload, update, and organize spatial data.
3. Decision Maker Tools: provide the user possibility to develop and execute various scenarios by different data series, and to analyze and make predictions on the phenomenon evolution. Graphical data visualization and mapping are available as well.
4. Citizen Tools: provide the citizen, as an Internet visitor, the execution of a given set of scenarios by limited set of data, and graphical visualization of the results.

A more detailed description of the enviroGRIDS infrastructure is available in the deliverable D2.2 on "Data Storage guidelines".

In summary, there are:

- Two data major data repositories:
  - enviroGRIDS.ch [UNIGE] (http://129.194.231.202:8080/geoportal/catalog/main/home.page): that stores baseline data, WP3 (scenarios), WP4 (SWAT outputs).
  - enviroGRIDS.cz [CCSS] (http://www.envirogrids.cz): that stores partners data who do not have the capacities to install/manage data on their own.
- Partners data repositories: some partners within the project framework and after having participated to the "Bringing GEOSS services into practice workshop" have started to share their data and metadata using OGC/ISO standards.
- EnviroGRIDS URM geoportal (http://www.envirogrids.cz): this is the entry point to search and access data used and produced within the project. It enables also users to discover other data within the Black Sea catchment area that are not in the scope of the project.
- gSWAT: to run SWAT models overs the Grid.
- Greenland/ESIP: to process remote sensing images over the Grid.
- eGLE: to build lessons (e-learning) on data processing over the Grid.
- BASHYT: SWAT outputs visualization and handling

2.2 Link between geospatial tools and grid tools

Various solutions have been implemented to make interoperable geospatial and grid tools. The solutions are explained in detail in the deliverable D2.7 "Technical Report and Software packages of grid services supporting massive data management".

Based on the experience acquired, it appears the brokering approach to enable interoperability among heterogeneous resources is promising.

According to such an approach, Users and Data Providers are not asked to implement any specific interoperability technology but to continue using their tools and publishing their resources according their standards -as much as possible. The broker binds the heterogeneous resources published by the Data Providers, adapting them to the tools commonly used by the Users.

In the case of enviroGRIDS, this enables grid tools to access data using OGC web services to retrieve data and process/handle them within a Grid environment. Such approach has been successfully tested to process remote sensing images with ESIP and will be further extend to the other enviroGRIDS grid-enabled tools. Moreover within such approach it is also possible to (automatically) publish processed data (at the end of a geoprocessing task) within the URM. Currently, we are testing such possibility with the GeoServer REST interface.

The brokering approach has also been used to grid-enable the OGC WPS specification and allowing users to process geospatial data over the Grid using a WPS service (Giuliani et al., 2012).

2.3 Data flow

With the adopted brokering approach and the use of OGC web services data are made available to all enviroGRIDS components/applications in a standardized way as seen in figure 2.

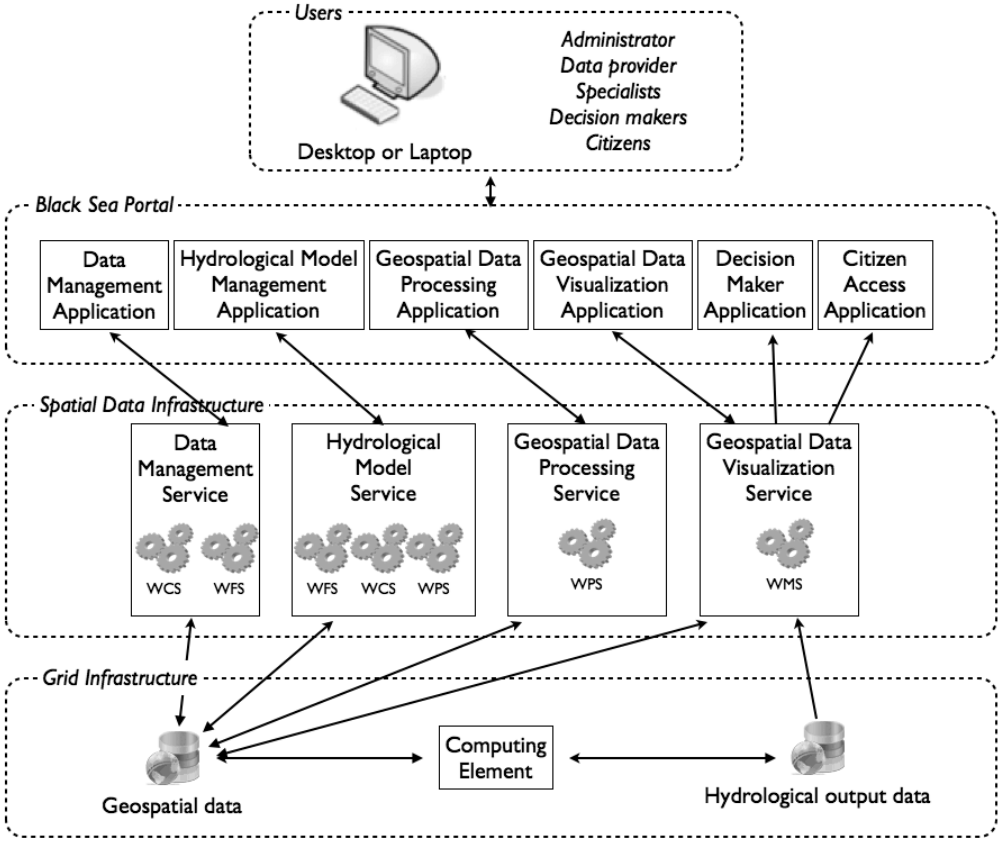


Figure 2: EnviroGRIDS Data flow and components

Basically, the data flow will be mostly "bottom-up", meaning that data (through OGC standards) will be served to tools/components of a higher level. However, as mentioned in the previous section, some tools will also be able to "upload and publish" data after processing. Data are available in WMS (visualization), WFS (vector data), WCS (raster data) formats and will feed dedicated specialized applications of enviroGRIDS framework.

2.4 Integration with the BSC-OS

All tools and application developed in the context of enviroGRIDS will be available under a common, single access point commonly known as the Black Sea Catchment Observation System.

The BSC-OS Portal is the single way the users access the enviroGRIDS applications and spatial data. The portal provides Web applications for data management, hydrologic models calibration and execution, satellite image processing, report generation and visualization. The portal allows the users the access to geospatial functionality given by Web infrastructure, and to high power computation resources given by the Grid infrastructure.

The BSC-OS portal architecture is presented in details in the deliverable D6.1 "Requirements and specifications for the development of BSC-OS Portal".

2.5 EnviroGRIDS VO

The key challenges in the Grid concept are coordinated resource sharing and problem solving in dynamic, multi-institutional settings. According to Foster and colleagues in their key paper "The Anatomy of the Grid", this sharing is not primarily file exchange but rather direct access to computers, software, data, and other resources, as is required by a range of collaborative problem-solving and resource brokering strategies emerging in industry, science, and engineering. This sharing is,

necessarily, highly controlled, with resource providers and consumers defining clearly and carefully just what is shared, who is allowed to share, and the conditions under which sharing occurs. A set of individuals and/or institutions defined by such sharing rules form what Foster et al. initially coined a "virtual organization" (VO). In other words, a VO is simply a group of users who shares the same computing resources.

To access the grid and use its resources, a user must first obtain a so-called grid certificate17 for his/her authentication. The second step is to obtain affiliation to at least one VO. A job can only be launched on the grid within the pool of resources defines in the VO the user is affiliated to.In the context of the enviroGRIDS a dedicated VO has been set up and managed by CERN and UTC partners.

Every project member who wants to run his SWAT jobs on the grid needs to register to the EnviroGRIDS VO. The first step is to obtain a proper grid certificate form the specific national Certificate Authority (CA). Here is the list of websites that can help obtaining the certificate:

- http://lcg.web.cern.ch/LCG/digital.htm - CERN website describing the process of obtaining certificates
- http://www.eugridpma.org/members/worldmap - World map of CAs

After getting the grid certificate and installing it on the browser user should register using the VOs

registration page:

- https://lcg-voms.cern.ch:8443/vo/envirogrids.vo.eu-egee.org/vomrs

Registration procedure takes few minutes and requires the following information:

- DN – Title of members certificate
- CN – Issuer of members certificate
- Email Address
- Phone number

After registration, the member needs to wait for the VO manager approval.

The most important information about EnviroGRIDS VO can be found on the VOs CIC Identity Card available under the following URL (website also requires grid certificate):

- https://cic.egi.eu/index.php?section=vo&vo=envirogrids.vo.eu-egee.org

Currently Romania and Armenia partners provide resources to the enviroGRIDS VO. Statistics showed that 5330 CPUs are available, storage space is equivalent to 24182395 GB, and 93380 jobs have been processed.

To configure software to use the EnviroGRIDS VO, information from this website are needed:

- https://voms.cern.ch:8443/voms/envirogrids.vo.eu-egee.org/configuration/configuration.action

3. Contribution to the Global Earth Observation System of Systems (GEOSS)

3.1 What is the GEOSS

Website: http://www.earthobservations.org

The GEOSS is being established by the intergovernmental Group on Earth Observations (GEO) and is a worldwide effort to build a system of systems on the basis of a 10-Year Implementation Plan for the period 2005 to 2015 . GEO is voluntary partnership of governments and international organizations where membership and participation is contingent upon formal endorsement of the Implementation Plan mentioned above.

GEOSS is an effort to connect already existing SDIs and Earth Observations infrastructures and thus will not create and/or store data but rather works with and build upon existing systems. GEOSS, through its developing GEOportal, is foreseen to act as a gateway between the producers of environmental data and the end users, with the aim of enhancing the relevance of Earth observations for the global issues and to offer a public access to comprehensive, near-real time data, information and analyses on the environment (GEO, 2007).

GEOSS aims to provide a broad range of so-called Societal Benefits Areas (GEO, 2005):

- Reducing loss of life and property from natural and human-induced disasters,
- Understanding environmental factors affecting human health and well-being,
- Improving the management of energy resources,
- Understanding, assessing, predicting, mitigating, and adapting to climate variability and change,
- Improving water resource management through better understanding of the water cycle,
- Improving weather information, forecasting and warning,
- Improving the management and protection of terrestrial, coastal and marine ecosystems,
- Supporting sustainable agriculture and combating desertification, and
- Understanding, monitoring and conserving biodiversity.

The mechanisms for data and information sharing and dissemination are presented and described in the 10-Year Implementation Plan Reference Document (GEO, 2005) where information providers must accept and implement "a set of interoperability arrangements, including technical specifications for collecting, processing, storing , and dissemination shared data, metadata and products. GEOSS interoperability will be based on non-proprietary standards, with preference to formal international standards. Interoperability will be focused on interfaces, defining only how system components interface with each other and thereby minimizing any impact on affected systems". GEOSS is based on existing technologies using internet-based services.

Moreover members must fully endorse the following data sharing principles:

1. There will be full and open exchange of data, metadata, and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation.
2. All shared data, metadata, and products will be made available with minimum time delay and at minimum cost.
3. All shared data, metadata, and products being free of charge or no more than cost of reproduction will be encouraged for research and education.

These principles push data owners to go "open" and to share their data using standards and thus becoming interoperable.

3.2 Registered services

EnviroGRIDS is registered into GEOSS as a component since 2009. It can be found at the following URL:

http://geossregistries.info/geosspub/component_details_ns.jsp?compId=urn:uuid:4f47ce0b-1eff-47e0-b3e2-82de20c1f783

Currently (March 2012), it provides access to six associated services:

1. Black Sea Catchment DEM – WMS:

   http://geossregistries.info/geosspub/service_details_ns.jsp?serviceId=urn:uuid:03c57600-d514-4c81-869d-ff486b8745c5

2. EnviroGRIDS URM Portal – Catalog:

   http://geossregistries.info/geosspub/service_details_ns.jsp?serviceId=urn:uuid:c8765f74-9970-4e71-953e-b71d314702f1

3. EnviroGRIDS Map toolkit – WMS:

   http://geossregistries.info/geosspub/service_details_ns.jsp?serviceId=urn:uuid:6da8d0b1-68ed-4dfb-b9fb-9259b3b34329

4. EnviroGRIDS Hydrological modeling (WP4) – WMS:

   http://geossregistries.info/geosspub/service_details_ns.jsp?serviceId=urn:uuid:7bd7087d-e4da-47cc-ab2a-b7873da58241

5. EnviroGRIDS Scenarios of change (WP3) – WMS:

   http://geossregistries.info/geosspub/service_details_ns.jsp?serviceId=urn:uuid:6eed85e8-bdf8-452d-856b-daeb1c4ba24b

6. Black Sea Commission:

   http://geossregistries.info/geosspub/service_details_ns.jsp?serviceId=urn:uuid:68a87562-fd48-49be-8bb7-a6c5afb90fca

These services provides baseline data (such as Digital Elevation Model, Soils, Land Cover, ...) used within the different models/scenarios, and were also used to test the infrastructure and data flow mentioned in Chapter 2. They will be updated on a regular basis by the end of the project to bring all the relevant and useful data sets used along the whole duration of the project. Additionally, much more services will be registered during the last year of the project. These services can be broadly separated in four categories

- *Project outputs:* All the data sets produced in WP3 (scenarios of Land Use, Demographic, and Climate Changes) and in WP4 (hydrological models) will be properly registered.
- *From partners:* some partners have installed all necessary software to share local/regiona data sets (as well as metadata). This mostly concerns ONU, TNU, SPSU partners.
- *Tools:* All the tools/components of the Black Sea Observation System developed within the framework of the project will be also registered into the GEOSS Common Infrastructure (GCI):
  - gSWAT
  - eGLE
  - GreenLand/ESIP

- BASHYT

These tools are extensively presented in deliverables of the WP6. It should be mentioned that we will explore a possibility to expose gSWAT as a Web Processing Service using PyWPS.

- *Map composition:* each case study of the WP5, covering the nine GEOSS SBAs, will be featured by an interactive map composition (a tool provided by the enviroGRIDS URM) and registered into GEOSS.

Finally the teaching material called "Bringing GEOSS services into practice" that explains how to install, configure and deploy a set of open source software to publish and share data and metadata through GEOSS using OGC web services & ISO standards, has been also registered into the GCI:

http://geossregistries.info/geosspub/component_details_ns.jsp?compId=urn:uuid:b96c48ad-1e85-49df-bbaa-d1bf04c0bba8

3.3 How to register

Main project end-users (BSC and ICPDR) have been encouraged to register their services on their own (in order to gain visibility). Other project partners have (or will) registered their services under the enviroGRIDS component. In the latter case, they should contact WP2 leader and send him the URL of the interface.

Once registered all these services are harvested and searchable directly through the enviroGRIDS URM (http://www.envirogrids.cz) that offers discovery facilities and is able to query GEOSS, INSPIRE, and enviroGRIDS catalogs. Consequently data is available to create dedicated map composition to show case either main outputs of the project or specific results within a SBA. As all data are shared using OGC standards, they are readily available to be consumed within various types of clients (web or desktop).

The OGC web service flow is presented and summarized in the figure 3.

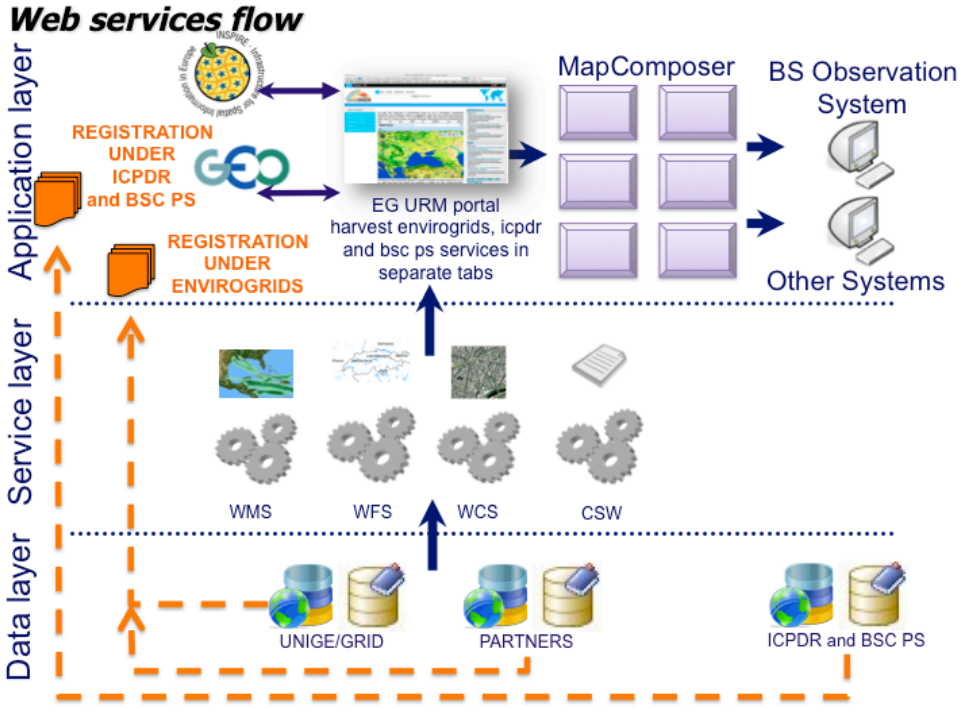
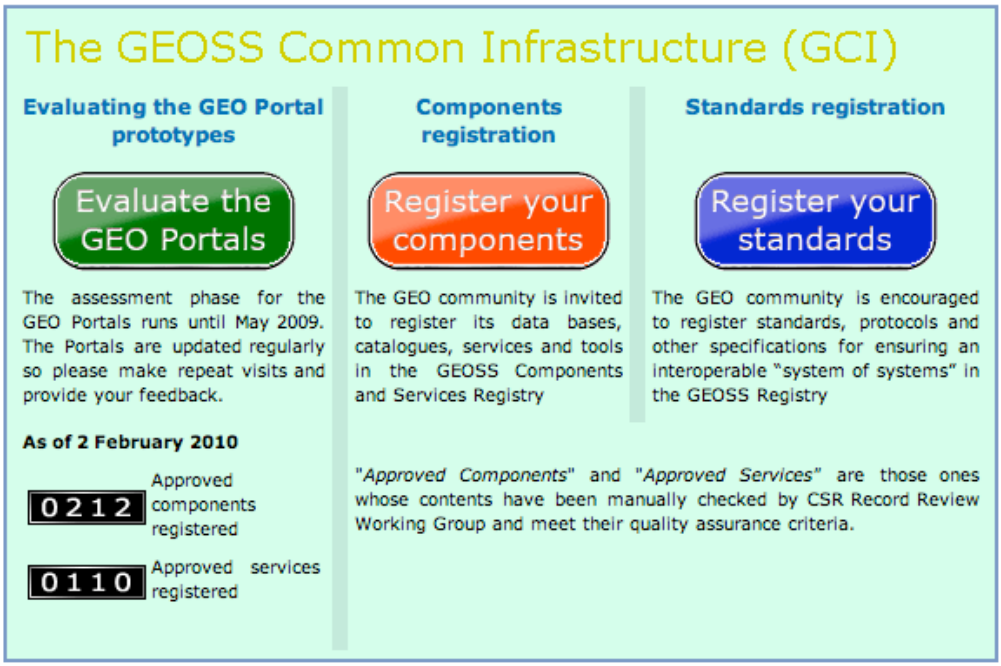


Figure 3: OGC Web Services flow within enviroGRIDS

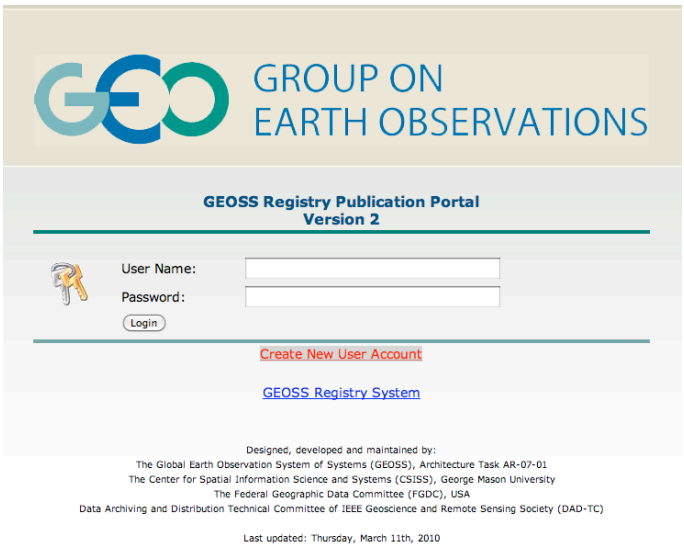
In order to register services into GEOSS, we have followed and shared among our partners the following procedure.

1. Creating a new user account



Go to http://www.earthobservations.org/gci_cr.shtml

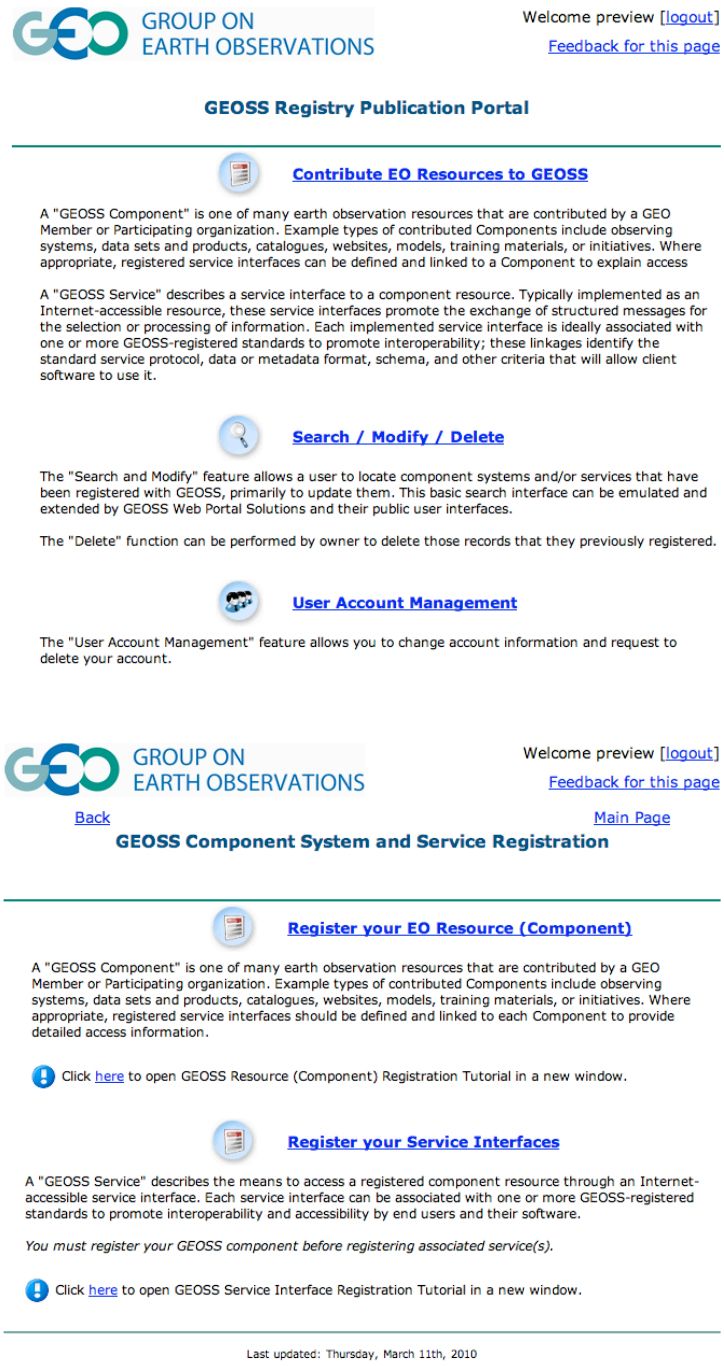
The GEO community is invited to register its databases, catalogues, services and tools in the GEOSS Components and Services Registry (see following screenshots).



http://geossregistries.info/geosspub/

Create a new user account

After that LOGIN you can register your component and related services.



2. Registering a component

A "GEOSS Component" is one of many earth observation resources that are contributed by a GEO Member or Participating organization. Example types of contributed Components include observing systems, data sets and products, catalogues, websites, models, training materials, or initiatives. Where appropriate, registered service interfaces can be defined and linked to a Component to explain access

1. Log into GEOSS Component and Service Registry System with username and password. Click

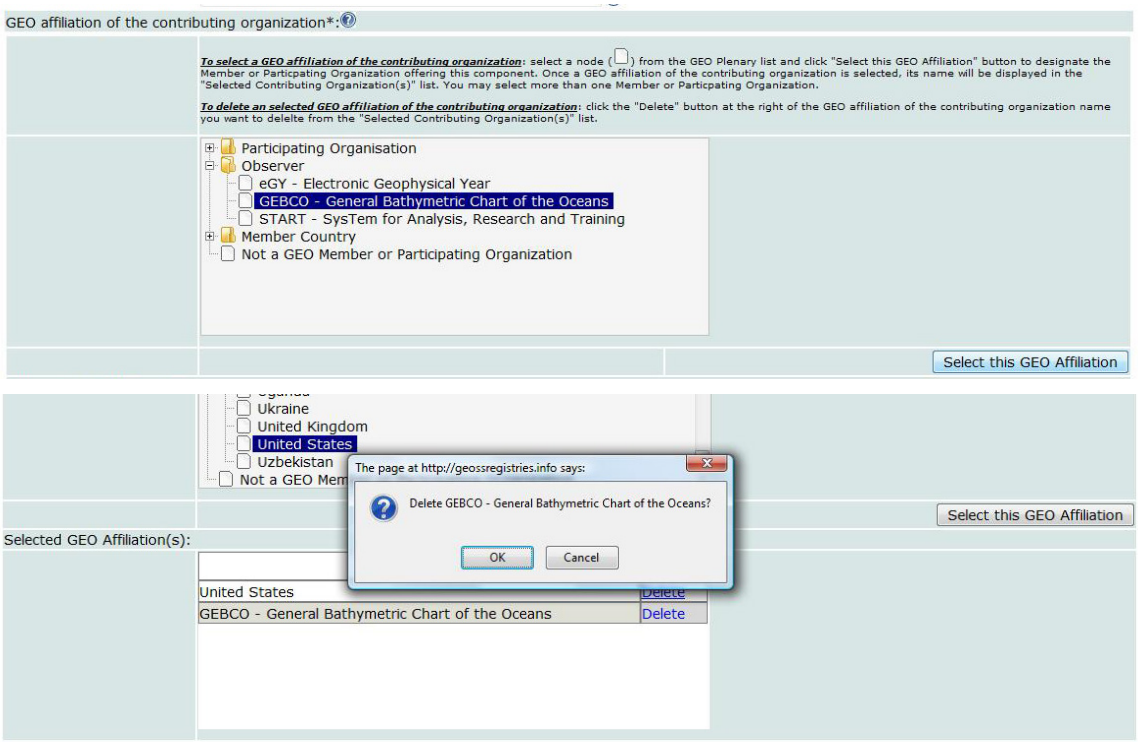
"Contribute EO Resources to GEOSS" from the main page after login. In the next page, click "Register your EO Resource (Component)" to proceed to Resource (Component) registration page.

If you have saved a Resource (Component) registration draft, you may continue with the saved registration process by click the draft Resource (Component) Name, or click "Start a new Component Registration" to register a new Resource (Component).

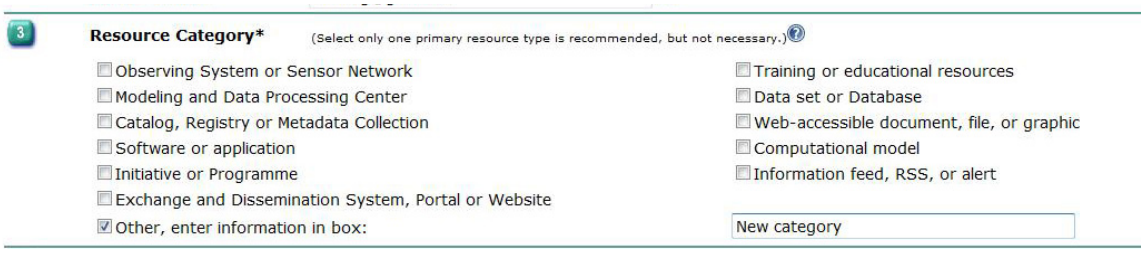
2. In the registration page, specify Resource (Component) name, description, GEO affiliation, URL to Resource, contact name, email respectively.

To select a GEO affiliation of the contributing organization: select a node () from the GEO Plenary list and click "Select this GEO Affiliation" button to designate the Member or Participating Organization offering this component. Once a GEO affiliation of the contributing organization is selected, its name will be displayed in the "Selected Contributing Organization(s)" list. You may select more than one Member or Participating Organization.

To delete an selected GEO affiliation of the contributing organization: click the "Delete" button at the right of the GEO affiliation of the contributing organization name you want to delete from the "Selected Contributing Organization(s)" list.



Then, select resource category from the ten types listed or specify your own category if none of the predefined categories matches your resource. To specify a new category, click other, and enter the new category name in the text box.



[1] Societal Benefit Areas and Resource Availability are also required field for Resource registration. Select all relevant social benefit areas for your resource and specify the availability.

At the bottom of the page, you may find a check box of "Also send out a "Request for Approval" notice to the GEOSS CSR Record Review Working Group.". By choose this option, you allow the GEOSS CSR Record Review Working Group to manually review this record. Only approved record will be listed in the CSR holdings page, searchable through the public search interface and viewable to the GEOSS Clearinghouse through the API interface. You may also request for approval of this component later in the Component Search/Modify/Delete page.

You may save the process at any time of your registration by clicking the "Save Draft" button at the bottom of the registration page. When a registration draft is saved, you will find when next time you come to the Resource registration module with the same user name you are using. Click "Register" button to register the Resource when all the required information are ready.

If the Resource is successfully registered, you will be redirected to a confirmation page. You may go ahead and register a Service Instance for this Resource by clicking the button "Register a Service for this Component" or go back to main page by clicking the button "Go Back to GEOSS Component System and Service Registration Page".

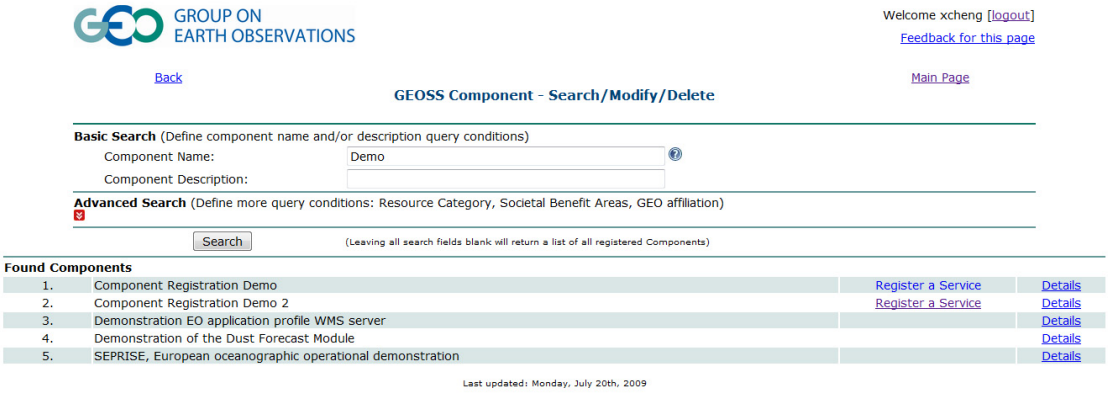
3. Registering services

A "GEOSS Service" describes a service interface to a component resource. Typically implemented as an Internet-accessible resource, these service interfaces promote the exchange of structured messages for the selection or processing of information. Each implemented service interface is ideally associated with one or more GEOSS-registered standards to promote interoperability; these linkages identify the standard service protocol, data or metadata format, schema, and other criteria that will allow client software to use it.

1. Log into GEOSS Component and Service Registry System with username and password. Click "Contribute EO Resources to GEOSS" from the main page after login. In the next page, click "Register your Service Interfaces" to proceed to Service Instance registration page.

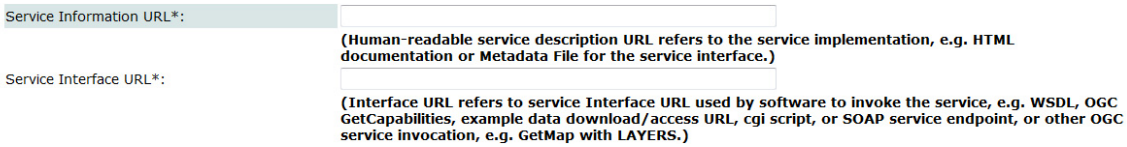
If you have saved a Service Instance registration draft, you may continue with the saved registration process by click the draft name, or click "Start a new Service Instance Registration" to register a new Service Instance.

Before registering a Service Instance, you have to register a Resource (Component) or find your registered Resource (Component). To find a registered Resource, click "Already have a Component? Find it" button. In the next page, find the resource first and click "Register a Service" button defined the Resource you want to associate this Service Instance with. Please note that, you can only register Service Instance for the Resource you have registered before.



2. Specify Service Instance Name, Service Description, Service Information URL, Service Interface URL and Service Contact Information respectively. You may also describe more detailed information about the Service Instance such as Abbreviation, Service Geographic Extent, Service Time Period of Information Content in the registration form.

Please notice the difference between Service Information URL and Service Interface URL. Service Information URL is a human-readable service description URL refers to the service implementation, for example HTML documentation or Metadata File for the service interface. Service Interface URL is interface URL refers to service Interface URL used by software to invoke the service, such as WSDL, OGC GetCapabilities, example data download/access URL, cgi script, or SOAP service endpoint, or other OGC service invocation, e.g. GetMap with LAYERS.



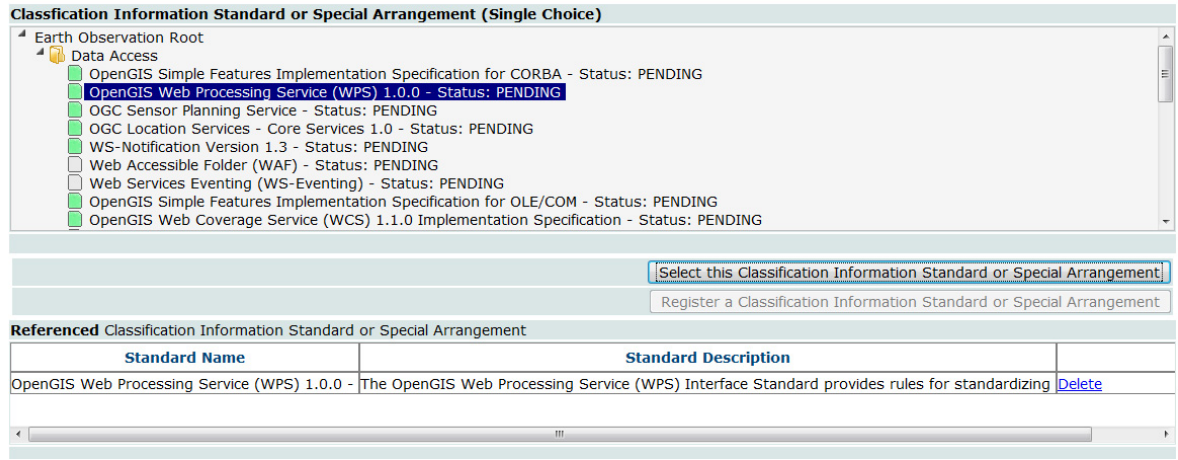
3. If this Service Instance is implemented in compliance with GEOSS registered Standards or "Special Arrangements" (ad hoc or community specifications), they should also be referenced by this Service Instance. GEOSS Component and Service Registry system (CSR) has been integrated with GEOSS Standards Registry System (SIR) so that all the registered GEOSS Standards and Special Arrangements records are retrieved from SIR dynamically during the CSR Service Instance ,registration, modification or search.

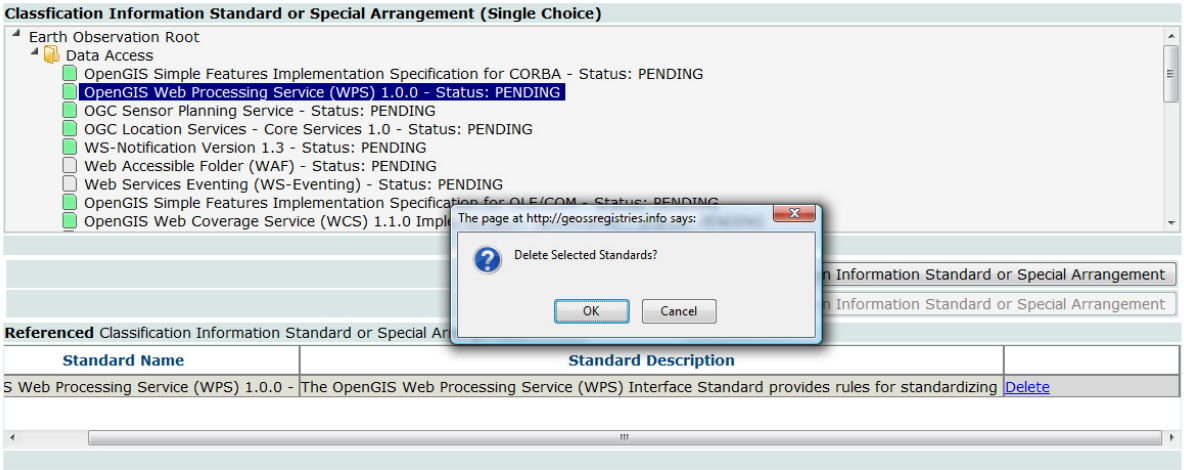
GEOSS Standards and Special Arrangements have been divided into Classification Information Standards or Special Arrangements and Supportive Information Standards or Special Arrangements. For one specific Service Instance, no more than one Classification Information Standard or Special Arrangement could be referenced, but reference of multiple Supportive Information Standards or Special Arrangements is supported.

To associate a Standard or Special Arrangement, select a Standard or a Special Arrangement from the Standards/Special Arrangements list, then click "Associate Classification Information Standard or

Special Arrangement" or "Associate Supportive Information Standard or Special Arrangement" button to associate it with the Service Instance to be registered.

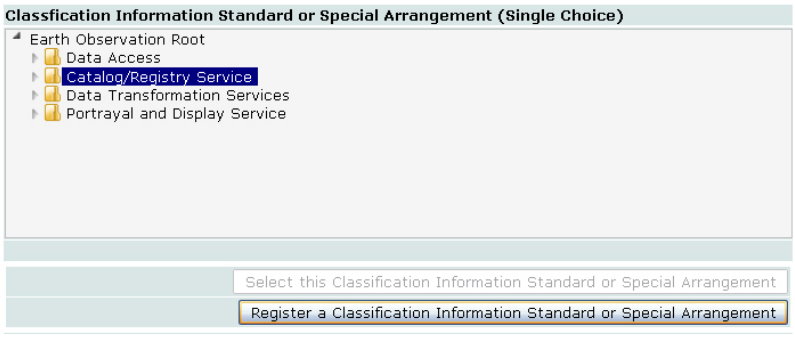
To remove a referenced Standard or Special Arrangement, click "Delete" button in corresponding row of the "Referenced Classification Information Standard or Special Arrangement" or "Referenced Supportive Information Standards or Special Arrangements".

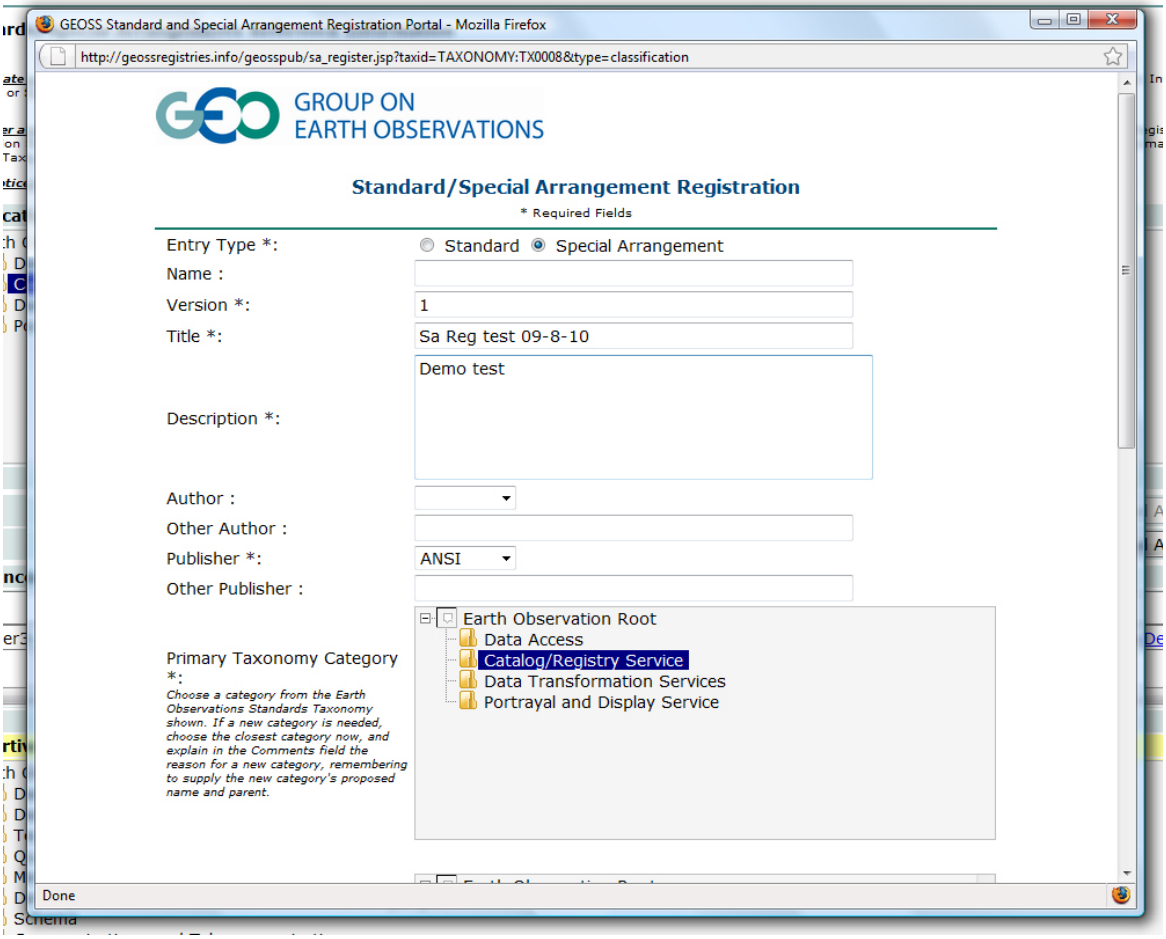




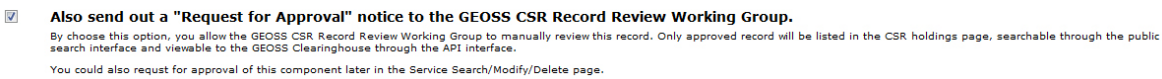
4. If the Standards or Special Arrangements you built the Service Instance with is not listed, you may registered it into SIR during Service Instance registration process in CSR. CSR provides portal to register a new Standard or Special Arrangement into SIR, and the newly registered Standards or Special Arrangements will be referenced by your Service Instance automatically.

To register a new Standard or Special Arrangement, select a a high-level Classification or Supportive Information Node from the Standards/Special Arrangements list, then click "Register Classification Information Standard or Special Arrangement" or "Register Supportive Information Standard or Special Arrangement" button to register a new Standard or Special Arrangement whose primary category is the selected Taxonomy. In the following pop-up page, provide all required information to proceed. The newly registered Standard or Special Arrangement will be associated with the Service Instance to be registered automatically.



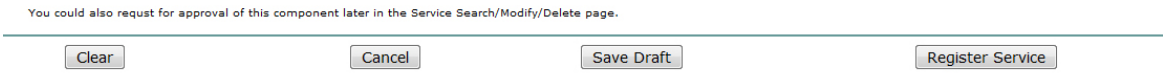


At the bottom of the page, you may find a check box of "Also send out a "Request for Approval" notice to the GEOSS CSR Record Review Working Group.". By choosing this option, you allow the GEOSS CSR Record Review Working Group to manually review this record. Only approved record will be listed in the CSR holdings page, searchable through the public search interface and viewable to the GEOSS Clearinghouse through the API interface. You could also request for approval of this component later in the Service Search/Modify/Delete page.

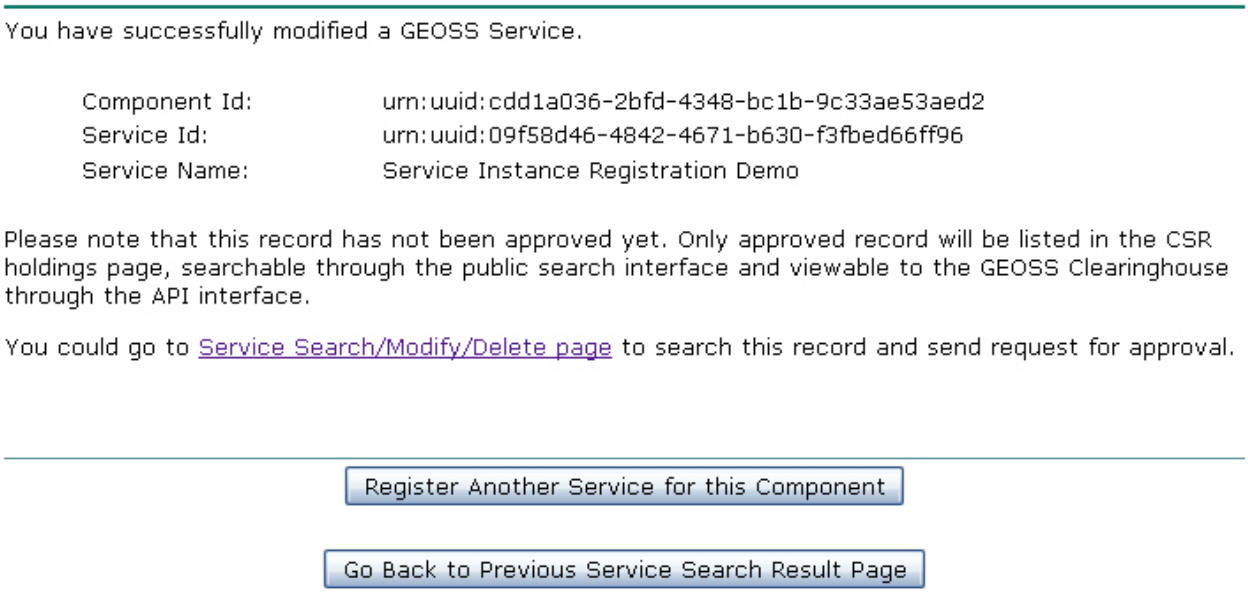


You may save the process at any time of your registration by clicking the "Save Draft" button at the

bottom of the registration page. When a registration draft is saved, you will find when next time you come to the Service Instance registration module with the same user name you are using. Click "Register Service" button to register the Service Instance when all the required information are ready.



If the Service Instance is successfully registered, you will be redirected to a confirmation page. You may go ahead and register another Service Instance for this Resource by clicking the button "Register another Service for this Component" or go back to main page by clicking the button "Go Back to GEOSS Component System and Service Registration Page".



3.4 Challenges

Participating and promoting an initiative like GEOSS is challenging, especially due to the fact that at the beginning of the project most of the partners and institutions within the Black Sea catchment were not aware of the existence of such initiative. It should be noted that there was also some reluctance to share data and metadata.

By building capacities around different themes, especially on data sharing, interoperability, and open standards, partners and institutions realized the potential benefits they can get. At this stage of the project, we can say that most of the partners are now convinced about this approach and are already sharing (or at least installing software) data and/or metadata.

Based on our experience, the main challenges we encountered were:

- Reluctance to share data
- Lack of capacities (data management, standards, ...)
- No support from institution

4. INSPIRE compliance

4.1 What is INSPIRE

Website: http://inspire.jrc.ec.europa.eu/

INSPIRE Geoportal: http://www.inspire-geoportal.eu/

INSPIRE Forum: http://inspire-forum.jrc.ec.europa.eu/

The Infrastructure for Spatial Information in the European Community, namely INSPIRE, is of particular interest for the EnviroGRIDS project. INSPIRE is a European Directive (entered into force in May 2007 and fully operational by 2019) that aims to create a European Union Spatial Data Infrastructure. This will enable the sharing of environmental spatial information among public sector organizations and better facilitate public access to spatial information across Europe. When fully implemented, it will, theoretically enable data from one Member State to be seamlessly combined with data from all other States. This is particularly important for activities relating to the environment.

The main purpose of INSPIRE is to support the formulation, implementation, monitoring, and evaluation of Community environmental policies. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes and will be based on Spatial Data Infrastructures established and operated by the Member States.

This initiative wishes to overcome the barriers affecting data access and exchange in Europe, including:

- Inconsistencies in collection of geospatial data: geospatial data are often missing and/or incomplete, or are collected twice by different organizations.
- Lacking of documentation, description (metadata) of the data.
- Geospatial data are often incompatible and thus cannot be combined.
- Infrastructures used to find, access and use geospatial data often function in isolation and are incompatible.
- Barriers to sharing: cultural, linguistic, institutional, financial and legal.

In order to overcome these barriers, it has been recognized that it would be necessary to develop a legislative framework asking the Member States to coordinate their activities and to agree on a set of requirements, common standards and processes. In consequence, INSPIRE is unique in the sense that it is an important collaborative and participative process to formulate the directive, create implementing rules and develop relative specifications and services.

INSPIRE seeks to create a European SDI and the INSPIRE Directive defines it: *"infrastructure for spatial information means metadata, spatial data sets and spatial data services; network services and technologies; agreements on sharing, access and use; and coordination and monitoring mechanisms, processes and procedures, established, operated or made available in accordance with this Directive"*.

The end users of INSPIRE include policymakers, planners and managers at the local, national and regional levels, and the citizens and their organizations.

INSPIRE is based on common principles:

1. Data should be collected only once and kept where it can be maintained most effectively.
2. It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.
3. It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.
4. Geographic information needed for good governance at all levels should be readily and transparently available.
5. Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

A step-by-step approach is used to implement and develop the infrastructure because such an initiative cannot be built from one day to another and is asking Member States to drastically change their existing infrastructure. Thus the implementation of services has been stated just after the adoption of the Directive, whereas the harmonization of INSPIRE data themes will be made in three phases up to 2013.

The European Commission Joint Research Center (JRC) plays a major role in this initiative as it has supported the development of the proposal and now endorses the responsibility of the overall technical coordination of the Directive, providing support to the preparation of the technical rules on implementation, data harmonization, documentation and the required services to discover, view and download data.

The Directive provides five sets of Implementing Rules (IR) that set out how the various elements of the system (metadata, data sharing, data specification, network services, monitoring and reporting) will operate and to ensure that the spatial data infrastructures of the Member States are compatible and usable in a Community and transboundary context. The Drafting Teams now working on these IRs are composed of international experts and the process includes open consultation – particularly with Spatial Data Interest Communities (SDIC) and Legally Mandated Organizations (LMO).

The Directive specifically states that no new data will need to be collected. However it does require that two years after adoption of the Implementing Rules for data sets and their related services each Member State will have to ensure that all newly collected spatial data sets are available in conformity with the IR. Other data sets must conform to the Rules within 7 years of their adoption. Implementing Rules will be adopted in a phased manner between 2008 and 2012 with compliance required between 2010 and 2019.

The envisioned interoperability in INSPIRE is a possibility offered to the user to combine geospatial data and services from different sources across the European Community in a consistent way without involving specific efforts of humans or computers. Thus users will spend less time and efforts to integrate data delivered within the INSPIRE framework.

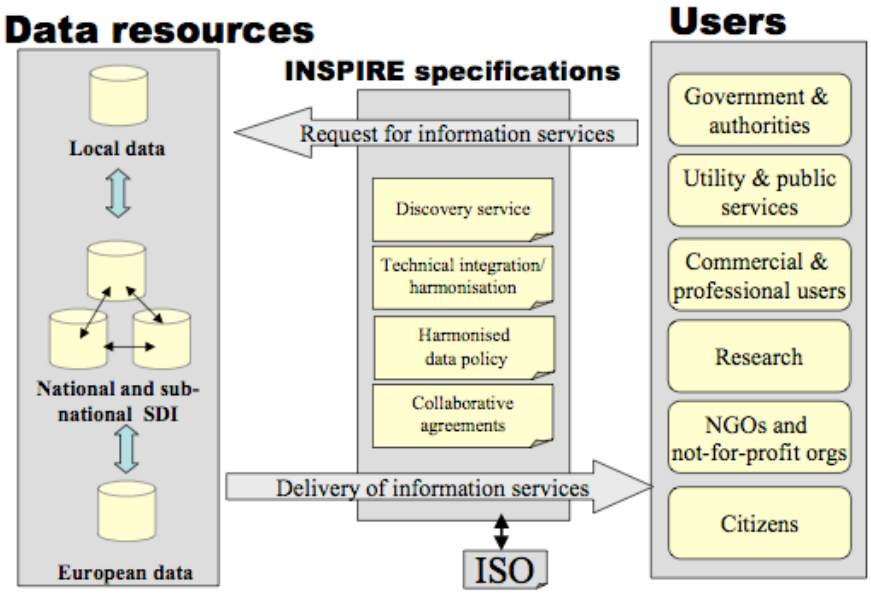


Figure 4: Data and information flow within the INSPIRE framework (Source: INSPIRE)

The Directive defines 34 "spatial data themes" that have been defined in three Annexes sorted in order of priority. Annex 1 datasets cover the 'basic' spatial building blocks such as spatial referencing systems, geographic names, addresses, transport networks, hydrography and land parcels. Because of the range of data types involved, the impact of INSPIRE is comprehensive. Annex 1 datasets have to be prepared and made available from 2011, with the other Annexes at later dates. In order to enable full

system interoperability across the EU, each spatial data theme is described in a data specification. As mentioned on the INSPIRE website *"The process for developing harmonized data specifications is designed to maximize the re-use of existing requirements and specifications, in order to minimize the burden for Member States' organizations at the time of implementation. The consequence of this is that the process of developing Implementing Rules for interoperability of spatial datasets and services may be perceived as being complex: it involves a large number of stakeholders, with many interactions and consultations"*.

Finally, all the data, information and services shared within INSPIRE would be accessible through the INSPIRE Community Geoportal. This geoportal will not store or maintain data and metadata. Instead, it could be seen as a gateway aggregating a number of instances of specific geospatial information services distributed across the Europe and maintained by the organization responsible for the data.

According to the INSPIRE network architecture, Member States shall establish, operate and provide access to the following network services:

- *discovery services:* support discovery of data, evaluation and use of spatial data and services through their metadata properties
- *view services:* as a minimum, display, navigate, zoom in/out, pan, or overlay spatial data sets and display legend information and any relevant content of metadata.
- *download services:* enabling copies of complete spatial data sets, or parts of such sets, to be downloaded.
- *transformation services:* enabling spatial data sets to be transformed (projection and harmonization).
- *invoke spatial data services:* enabling data services to be invoked.

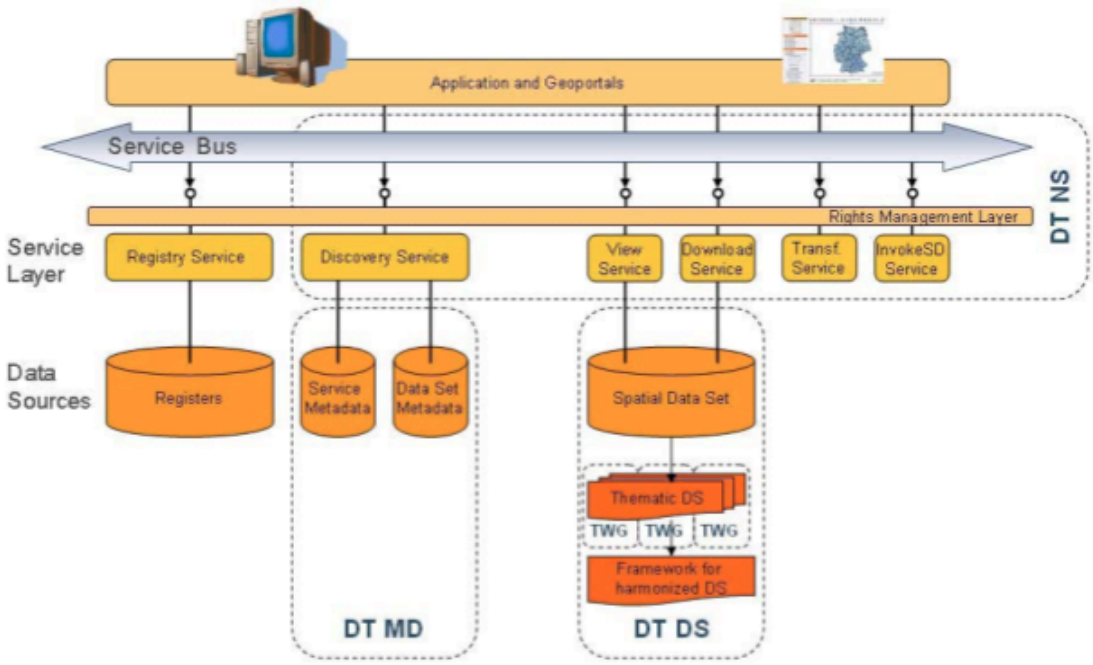


Figure 5: INSPIRE network architecture (Source: INSPIRE)

The INSPIRE Directive addresses 34 spatial data themes needed for environmental applications. These themes are subdivided in the three annexes of the directive.

Annex I	**Annex III**
1 Coordinate reference systems 2 Geographical grid systems 3 Geographical names 4 Administrative units 5 Addresses 6 Cadastral parcels 7 Transport networks 8 Hydrography 9 Protected sites	1 Statistical units 2 Buildings 3 Soil 4 Land use 5 Human health and safety 6 Utility and governmental services 7 Environmental monitoring Facilities 8 Production and industrial facilities 9 Agricultural and aquaculture facilities 10 Population distribution and demography 11 Area management/restriction/regulation zones & reporting units 12 Natural risk zones 13 Atmospheric conditions 14 Meteorological geographical features 15 Oceanographic geographical features 16 Sea regions 17 Bio-geographical regions 18 Habitats and biotopes 19 Species distribution 20 Energy Resources 21 Mineral Resources
Annex II	
1 Elevation 2 Land cover 3 Orthoimagery 4 Geology	

Table 1: INSPIRE Annexes

4.2 How to be compliant

A good presentation explaining what does it means and what is required to be INSPIRE compliant: http://www.gsdi.org/gsdiconf/gsdi12/slides/1.1a.pdf

Currently there is a lot of software that implement some of INSPIRE Implementing Rules (IR). Hereafter you will find a selection of tools that are widely accepted in the GI community and that can provide a solid ground to reach the objective of INSPIRE compliance.

4.2.1 Metadata publishing

4.2.1.1 GeoNetwork

GeoNetwork is a catalog application to manage spatially referenced resources. It provides powerful metadata editing and search functions as well as an embedded interactive web map viewer. It is currently used in numerous Spatial Data Infrastructure initiatives across the world.

GeoNetwork has been developed to connect spatial information communities and their data using a modern architecture, which is at the same time powerful and low cost, based on the principles of Free and Open Source Software (FOSS) and International and Open Standards for services and protocols (a.o. from ISO/TC211 and OGC).

The software provides an easy to use web interface to search geospatial data across multiple catalogs, combine distributed map services in the embedded map viewer, publish geospatial data using the online metadata editing tools and optionally the embedded GeoServer map server. Administrators have

the option to manage user and group accounts, configure the server through web based and desktop utilities and schedule metadata harvesting from other catalogs.

- Website: http://geonetwork-opensource.org/
- Documentation: http://geonetwork-opensource.org/docs.html
- Download: http://geonetwork-opensource.org/downloads.html
- GeoNetwork INSPIREd capabilities:

  http://geonetwork-opensource.org/manuals/2.6.4/users/search.html?check_keywords=yes&area=default&q=inspire&x=0&y=0
- An excellent report on "INSPIRE support in GeoNetwork": http://www.neogeo-online.net/blog/wp-content/uploads/2011/01/201012_geonetwork_inspire.pdf

4.2.1.2 Micka

MicKa is a complex system for metadata management used for building Spatial Data Infrastructure (SDI) and geoportal solutions. It contains tools for editing and management of metadata for spatial information, web services and other sources (documents, web sites, etc.). It includes online metadata search engine, portrayal of spatial information and download of spatial data to local computer.

MicKA is compatible with obligatory standards for European SDI building (INSPIRE). Therefore it is ready to be connected with other nodes of prepared network of metadata catalogues (its compatibility with pilot European geoportal is continuosly tested).

- Website:http://www.ccss.cz/en/?menuID=49&articleID=76&action=article&presenter=ArticleDetail

4.3.1.3 European Open Source Metadata Editor (EUOSME)

The European Open Source Metadata Editor (EUOSME) is a web application written in Java and based on Google Web Toolkit (GWT) libraries. EUOSME has been developed as part of the EuroGEOSS project (www.eurogeoss.eu) to help create metadata compliant with the INSPIRE Directive (2007/2/EC) and the INSPIRE Metadata Regulation (1205/2008).

This editor builds on the experience acquired in the development of the INSPIRE Metadata Implementing Rules, and includes the INSPIRE Metadata Validator Service available from the INSPIRE EU Geo-portal (http://www.inspire-geoportal.eu/).

- Website & download: http://forge.osor.eu/projects/euosme/

4.2.2 Data publishing

4.2.2.1 GeoServer

GeoServer is an open source software server written in Java that allows users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards.

Being a community-driven project, GeoServer is developed, tested, and supported by a diverse group of individuals and organizations from around the world.

GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS). GeoServer forms a core component of the Geospatial Web.

- Website: http://www.geoserver.org
- Documentation: http://docs.geoserver.org/
- Download: http://geoserver.org/display/GEOS/Download
- INSPIRE extension doc: http://docs.geoserver.org/stable/en/user/community/inspire/index.html
- INSPIRE extension download: http://files.opengeo.org/inspire/
- INSPIRE view service and Geoserver: http://blog.opengeo.org/2011/07/12/inspire-update/
- How to publish INSPIRE view service with GeoServer: http://location.defra.gov.uk/wp-content/uploads/2011/07/Data-Publisher-How-To-Guide-Understand-the-background-to-establishing-an-INSPIRE-View-Service-using-GeoServer.pdf

4.2.2.2 MapServer

MapServer is a popular Open Source project whose purpose is to display dynamic spatial maps over the Internet. It supports OGC WMS, WFS, and WCS standards.

- Website: http://www.mapserver.org
- Documentation: http://mapserver.org/documentation.html
- Download: http://mapserver.org/download.html
- An excellent report on "INSPIRE support in MapServer": http://www.neogeo-online.net/blog/wp-content/uploads/2011/04/MAPSERVER_INSPIRE.pdf

4.2.2.3 Deegree

Deegree is a comprehensive geospatial software package with implementations of OGC Web Services like WMS and WFS, a geoportal, a desktop application, security mechanisms, and various tools for geospatial data processing and management.

Additionally, deegree inspireNode provides INSPIRE View and Download Services (deegree mapService and deegree featureService) based on the advanced application schema support of deegree 3.

- Website: http://www.deegree.org/
- Documentation: http://wiki.deegree.org/deegreeWiki/deegree3
- Download: http://www.deegree.org/deegree/portal/media-type/html/user/anon/page/default.psml/js_pane/download
- inspireNode: http://wiki.deegree.org/deegreeWiki/InspireNode?action=show&redirect=deegree3%2FInspireNode

4.2.2.4 ArcGIS INSPIRE extension

ArcGIS provides a powerful and comprehensive SDI solution that now includes capabilities to ensure INSPIRE compliance supporting data, services, and metadata, which are delivered in the new ArcGIS for INSPIRE.

ArcGIS for INSPIRE helps meet INSPIRE compliance in a timely manner by extending the ArcGIS software that already exists in your organization. It provides View, Download, Discovery services, and Annex I data models

- Website: http://www.esri.com/software/arcgis/arcgis-for-inspire/index.html
- Whitepaper: http://www.esri.com/library/whitepapers/pdfs/arcgis-for-inspire.pdf

4.2.3 Data transformation

4.2.3.1 FME

The FME technology platform makes it easier to handle the diverse range of spatial data formats and evolving standards make interoperability such a challenge. With a unified view of your spatial and non-spatial data, you can better meet business goals and required standards, generating new insight across the organization. Solve more spatial data transformation challenges than with any other technology: transform more than 250 spatial and non-spatial formats, unlimited flexibility to restructure, reformat, and integrate your spatial data, answers the complete range of spatial data interoperability challenges with a single platform.

- Website: http://www.safe.com
- FME solution for INSPIRE: http://www.safe.com/solutions/for-initiatives/inspire/
- Data transformation: http://www.conterra.de/en/products/fme/desktop/desktop-inspire-solution.shtm
- SpatialWorld: http://www.spatialworld.fi/public/fme/en/inspire.shtml

4.2.3.2 SnowFlake GO publisher

The GO Publisher product range, enables you to publish data stored in your database to open standards including GML, KML and XML. This allows to translate and/or publish data to open standards, publish to INSPIRE compliant data specifications, translate your data on INSPIRE Annex I specification.

- Website: http://www.snowflakesoftware.co.uk/products/gopublisher/index.htm
- Community Edition & download: http://www.snowflakesoftware.co.uk/products/gopublisher/desktop/community/index.htm

4.2.3.3 INSPIRE FOSS

This project aims to provide reusable Free and Open Source Software (FOSS) components for implementing INSPIRE, specifically: ETL (Extract, Transfer, Load) : converting national geodata to INSPIRE-compliant data, storage: data(base) storage models for INSPIRE data, web services: setting up WFS/WMS/CSW/WPS to support INSPIRE network services

- Website & download: http://code.google.com/p/inspire-foss/

4.2.3.4 Humboldt

The technical goal of HUMBOLDT is to support Spatial Data Infrastructure (SDI) enablement by providing the functionalities for covering the data hamonisation process as a whole. The HUMBOLDT Tools and Services are built on current state of the art and standards, designed to provide solutions to

all types of users, data custodians as well as private end-users. HUMBOLDT enables the use of single functionalities as part of your own infrastructure.

- Website: http://www.esdi-humboldt.eu/home.html
- Downloads: http://community.esdi-humboldt.eu/

4.3 Challenges for compliance

This table compares and summarizes the different tools to the various INSPIRE services that need to be implemented.

	Discovery	View	Download	Transform
GeoNetwork	YES	PARTIAL	PARTIAL	NO
Micka	YES	NO	NO	NO
EUOSME	YES	NO	NO	NO
GeoServer	NO	YES	YES	NO
MapServer	NO	YES	YES	NO
Deegree	YES	YES	YES	YES
ArcGIS	YES	YES	YES	YES
FME	NO	PARTIAL	PARTIAL	YES
GO publisher	NO	NO	NO	YES
INSPIRE FOSS	NO	YES	YES	YES
Humboldt	NO	PARTIAL	PARTIAL	YES

Table 2: INSPIRE compliant software vs. INSPIRE services

The tools that are mostly used and that are promoted within enviroGRIDS, namely GeoNetwork, Micka, GeoServer and ArcGIS, propose already good support for INSPIRE compliance in term of discovery, view, and download services. The main issue concerns data models compliance and related transformation service.

Other tools like EUOSME, GO publisher, Deegree, FME or Humboldt appear promising and can offer good support to comply with INSPIRE IR.

We recommend referring to software documentation in order to know exactly what to do to comply with INSPIRE.

In a more general context, we can conclude that:

- **Discovery service:** available solutions allow writing and publishing INSPIRE-compliant metadata (through desktop and web-based clients).
- **View service:** current software solutions offer already good support of INSPIRE-compliant view service (e.g. WMS 1.3.0, service metadata).

- **Download service:** software solutions offer also good support. However it is still not fully INSPIRE-compliant (e.g. performances, service metadata).
- **Transformation service:** this is the biggest issue as this service depends on INSPIRE data models that are not yet fully finalized (for Annex II and III). Currently only Annex I is supported is some software implementations. Additionally, solutions to transform data in INSPIRE-compliant data (e.g., schema mapping) are only partially supported.

This situation will positively evolve in the near future and solutions to achieve INSPIRE-compliant transformation service will be available for all Annexes.

4.4 INSPIRE compliance within enviroGRIDS

Within the framework of the project, INSPIRE had an influence only on EU members countries. It should be noted also that this is an on-going effort and it is difficult (as mentioned previously) to be fully compliant.

Nevertheless, several actions will be taken during the last year of the project to ensure that at least the relevant outputs will be compliant in term of discovery and view services.

The various solutions proposed by enviroGRIDS for metadata (URM, GeoNetwork, ArcGIS for INSPIRE) allow capturing INSPIRE-compliant metadata. It is suggested that outputs from WP3 and WP4 have to be documented using INSPIRE/ISO19139 standards in order to ensure good compliance to major international standards.

In the same direction, for view services, WMS 1.3.0 is supported by all software tools that are used in the context of the project. GeoServer WMS metadata services should be extendedw with a pluging while ArcGIS for INSPIRE offers an out-of-the-box solution.

Download and Transformation services will be investigated on a few key datasets (targeting mostly Hydrology theme) using ArcGIS for INSPIRE capabilities.

Due to the importance of this topic, in April 2012 during the enviroGRIDS Full Meeting, an advanced session of "Bringing GEOSS services into practice" will tackle the topic of improving performances of services, and INSPIRE compliance.

5. Contributions to UNSDI / Eye on Earth

5.1 What is UNSDI

Website: http://www.ungiwg.org/unsdi.htm

The United Nations Spatial Data Infrastructure in an initiative conducted by the United Nations Geographic Working Group (UNGIWG) that aims at building an institutional and technical mechanism to establish a coherent system to exchange data and services concerning geospatial data and information within the United Nations, and also supporting SDI development activities in the Member Countries.

As stated in the UNSDI Compendium (UNGIWG, 2007), "Historically, the production and use of geospatial data have been accomplished within the United Nations by its component organizations, in accordance with their individual needs and expertise. But concordant with the recent, rapid increase in the use of geospatial data for UN activities is the need for greater coherence in its management system-wide".

This initiative aims to contribute to the general mission of the United Nations to maintain peace and security, to address humanitarian emergencies, to assist sustainable development and support achievement of the UN Millennium Development Goals. The hope is to facilitate efficient access, exchange and utilization of georeferenced information in order to make the UN system more effective, increase the system coherence and support its "Delivering as One" policies.

The UNSDI provides an institutional and technical foundation of policies, interoperable standards procedures and guidelines that enable organizations and technologies to interact in a way that facilitates spatial discovery, evaluation and applications (UNGIWG, 2007).

5.2 Contribution to UNSDI

The contribution of enviroGRIDS services to UNSDI is rather low. This is caused by the fact that major organizational changes have affected the entire UNSDI project (restructuration, new committees, ...) and currently there is not a clear vision where UNSDI can benefit from the enviroGRIDS services.

However, some of the services have been used to test the UNEP-Live system that is expected to be the environmental component of UNSDI. UNEP-Live has successfully accessed all the metadata and data services available and integrated them.

One enviroGRIDS representative (Gregory Giuliani) has also participated to the UNGIWG tenth (19-21 Ocotber 2009, Bonn, Germany) and eleventh (14-16 March 2011, Geneva, Switzerland) plenaries and presented the envrioGRIDS project and experience.

5.3 What is Eye on Earth

Website: http://www.eyeonearth.org/

Eye on Earth is recent initiative launched in December 2011 at the 17th Conference of the Parties (COP17) to the United Nations Framework Convention on Climate Change. This network aims to act as a community for developing innovative services that map environmental parameters. "The new cloud computing-based network provides a collaborative online service for hosting, sharing and discovering data on the environment and promotes the principles of public data access and citizen science." (Microsoft, 2011). The Network has already launched three services on:

- Noise (NoiseWatch: http://watch.eyeonearth.org/?SelectedWatch=Noise) combines EEA data with input from citizens
- Air (AirWatch: http://watch.eyeonearth.org/?SelectedWatch=Air) illustrates air quality in Europe

- Water (WaterWatch: http://watch.eyeonearth.org/?SelectedWatch=Water) uses the EEA's environmental data to monitor and display water quality ratings across Europe's public swimming sites

5.4 Contribution to Eye on Earth

Eye on Earth being a recent initiative, it is not clear at this stage how enviroGRIDS can contribute. However, being an initiative aiming to bring relevant environmental information to citizens, there are obvious linkages between enviroGRIDS and Eye on Earth. The contribution of the project to this initiative should be investigated during the last year of the project and should aim at serving major outputs of the project to Eye on Earth (e.g., hydrological information).

UNEP/GRID-Geneva director, Ron Witt, has participated to the Eye on Earth Summit (13-15 December 2011, Abu Dhabi) where he also mentioned in a talk the enviroGRIDS project.

6. Data policy, capacity building

6.1 Capacity building strategy

EnviroGRIDS has developed its own capacity building strategy to strengthen people, institutions and infrastructures for GEO and INSPIRE activities in the Black Sea region. The achievements so far are the following ones:

- *Institution*
  - Connect 30 partners in 15 countries
  - Target the needs of main end users: BSC PS, ICPDR and UNEP
  - Achieve a Gap analysis on available data sets and services in the Black Sea Catchment
  - Publish factsheets, newsletters and policy briefs translated in regional languages
  - Involve International Organisations as partners: UNEP; UNESCO; CERN
  - Integrate officially the work plan of UNEP and GEOSS
  - Create close collaborations with other EC FP7 projects: GENESI-DR, EuroGEOSS, PEGASO, ACQWA, AFROMAISON, ECOARM2ERA
  - Work with IEEE for capacity building and quality assessment
  - Involve associated partners (from Russia, Ukraine, and Armenia; see list on the enviroGRIDS website)
- *People*
  - Teach policy and decision makers about GEOSS and INSPIRE
  - Teach technicians how to install a GEO nodes
  - Teach the partners of the project to become the future trainers
  - Organize a series of hand-on sessions in the Black Sea region
  - Develop an e-learning platform
  - Demonstrate the interest of GEOSS to end users
  - Show the potential of GEOSS to the public (e.g. The Story of Data on the Environment: http://www.youtube.com/envirogrids)
- *Infrastructure*
  - Promote OGC, GEOSS, INSPIRE, UNSDI interoperability standards
  - Create a new distributed SDI for the Black Sea catchment
  - Build a GRID-enabled SDI for data storage and processing
  - Connect real time sensors and remote sensing data
  - Build an observation system for decision makers
  - Build an observation system for citizens

6.2 EnviroGRIDS workshops

Several workshops are being organized around the Black Sea to Bring GEOSS and INSPIRE into practice, and to present them to important decision and policy makers.

- *Bringing GEOSS Services into practice*

  The Black Sea regional training workshop series "Bringing GEOSS Services into Practice", sponsored by the European Commission's 7th Framework Programme (FP7) project enviroGRIDS, aims at teaching how to install, configure and deploy a set of open source software to publish and share spatial data and metadata through the Global Earth Observation System of Systems (GEOSS) using OGC web services & ISO standards.

  GEOSS has been created as an international voluntary effort that connects y geospatial and Earth Observation and information infrastructures, acting as a gateway between producers of environmental data and end users. The aim of GEOSS is to enhance the relevance of Earth observations and to offer public access to comprehensive, near- real time data, information and analyses of the environment.

  The training workshop covers interoperability, hands- on experience with web portals, information access, open source software and spatial data sharing through web services and the GEOSS registries.

  This workshop has been given to more than 120 participants (projects partners as well as local attendees) in four sessions in: Romania (Bucharest, May 3rd 2010), Georgia (Tbilisi. November 29th 2010), The Netherlands (Delft, April 18th 2011), Turkey (Istanbul, September 23r 2011).

- *Bringing GEOSS Services into practice - advanced*

  This will be the new workshop proposed by the enviroGRIDS consortium for 2012 (Bulgaria, Sofia, April 18th). This second workshop of the "Bringing GEOSS services into practice" aims at presenting some tips and tricks in order to deliver efficient data services with GeoServer (data tiling, Java configuration, ...) and also present to participants what needs to be done to deliver discovery and view services compliant with the INSPIRE directive.

- *GEOSS for Decision Makers in the Black Sea Area*

  The Black Sea Catchment is internationally known as one of ecologically unsustainable development and inadequate resource management, which has led to severe environmental, social and economic problems. The enviroGRIDS project addresses these issues by taking advantage of emerging information technologies that are revolutionizing the way we are able to observe our planet.

  The Global Earth Observation System of Systems (GEOSS), being created by the Group on Earth Observations (GEO), provides a framework and the information for environmental management and decision making perspective. enviroGRIDS aims to enhance GEOSS by building the capacity of scientists to assemble such a capability in the Black Sea Catchment, the capacity of decision-makers to use it, and the capacity of the general public to understand the important environmental, social and economic issues at stake.

  This workshop provides a high level overview of GEOSS and data interoperability as they relate to the needs of senior government officials and decision makers in the Black Sea area.

6.3 Data Policy

In the context of the project, a specific Data Policy has been developed aiming to promote and sustain data sharing among partners as well as raising awareness on the potential benefits when exchanging data using interoperability standards.

This data policy has been accepted by all partners during the 2010 General Assembly in Delft (Netherlands).

1. Scope of this document

This document describes the policy for accessing, using and disseminating data and information through the enviroGRIDS Spatia Data Infrastructure (SDI).

This policy aims to find a good balance between the rights of data providers and the need for a wide usage and dissemination through free and unrestricted sharing, exchange and use of enviroGRIDS data, metadata and products.

The final goal of this policy is to serve the scientific community, public organizations, and environmental agencies, and to stat the conditions for data submission, access and use.

This policy applies to data managed by enviroGRIDS partners for providing access to data managed in the enviroGRIDS distributed systems.

By maximizing the availability of data to the community at large, enviroGRIDS promotes the use of these data, thereby ensuring that their maximum value can be realized and thus contribute to an increased understanding of the Black Sea catchment environment.

The enviroGRIDS data policy is consistent with, and in the spirit of, national and international policies and laws. Applicable policies or laws are those related to UN conventions, policies of international bodies often within the UN, policies and laws of the European Union. The enviroGRIDS data policy is intended to be fully compatible with the Directive of the European Parliament and of the Council on public access to environmental information, the INSPIRE Directive, and GEOSS principles.

2. Definitions

Observation data: these are measurements or observations (in situ and remote sensing) of environmental variables. In order to interpret and process these data, related attribute data such as type of data, location, time and unit of measurement are also required.

Model data: these are estimates of environmental variables from model outputs (including analyses).

Reference data: reference data are a necessity as they provide the basic geographic framework on top of which additional (thematic) spatial information can be produced. They are typically provided by data providers on regional or national level.

Metadata: these are data about data sets: information about observation, model or other data sets, the related attribute data such as type of data, location, date/time and unit of measurement, accuracy, precision or method of measurement, structure or ownership of the data.

Data products: these are aggregated or combined sets of observation data, model data, images or metadata (including web services).

Asset: An asset is an object to which access is to be controlled: data, metadata or a web service.

3. Objectives and Framework for Data Policy

The overall policy is designed to serve the following aims:

Timely, easy and free access to the SDI by the EnviroGRIDS community;

maximum use of the SDI, for data exchange within the EnviroGRIDS community;

maximum use of the SDI, for presenting the results of EnviroGRIDS to various end users;

easy access to the SDI for users and stakeholders at large, now and in the future.

The policy needs to ensure:

any existing ownership rights are respected,

the ownership of each dataset is acknowledged, well referenced;

the owners are protected from any liability arising from the use of their data;

groups of users with preferential rights of access to any data are clearly defined;

3. The enviroGRIDS Spatial Data Infrastructure (egSDI) and standards

The EG-SDI will contain the data and metadata stored according to international standards (e.g. ISO 19115/19119/19139 & OGC WMS, WFS, WCS, CS-W, SWE) and fed on a continuous basis by the partners through a web interface. These standards shall follow current technical directions of EU directives and international policies.

The SDI contains the metadata and the listing of data owners (enviroGRIDS partners and their collaborating institutes) who must fill-in their metadata on a mandatory basis. The metadata shall include information on how to access the data or at least identify the person to be contacted to access the datasets.

To identify the different data sources metadata should be immediately available. The partners and/or data providers within the Black Sea catchment, which already posses metadata catalogues, have to make them "queryable" directly from the enviroGRIDS portal (http://www.envirogrids.cz). Other partners have to submit their metadata into the catalogue system of enviroGRIDS portal.

All partners must communicate to the SDI coordinator which data and derived products are to be produced and provided to the SDI.

Additional information might be sent by the partners to the egSDI coordinator as deemed necessary.

Access to the SDI for the purpose of adding data is granted only to WP/task leaders on the basis of password privileges.

4. General conditions

enviroGRIDS makes data available freely and without restriction. "Freely" means not more than the cost of reproduction and delivery, without charge for the data itself. "Without restriction" means without discrimination against, for example, individuals, research groups, or nationality.

enviroGRIDS makes data available in a timely and easy way to users, but enviroGRIDS remains dependent on data contributions.

enviroGRIDS uses the most adapted and recent advances in communication to ensure widespread access to data collected under auspices of the project. The enviroGRIDS portal is the focal point for dissemination.

According to the different types of assets, the access conditions vary:

meta-data are freely accessible without any condition.

data and products are whenever possible freely accessible without any condition. However, on a case by case basis and depending on data providers inner policy some restrictions to access and use may be applicable (Creative Commons, ...).

5. Roles

Administrator: A user who is able to bypass any access control created by enviroGRIDS but with no bypass rights for local access controls.

Public: Any authenticated individual with sufficient credentials to satisfy enviroGRIDS access logging requirements.

Academic: A user who accesses data on the enviroGRIDS network for purposes of education or non-profit academic research.

Commercial: A user who accesses data on the enviroGRIDS network with the objective of making a financial profit from its use.

National and Local governmental bodies: A user who accesses data on the enviroGRIDS network for administrative or legislative purposes within the boundaries of a country or regions within a country.

International bodies: A user who accesses data on the enviroGRIDS network for international administrative or legislative purposes.

Partner: persons authorized by organization – partner of enviroGRIDS project. This gives the right to access, upload and (with ownership rights) maintain data and metadata entries.

In this context, it is expected that WP leaders could act as "catalyst" to push partners as well as data providers to share their data.

The SDI coordinator, is the enviroGRIDS WP2 leader (G.Giuliani [UNIGE-GRID]) and is expected to coordinate all the activities around the enviroGRIDS SDI.

The enviroGRIDS data manager (Andrea De Bono [UNIGE-GRID]), is the focal point regarding data (access, upload, availability) of the enviroGRIDS SDI.

6. Data access

Data access will vary depending on the type of data and whether the party requesting access is a member of the enviroGRIDS consortium or not.

The scientific teams and partners will always have free and unlimited access to the data of SDI. However they are not permitted to exchange, to sell nor to give away data outside the enviroGRIDS community without permission of the data owner.

Metadata is freely available and accessible to anybody.

Observations collected in the frame of or developed within enviroGRIDS and the model output remain with the data owners who must facilitate the work of enviroGRIDS by making them available to the scientific teams and partners of enviroGRIDS.

7. Data on the grid infrastructure

Data that will be used for geoprocessing in the grid environment must fulfill the requirements of grid infrastructures policies.

This topic will be completed once enviroGRIDS partners coud access the grid and work with it.

8. Data sources, owners, rights and licenses

Data sources may be the originators of the data, metadata, images or products, for example, persons responsible for the scientific work that produce them; or an intermediary such as the data sources' associated institute(s), the agency that commissioned or funded the work, or even the information technology group responsible for preparing the data for submission to enviroGRIDS. The data source must precisely specify any access restrictions that it wishes enviroGRIDS to uphold. Other cases that call for restrictions include data which is protected by law and data submitted during a prescribed period of exclusive use.

EnviroGRIDS ownership and rights remain with the enviroGRIDS partners.

EnviroGRIDS metadata shall always be under Open Use License.

EnviroGRIDS project should strongly encourage, sustain and promote enviroGRIDS partners to provide all possible data/products under Open Use License.

9. Data flow

For enviroGRIDS to succeed, high-quality data and metadata need to be processed and exchanged without significant delay in a free and unrestricted manner. All data available through the enviroGRIDS portal are considered to be freely accessible, unless otherwise explicitly specified and agreed. Restricted access will be considered on a case-by-case basis. enviroGRIDS urges data sources to re-enforce their commitment to free-of-charge and unrestricted use of their data.

Speed is becoming a primary factor determining the usefulness of data, thus data should be made accessible as soon as possible and to the broadest user group possible. This implies both technical and policy considerations and coordination on the part of data sources, users, and enviroGRIDS. For example, it will be possible for data sources to submit multiple versions of the same data set during the process of quality control.

10. Data integration

Uniformity of data format and quality have a high priority. All data and related meta-data and quality indicators should be submitted by using standard codes, formats, and protocols referenced in the enviroGRIDS deliverable guidelines (D2.1: interoperability guideline, D2.2: data storage guidelines, D2.3: sensor data use and integration guideline, D2.4: remote sensing data use and integration guideline).

11. Quality assurance

enviroGRIDS develops and applies quality assurance procedures as appropriate and feasible, and in cooperation with data sources and other organizations. The data prvodeirs always retains complete responsibility for data quality. The reporting of suspected errors in the data will be facilitated, and that information relayed to the respective data providers so corrections can be made.

12. Preservation of data

For enviroGRIDS to succeed, data providers must ensure archival systems, so that the collected data, images, products and metadata may be safeguarded for future analysis. Inventories of data, images and products and related metadata should be readily accessible and updated as needed on a routine basis. Long-term survival, integrity, and access to enviroGRIDS data will be preserved for future generations by data providers.

13. Pricing

All enviroGRIDS data, metadata and products shall be disseminated and distributed through web as much as possible, free of charge .

14. FP7 special clause

Furthermore, the consortium will apply the special clause 29 applicable to the FP7 model grant agreement on access rights to foregrounds (data) for policy purposes and transfer of ownership of foregrounds, which is specific to environment research:

“The Project should ensure that protocols and plans for data collection and storage are in line with Community Data Policy.

The Community Institutions and Bodies shall enjoy access rights to foreground for the purpose of developing, implementing and monitoring environmental policies. Such access rights shall be granted by the beneficiary concerned on a royalty-free basis.

Where foreground will no longer be used by the beneficiary nor transferred, the beneficiary concerned will inform the Commission. In such case, the Commission may request the transfer of ownership of such foreground to the Community. Such transfer shall be made free of charge and without restrictions on use and dissemination.”

15. GEOSS special clause

The societal benefits of Earth observations cannot be achieved without data sharing. EnviroGRIDS being part of the GEOSS workplan for 2009-2011 it should therefore apply the following GEOSS data sharing principles to present the outputs of the projects to the GEOSS community:

There will be full and open exchange of data, metadata, and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation.

All shared data, metadata, and products will be made available with minimum time delay and at minimum cost.

All shared data, metadata, and products free of charge or no more than cost of reproduction will be encouraged for research and education.

16. INSPIRE special clause

The INSPIRE directive came into force on 15 May 2007 and will be implemented in various stages, with full implementation required by 2019.

The INSPIRE directive aims to create a European Union (EU) spatial data infrastructure. This will enable the sharing of environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe.

A European Spatial Data Infrastructure will assist in policy-making across boundaries. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes.

INSPIRE is based on a number of common principles:

Data should be collected only once and kept where it can be maintained most effectively.

It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.

It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes.

Geographic information needed for good governance at all levels should be readily and transparently available.

It should be easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

17. Aahrus convention special clause

The European Union wishes to keep citizens informed about and involved in environmental matters and to improve the application of environmental legislation by approving the Convention on access to information, public participation and access to justice in environmental matter.

The Convention, in force since 30 October 2001, is based on the premise that greater public awareness of and involvement in environmental matters will improve environmental protection. It is designed to help protect the right of every person of present and future generations to live in an environment adequate to his or her health and well-being. To this end, the Convention provides for action in three areas:

- ensuring public access to environmental information held by the public authorities;
- fostering public participation in decision-making which affects the environment;
- extending the conditions of access to justice in environmental matters.

The Community institutions are covered by the definition of a public authority within the meaning of the Convention, on the same footing as national or local authorities.

The parties to the Convention undertake to apply the listed provisions, and must therefore:

- take the necessary legislative, regulatory and other measures;
- enable public officials and authorities to help and advise the public on access to information, participation in decision-making and access to justice;
- promote environmental education and environmental awareness among the public;

- provide for recognition of and support to associations, organisations or groups promoting environmental protection.

Public access to environmental information

The Convention lays down precise rights and duties regarding access to information, including deadlines for providing information and the grounds on which public authorities may refuse access to certain types of information.

Access may be refused in three cases:

- the public authority does not hold the requested information;
- the request is manifestly unreasonable or formulated in too general a manner;
- the request concerns material in the course of completion.

Requests may also be refused on grounds of confidentiality of the proceedings of public authorities, national defence and public security, to further the course of justice or to respect the confidentiality of commercial and industrial information, intellectual property rights, the confidentiality of personal data and the interests of a third party who has volunteered the information, though all these grounds for refusal must be interpreted in a restrictive way, taking into account the public interest served by disclosure of the information.

A decision to refuse access must state the reasons for the refusal and indicate what forms of appeal are open to the applicant.

Public authorities must keep the information they hold up to date, and to this end establish publicly accessible lists, registers and files. The use should be promoted of electronic databases containing reports on the state of the environment, legislation, national plans and policies and international conventions.

Public participation in environmental decision-making

The second part of the Convention concerns public participation in decision-making. This must be ensured through the authorisation procedure for certain specific activities (mainly of an industrial nature) listed in Annex I to the Convention. The final decision to authorise the activity must take due account of the outcome of the public participation.

The public must be informed, early in the decision-making procedure, of the following:

- the matter on which the decision is to be taken;
- the nature of the decision;
- the authority responsible;
- the procedure to be used, including the practical details of the consultation procedure;
- the procedure for an environmental impact assessment (if any).

The procedural time-frames must allow for genuine public participation.

A streamlined procedure has been set up for the formulation of environmental plans and programmes.

The Convention also invites the parties to promote public participation in the preparation of environmental policies as well as standards and legislation that may have a significant effect on the environment.

Access to justice in environmental matters

Regarding access to justice, all persons who feel their rights to access to information have been impaired (request for information ignored, wrongfully refused, inadequately answered) must have access, in the appropriate circumstances, to a review procedure under national legislation.

Access to justice is also ensured in the event of the Convention's participation procedure being infringed. Access to justice is also allowed for the settlement of disputes relating to acts or omissions by private persons and public authorities which contravene provisions of national law relating to the environment.

7. BSC and ICPDR

7.1 Influence from enviroGRIDS

What has convinced you to share your data/metadata with OGC standards?

BSC (Volodymyr Myroshnychenko):

- Need to incorporate GIS information in the web applications of BSC
- The GIS software, which was available at that time in the office, did not possess web-sharing capabilities.
- The idea to use open source interoperable software was in air, so when it appeared that enviroGRIDS project is going to build SDI on the base OGC standards with open source software, this way was selected particularly considering its advantages: efficiency, interoperability, saving costs, ability to access to distributed and heterogeneous sources.

ICPDR (Alex Hoebart):

OGC standards describe open interfaces which are implemented in many products and services, so are readily available for both data providers and data consumers. For data providers, this ensures that interfaces can be offered at the lowest possible cost. For data consumers, it means they can use data in the most efficient way.

What were the difficulties you encounter? How did you overcome them?

BSC:

No serious difficulties were encountered as activities on setting up Geo Server in the office were undertaken after the training organized by EnviroGRIDS project (the workshop "Bringing GEOSS services into practice" held in Bucharest in May 2010).

ICPDR:

The still limited knowledge about the benefits of data sharing and OGC standards in particular and the different restrictions on data distribution in the Danube countries make it currently still difficult to apply OGC standards compliant data sharing on a basin-wide level. The ICPDR, in the frame of the further development of the DanubeGIS, is discussing these issues and the current efforts in the development of reference datasets for the Danube River Basin will result in key milestones towards sharing basin-wide metadata and data sets on the basin-wide level.

What were the benefits brought by the enviroGRIDS project?

BSC:

The Geo Server is included as a component of the information system for monitoring and reducing oil pollution (MONINFO system) supplying it with different environmental GIS layers (hot spots, protected areas, fish spawning areas, offshore installations etc). Using OGC standards also opens possibility to combine spatial information stored in different Activity Centers of the Black Sea Commission, e.g. to combine GIS layers in MONINFO system with GIS layers generated within the Regional Pollution Database in the Pollution Monitoring AC (note: not implemented yet).

ICPDR:

The activities and outputs of the enviroGRIDS project have been brought into and discussed in the meetings of the ICPDR expert groups and also at high-level meetings and have already and will further influence their activities. Particularly worth mentioning in this context are the use of open-source standards compliant software to publish data and metadata as shown in the project and taken into consideration in the future development of the DanubeGIS, and the output of the SWAT model to be

compared to the results of the MONERIS model used by the ICPDR Pressures and Measures Expert Group.

What are you plan to contribute to GEOSS and INSPIRE?

BSC:

Permanent Secretariat of the Black Sea Commission does perform observations – it just collect monitoring data, reported to the Black Sea Commission by countries. The information policy of the BSC does not allow to give access to raw data, therefore BSC PS can contribute to GEOSS only metadata about monitoring activities (observations) in the Black Sea countries.

The data reported to the BSC are not INSPIRE-compliant, and it is unlikely to make changes in the reporting standards in short time.

ICPDR:

The ICPDR will share metadata and data that is available on the basin-wide level in GEOSS - this could be the reference datasets which are currently under development. Sharing of national datasets in GEOSS and implementation of INSPIRE is a task of the countries. The ICPDR Information Management & GIS Expert Group is providing a platform for discussing and sharing experiences on these tasks as they are influencing the availability and structure of the data on the basin-wide level as well.

What are your future plans in term of data/metadata sharing?

BSC:

Different GIS layers with Black Sea environmental information as well as metadata on pollution monitoring in the Black Sea.

ICPDR:

The planned implementation of the DanubeGIS based on open-source OGC-compliant software is a prerequisite for sharing basin-wide data, e.g. reference datasets for the DRB river network. As soon as data will be published using this platform, the benefits will become more tangible can be demonstrated in a more effective way.

8. Conclusions and recommendations

8.1 Situation before vs after enviroGRIDS

The enviroGRIDS project through its grid-enabled SDI activities had a impact on project partners within the Black Sea catchment region. In particular the primary objective of building capacities around GEOSS can be considered as successful. Indeed, several partners have already started to share their data and metadata through GEOSS and more are expected services are expected in the last year of the project. Additionally, three countries that are not yet member of GEO (Bulgaria, Georgia, Armenia) are under active discussions with their government in order to become members of the Group on Earth Observation in the shortest term possible.

Concerning INSPIRE, UNSDI, and Eye on Earth initiatives, our contribution is less important because first, it was not the primary objective of the project, and second these are ongoing efforts that need further implementation (tools, software, rules, ...). However, we have raised awareness among our partners about these relevant initiatives, provided guidance, in order to ensure that those who are interested/willing to support will follow these efforts. The fact that most enviroGRIDS services are based on international standards (OGC and ISO) will facilitate the contribution of our partners to these initiatives.

A positive impact of enviroGRIDS is that the Black Sea Commission and the International Commission for the Protection of the Danube River have decided to share some of their data freely and openly. They were convinced by the enviroGRIDS approach and in a more general context by the (potential) benefits in facilitating the exchange of environmental information.

We think that our activities within the project have raised awareness in the region and we are sure that our partners will continue the effort in term of data sharing in the coming years. However one topic has not been addressed by the project and concerns the Data Quality issue. Despite the fact that there are some FP7 projects that are currently exploring solutions to communicate about data quality, no commonly agreed solutions are available as of today. However, we have decided to push our partners to already start sharing their data and use/participate to the enviroGRIDS SDI.

8.2 After life plan – long term support

The enviroGRIDS system is based on a Service Oriented Architecture meaning that it is based on distributed resources managed by partners themselves. This will ensure that all services will be maintained and operated after the end of the project because most of these services are now part of some partner's activities in their regular work. Obviously the main outputs of the project (e.g., scenarios of change, SWAT outputs, ...) will not evolve but will be still available through the enviroGRIDS infrastructure and through GEOSS has OGC web services. The different tools (gSWAT, eGLE, ESIP, BASHYT) will be also maintained and further developed by their developers

We have ongoing discussions about the idea of having a kind of repository at the University of Geneva of the various tools, data sets developed within the project time frame. This repository may act as a kind of backup solution in case one (or more) component will fail in the coming years.

The accessibility to the Grid computing infrastructure is guaranteed through the enviroGRIDS VO allowing to ensure to analytical and processing components of our system.

8.3 Lessons learned and recommendations

Despite the fact that SDIs methods, concepts and technologies can bring major benefits they still need to show their real benefits/added--value at large scale and therefore it is important to consider the factors that currently limit the diffusion and utilization of SDIs.

Henricksen (2007) identifies two classes of factors that can influence successful implementation and operation of SDIs: (1) tangibles (e.g., technology, tools, frameworks, methods, systems), and (2)

intangibles (e.g., behaviors, resistance, commitment, accountability, self-interest, culture). The relative influence is about 20% for technological factors and 80% for intangibles ones over SDI effectiveness. This author concludes that to achieve the objective of a successful SDI implementation, the key requirement is that institutions and people must be willing to work together and share a common vision. Results from various assessments and consultations (Crompvoets and Bregt 2003; Henricksen 2007; Craglia and Campagna 2009; Vandenbroucke 2010) showed that besides technological aspects the main issues are related to (1) political/cultural context, (2) policies, (3) organization, (4) people, and (5) resources.

Among the most frequent obstacles, lack of institutional and political wills to publish and share data is frequent (Nebert 2005). Indeed, data providers tend to hide data mostly for confidentiality, national security or "misuse prevention" reasons. This inevitably leads to duplication of activities, duplication and fragmentation of data, overlaps between initiatives and projects, lack of coordination, insufficient flow of information, and inadequate resources management. Additionally, insufficient staff skills can cause a lack of standardization (e.g., data, metadata, procedures) and lack of documentation on who is doing what and what is available. This incoherent, inconsistent and unshared vision of a SDI induces: (1) difficulties in finding/accessing required data, and (2) lack of knowledge from data providers about the value of what they have. Altogether, these reasons preclude a reliable organization for data dissemination purposes and prevent enhancement of the value of integrated information.

Various studies (Rajabifard, Feeney et al. 2002; Budhathoki and Nedovic-Budic 2006; Masser 2006; Masser 2006) highlighted potential weaknesses and threats that may also contribute to restrict the development and implementation of SDIs:

- Diversity of stakeholders (e.g., public sector, private sector) requiring taking into accounts a variety of (potentially conflictual) requirements and management structures.
- Changes in existing organizational structures in order to facilitate access and sharing of geospatial data to broad array of users. To overcome reluctance to changes, this requires a shift on the perception of the value of data, and to reach commitment on promoting data sharing.
- Developing and maintaining a consensus over time among the stakeholder involved because implementing a SDI is a long-term process.
- Dependencies to political support and commitment.
- Insufficient human and financial resources.
- Dependency on opportunities offered by the sociopolitical context (e.g., stability)
- Legal context & policies.
- Economical considerations (e.g., costs/benefits).
- No clear definition and consensus on SDI and its constitutive elements and principles. This contributes to give an incoherent and inconsistent vision of SDIs.
- Different models of SDIs (e.g., hierarchical, spider net) that do not necessarily take in consideration all the stakeholders involved. Too many standards create confusion for the user that cannot clearly identify which one to use and for which purpose.
- Lack of monitoring and evaluation mechanisms (e.g., indicators) helping to evidence who the users are, what they are using and how well SDIs can serve their needs.
- Finding the right balance between technology and social. Indeed, the risk is to concentrate too much on the technological component and neglect the social component.
- Need of multi/interdisciplinary approaches because SDIs rely on various disciplines such as sociology, cognitive science, political science, economics, informatics, and information science.

Developing and implementating a SDI implicitly ask for cooperation that often requires new forms of collaboration both internally and externally of an institution (de Vries 2009). Cooperation is strongly influenced by political-organizational factors such as insitutionalised historical practices or dominating legacy systems and standards. Moreover, resistence can appear if the perceived complexity of (top-down) SDI initiatives do not directly relate to the own/local objectives of an institution, organization or a country. Therefore it is important to consider appropriately requirements of each stakeholder that need first to fulfill their own mandate. De Vries (2009) showed that despite INSPIRE is a legal framework, local policy motives, local politics, local interests, local alternatives to national or regional initiatives can negatively influence its implementation. Limited financial resources can also lead organization to select other, potentially non--optimal, solutions or technologies, which still match their local and immediate needs. Consequently, organizations are intending to cooperate only if they can perceive benefits. To make cooperation successful in SDIs, various elements are essential: a shared vision between all participants, necessity to solve a dominant problem, incentives, and sufficient resources (Salzmann 2011). Actions can be initiated not only by legal regulations (like in USA or in Europe) but also by protecting/creating some interests, or minimizing some financial costs (de Vries 2009). Finally, for Salzmann (2011) collaboration is also strongly influenced by the maturity of the environment (e.g., staff skills, shared problem) in which the SDI implementation will take place. However, collaborations are a complex set of dynamic formal and informal relationships and are consequently difficult to assess (Warnest, Rajabifard et al. 2003). Organizational, institutional and economic obstacles can be overcome at the condition of better collaborations and parnterships. Neverthless, Warnest et al. (2003) stated that our current understanding on how to create and develop effective and efficient collaborations and partnerships is still limited and then bringing an important restriction. Participatory approaches can be useful to understand the nature of of interactions between the different stakeholders, their motivations, their requirements, and finally sustain effective SDI implementations (Warnest, Rajabifard et al. 2003; Strobl, Belgiu et al. 2010). Craglia et al. (2008) stated that to justify the initial investment and ensure long--term sustainability of an infrastructure, appropriate methodologies to assess social and economic impacts of geospatial information are needed. Currently such frameworks are still little developed (Booz, Allen et al. 2005; European Commission 2006; Garcia Almirall, Moix Bergada et al. 2008; Craglia and Campagna 2009) and required more work to be done in order to show positive financial impacts and, for example, associated costs of non-actions. As Nebert (2005) said: "...the *longer the harmonisation of stand--alone databases is post-poned, the more difficult it will be to make them interoperable. Costs for integrating standalone systems into a SDI concept are increasing exponentially with time and the number of data sets. This suggests that a co--ordinated initiative based on SDI principles should be considered as soon as possible. A feasibility study carried out in Malaysia prior to the implementation of a national SDI concluded that a SDI would present an opportunity with dynamic benefits that would grow over time, culminating in accelerated socio--economic development the nation combined with a reduction in delays in the implementation of projects".* A recent report of the Joint Research Center of the Europen Commission (Craglia and Campagna 2009) indicates that regional and local levels are interesting scales to study socio--economical impacts of geoinformation. In particular it is at the local level that SDIs can bring large benefits, directly influencing, affecting and supporting millions of citizens and local businesses in their daily activites. For the authors of this report *"think global but act locally"* is the only possibility to realize at large extent the (potential) economic and social benefits of geospatial information, as well as engaging various stakeholders and reaching commitments.

Rajabifard et al. (2002) suggested that to improve support and commitment to SDI intiatives it is important: (1) to increase the level of awareness about the nature and value of SDIs (e.g., capacity building), (2) assess and understand the dynamic nature of collaboration and partnership in order to support a culture of sharing, (3) improve SDI models to better match the needs of various communities, (4) improve SDI definition to giver a clearer vision, and (5) identifying the key factors (in a given context) that can facilitate interactions between social, economical and political issues. Due to the importance of their social dimension, SDIs can be thought as social networks of people and organisations supported by data and technology (Craglia and Campagna 2009). Indeed, developing the technological component is rather simple but building and maintaining the social one is much more difficult requiring important human and financial resources as well as collaboration, partnership,

commitment and trust. For Craglia et al. (2009): *"The technology is cheap, data is expensive, but social relations are invaluable"*.

Based on the experience acquires through the project that has shown benefits and limitations of SDIs methods, concepts, technologies and raised various issues on different topics both at scientific, technological and institutional levels, we aim to provide some recommendations and suggest directions of research.

Recommendation #1 Find simple ways to document geospatial data

Metadata are recognized as an essential element in SDI initiative for managing and discovering geospatial data. However, metadata documenting geospatial data sets are often missing, or are incomplete or fragmented. This is mainly explained by the following facts: (1) current metadata scheme and standards are complex and difficult to handle, (2) documenting geospatial data is often not perceived as an important task in projects (rather focusing on creating data sets but not taking into account the need to document them), (3) lack of resources both in term of time and financial support, and finally (4) documenting data is not really a enjoying task (and being honest, it is rather a boring task). Therefore, finding flexible and easy ways to document data would be very valuable otherwise the primary objective of SDIs will not be realized and SDIs would miss their essential purpose of making data discoverable. We can imagine systems that allow capturing relevant information when producing data reducing to the minimum the need to users to fill forms with numerous fields. Such metadata generation framework is essential in particular with the huge amount of geospatial data generated continuously. Such framework must offer various capabilities such as automatic creation, automatic update, and automatic enrichment (Kalantari, Olfat et al. 2009). Additionally, having metadata as close as possible to the produced data set is also very important. Indeed, it is common to see data and metadata completely separated, and this probably also explains why metadata are often missing. Separation of storage creates two independent components (i.e., a data set and its associated metadata) that must be managed and maintained. This will inevitably lead to inconsistencies, redundancies and lack of reliability. In this sense, the netCDF66 format (recently accepted by the OGC as a standard) appears interesting as it allows one having data and metadata in the same file. It is designed to represent space and time-varying data and netCDF and provides mechanisms to support multi-dimensional data. However, it requires implementing and supporting common metadata standards such as ISO19115/19139/19119 and also extends its supports to other data types (e.g., vector). In consequence, having a system where once a geospatial data set is updated, its metadata is also immediately (and automatically) updated will bring major benefits (Rajabifard, Kalantari et al. 2009).

Recommendation #2 Manage and communicate about data quality

An important challenge that is not yet achieved concerns the quality of data. Once users have found required data, one of the first questions they may ask regards the quality of data. Quality can be assessed at quantitative and qualitative levels: (1) quality control describing data completeness (amount of missing features), data precision (degree of details), data accuracy (degree to which data reflects correctly the real object) and data consistency (usability of the data), (2) managing uncertainty associated to data and models (quantifying uncertainty and encode it into metadata), (3) users feedback (e.g., user view of data utility). In our vision, the last point is rather important because even if a data is complete, precise, accurate and consistent, sometimes it might be not useful from a user point of view. Hence, we think that the act of sharing data is really important in the sense that exposing data to the judgement of a community may also contribute to assess the quality of data. Communicating about the uncertainty of data and models obviously appears a necessity. Interesting efforts to manage and communicate on data quality are exemplified by projects such as GeoViQua and UncertWeb. GEO/GEOSS is seeking to define a GEO Label that will inform users about quality, relevance and acceptance on data and services.

Recommendation #3 Exploring the potential of mobile devices

The growing adoption of smartphones and tablets (with GPS and wireless communication for internet access) has changed the way users are accessing the Web and consequently offers new possibilities to stream information to users (e.g., data consumers) and to capture information (e.g., data producers).

Although desktop computers will still exist we can already see a clear shift to mobile devices. Therefore, we can imagine that most of tomorrow's applications will be accessed on such devices allowing users to seamlessly access data and information at anytime and everywhere. The current convergence between telecommunication and data communication is a sign in that direction. This will raise constraints in term of processor speed, memory space, screen size, network bandwidth, data visualization, and diversity of devices (e.g consistent functionalities and understandable interfaces). This new mobile environment will obviously influence GIS and offer new possibilities particularly for field data collection and editing allowing data capturers to introduce data directly into a database in real time. This may also offer the possibility to work in either connected or disconnected environment by accessing large amount of geospatial data and cache it locally. That way, users can perform their task in the field without the need to go back to the office, only synchronizing new or update data in the field. Finally, this will allow users to discover content, display relevant information and eventually capture new information on real time. This possibly extends geospatial data to a wider audience and allows data consumers to interact with data more easily.

Recommendation #4 Exploring the potential of Volunteered Geographic Information

Related to recommendation #3 and the new possibilities offered to users to generate content, Volunteered Geographic Information (VGI) is defined by Goodchild (2007) as *"the harnessing of tools to create, assemble, and disseminate geographic data provided voluntarily by individuals"*. Good examples of such participative approaches are Wikimapia, OpenStreetMap and Google MapMaker. VGI is enabled by the Web 2.0 paradigm allowing users to generate content, populate web sites, and interact with other participants. Additionally simple and widely diffused means such as mobile phone (equipped with a GPS) allow users to capture information (e.g., pictures, messages) with a geographical reference. VGI can be thought as a participative approach to GIS, allowing users to generate data/content by providing information on specific locations where events may occur (e.g., damages to buildings after an earthquake event) or features that can exist but are not available on publicly available data sets (e.g., road network in developing countries). Consequently any (potential) users can be thought as a sensor. Goodchild (2007) distinguished three types of sensors: (1) static sensors used to acquire measurements on a bounded location, (2) mobile sensors carried by humans, or vehicles (e.g., air pollution monitoring, noise monitoring), and (3) humans themselves (with their senses and intelligence) that are able to gather and interpret what they perceive on their local environment. If static and mobile sensors can provide quantitative values it is not the case for human sensors that generate more qualitative data. Consequently, the main issue it has to deal with, regards data accountability (e.g., data quality, data comparability) and credibility. In our opinion, VGI can be seen as a complement of traditional SDI components, built upon the collective observations and expertise of citizens in their everyday life providing useful information on their surroundings. However, to gain credibility VGI needs to develop mechanisms to acquire, integrate, share that information while assuring its quality. This can be an interesting and promising tool to empower citizens informing about environmental phenomena occurring in their region.

Recommendation #5 Enable new tools to communicate spatially-enabled data within social media

Closely related to the last two recommendations, the emergence and fast growing of social media/networks like Facebook, LinkedIn, Twitter, Flickr or YouTube allows users to share information and rapidly proliferate content. Indeed, users can now very easily share any reports, images, maps or whatever information about their communities with their entire network. Therefore, it can be expected that this kind of medium will become increasingly important to communicate information on the environment and potentially also generate new data as exemplified by the geotagging capabilities of pictures published on Flickr (e.g., identifying pictures on a map) or mapping of tweets (e.g., Twitter messages) in order to spatially analyze this data and make sense of it (e.g., in crisis situation). This may potentially foster communication, sharing and collaboration around emerging problems or current situation/event on a specific location and influence the development of new widgets, mash--ups, etc... to consume this information.

Recommendation #6 Building capacities and promoting an open and sharing spirit

We strongly believe that capacity building at human (education and training of individuals), infrastructure (installing/configuring/managing of the needed technology) and institutional (enhancing the understanding within organization and governments of the value of geospatial data to support decision-making) levels is a major element for large adoption, acceptance and commitment to SDI concepts inside and outside the GI community (e.g., climatologists, hydrologists, ecologists). In particular, showing and proving the benefits of sharing interoperable data/metadata through appropriate examples, best practices and guidelines will help to strengthen (1) existing observation systems, (2) capacities to decision-makers to use it, (3) capacities of the general public to understand important environmental, social and economical issues. Altogether this will help to reach agreement and endorsement on the use of new standards. Such a participative approach will certainly stimulate data providers to be more "open" and consequently to share their data. Probably the best way to reach this objective is to establish a long-term commitment to education and research, otherwise the SDI vision will remain unclear and unachievable. All these actions will help to reach endorsement on the use of such technologies, raising and increasing awareness on the benefits of using and sharing geospatial data, and finally creating new commitments.

Recommendation #7 Promote and engage stakeholders in initiatives such as GEO/GEOSS and INSPIRE.

At the global and regional scales there are well known initiatives such as GEO/GEOSS or INSPIRE that need the support and engagement of different stakeholders of various communities involved. There is two major differences between these initiatives: (1) GEO/GEOSS is based on voluntary contributions while INSPIRE is a directive, and (2) GEO/GEOSS is primarily targeting the scientific community while INSPIRE targets environmental policies. However they both wish to enhance the relevance of earth observations and geospatial information to support decision-making processes. Consequently, these differences will noticeably influence the means of engaging stakeholders. INSPIRE is more restrictive in the sense that Member States do not have the choice and must be compliant with the legislation by 2020. Therefore compliance with the various Implementing Rules (e.g., data harmonization, metadata harmonization, view-download-transform services) will be of primary interest for stakeholders. GEO/GEOSS is aiming to provide a framework where voluntary participants can develop new projects and coordinate their strategies and investments. Hence, providing access to good, reliable andaccountable data, best practices documentation, tutorials (for data providers and data users), and sets of interoperability arrangements will help enabling stakeholders to participate and obtaining new commitments to GEO/GEOSS.

Finally, for both initiatives, capacity building, promoting/raising awareness and showing their related benefits are essential elements to strengthen engagement and support coordination (and not scattering) of efforts, investments and energies otherwise GEO/GEOSS and INSPIRE visions will remain unclear and unachievable.

Recommendation #8 Continue to evaluate the distributed computing paradigm to support SDIs

We are convinced that distributed computing paradigm, especially Grid infrastructures, can bring major benefits to support SDIs. However, if we want to take full advantage of this technology several issues must be tackled: (1) test the mediation approach on different computing backends such as Clouds or clusters (allowing to control all the resources and building responsive/efficient processing interfaces), (2) develop plugins for various clients (such as ArcGIS and GRASS) giving access to grid-enabled WPS capabilities and allowing users to access seamlessly different resources depending on their needs (e.g., data retrieval, processing or map making), (3) evaluate the capabilities offered by Desktop Grids providing a simple access to unused resources of Desktop computer (CPU, storage and network), (4) build efficient workflow based on grid and non-grid services using orchestration engine, and (5) evaluate the potential of Grid in term of data management, because Grids can offer capabilities that are currently not (or only partially) provided by SDIs: distribution storage, data replication, data stored as close as possible to components that access them, security, and efficient data moving protocols (e.g., GridFTP). This last point requires making Grid middleware spatially-enabled and then implementing OGC standards and interfaces directly into them.

Recommendation #9 Improve and extend interoperability experiments

We have seen that interoperability is an essential element to facilitate data discovery, access and integration. However, to be fully interoperable it is required to be syntactically and semantically interoperable. If syntactic interoperability is mostly achieved using OGC and ISO standards, semantic interoperability is currently not fully realized and has not shown its real added value. Therefore, we need to find suitable practical applications and benefits. Another issue concerns capabilities of models to exchange data with each other, and with other modeling tools on a time step basis as they run. This requires a standard interface like OpenMI to facilitate the modeling of process interactions (coming from different suppliers, representing processes from different domains, based on different concepts, with different spatial and temporal resolutions and having different representations). Making different infrastructures (SDI and Grid) interoperable is a strong requirement in order to make these infrastructures mutually beneficial from the capabilities offered.

Recommendation #10 Move towards a real multi---disciplinary framework

Understanding the complexity (e.g., interactions, multi-dimensionality, continuously evolving, spatial and temporal scales) of Earth system requires gathering and integrating different data sets about physical, chemical and biological system. Consequently, it necessitates a collaborative and multi---disciplinary effort to provide an integrated access to a wide range of services and resources on the environment. This obviously raises the challenge of a multi-stakeholder participation. The top-down approach emphasizes the need for standardization and uniformity, while the bottom-up stresses the importance of diversity and heterogeneity due to the different aspirations of the various stakeholders. In consequence, it is necessary to find a consensus to ensure some measure of standardization and uniformity while recognizing the diversity and the heterogeneity of the different stakeholders performing different tasks at different levels.

Therefore, a suitable approach to tackle this issue can be the so-called System of Systems (SoS) exemplified by GEOSS or INSPIRE. These initiatives underpin a multi-disciplinary framework built on existing systems. This allows recognizing the heterogeneity of systems reflecting the diversity of stakeholders involved while specifying arrangements in order to federate these systems. Such framework provides interesting features: (1) each component can operate independently (e.g., in order to match their own objective) and can be connected to others component by agreeing and specifying interoperability arrangements. This provides flexibility (the overall framework will not fail if one or more components disappear), (2) increase the capacity to turn data into information by sharing resources, (3) provides a holistic approach, (4) supplement but not supplant existing systems, (5) enhance composability of resources, (6) avoid single point of failure, (7) based on SOA principles, and (8) can incorporate incrementally new components/systems. This approach is also interesting as it lowers the entry---level barrier, which translates into implementing only a few standards to achieve at least syntactic interoperability. However, many challenges on interoperability can be highlighted like semantic, different interoperability levels, scalability, extensibility, evolution, flexibility and diversity of standards. The latter is very interesting due to the fact that in the GI community there are hundreds of standards' making it impossible for clients to implement all of them. Hence we need solutions that may act as gateways, exposing to clients only a few common and widely accepted standards. This brokering approach (proposed for example by EuroGEOSS) appears promising and need further investigations in order to test this applicability in a wider context. In our vision, SoS framework and brokering approach can ease commitment and facilitate endorsement and acceptance on interoperability allowing interconnecting different systems and providing a real multi-disciplinary framework.

8.4 Concluding remarks

To conclude, we are convinced that SDIs and related concepts, methods and technologies are suitable and can bring major benefits to support and facilitate environmental data discovery, accessibility, visualization, dissemination and analysis. On a technical level, all the building blocks are available, supported by OGC and ISO standards, allowing data providers to start sharing and disseminating their

data and metadata in an interoperable way. Our work has shown that this is feasible, software implementation are reliable and facilitating access, integration and use of geospatial data can answer the requirements of a specific community, as well as making these data available to the widest possible audience. SDIs have the potential to support the exchange and management of environmental data and information like what it is done since a long time in airports (e.g., management of passengers, flight and luggage) or banking (e.g., financial market) activities. Indeed, such private activities rely on a few, commonly accepted standards and protocols implemented in a few, widely used software. This contrast with the variety of standards, protocols, software implementations, data types and data formats that are available within the geospatial community. Despite the fact that this situation is probably caused by the diversity and heterogeneity of stakeholders involved in geospatial data creation and management, it would be good to rationalize and coordinate efforts (like in the OGC approach) for the development of standards, protocols and implementations.

An important lesson learnt is that we do not need to convince people. Instead, we need to keep all these concepts simple, make them understandable, and let people experience by themselves the benefits of working in an interoperable context and the potential positive influence it can have on their daily business. This will ease commitment to use standards, to endorse SOA and SoS principles, and to support/engage in initiatives like GEOSS and INSPIRE.

In our vision, it is time to make all these components operational otherwise SDI will remain only an innovative concept. Let the dream comes true because we cannot wait! The challenges that humankind is facing require acting now, and therefore we need to provide decision-makers with tools that allow them accessing rapidly and efficiently good and reliable environmental information. SDIs have clearly the potential to be a part of the answer to bridge the gap between science and policy-making. It is obvious that to achieve this objective in the shortest term possible it will mostly depend on political, social, and economical constraints. We have shown in this research that the human/social component is probably the most influencing one, and discussing and reaching agreements are important. Nevertheless, it must not be an excuse not to start sharing data and metadata. Scattering efforts and energies in discussions that sometimes concern only details can block entire process, resulting in lost of (precious) time and motivation, and finally leading to the risk of disappointment and disengagement. Therefore, finding the right balance between actions/decisions and discussions is an essential factor to address.

The System of Systems approach appears to be a valuable and promising concept in order to lower the entry-level barrier to a real multi-disciplinary framework where each component can perform independently their own tasks, while ensuring sufficient flexibility in connecting other components by agreeing and specifying interoperability arrangements. One of the major benefits of the SoS approach is to allow users to perform functions that cannot be made with any single component. This means that such a system is more than the sum of its parts, and offers the possibility to better understand the complex relationships between the different components of the Earth system. Consequently, such a framework can offer possibilities for SDIs to extend, complement and benefit from capabilities offered by other type of infrastructures. In this regard, distributed computing infrastructures and especially Grids can be really beneficial/advantageous for data processing and data management of ever-increasing amounts of high---resolution data.

Finally, as mentioned by Craig (2005) and Arzberger et al. (2004), it is important to keep in mind that data sharing and related SDI developments rely mostly on individuals that should have in common: (1) a sense that better data will lead to better decisions, (2) a sharing spirit that they got something in return and are viewed as collaborative partners, and (3) the fact that they are involved in a professional culture that honours serving society and cooperating with others. Hence, ensuring that data are easily accessible so that they can be used as often and widely as possible is a matter of sound stewardship of public resources. These authors stated that publicly funded data are a public good, produced in the public interest and thus should be freely available to the maximum extent possible. In a general scientific context, sharing and documenting data is part of the elementary scientific approach, allowing scientists to compare their results and methods more easily, and then enhancing scientific accountability, credibility and potentially improve quality of data for the benefit of everyone.

WITHOUT SHARING DATA: DOING SCIENCE IS DIFFICULT, TAKING SOUND DECISIONS CAN BE PROBLEMATIC, AND ENVISIONING A SUSTAINABLE DEVELOPMENT CAN BE COMPLICATED.

ANNEXES

A.1 ArcGIS for INSPIRE

The ArcGis for Inspire extension provides following components:

- Server components: Discovery services (with Geoportal Server) and view services (with ArcGis Server extension),
- Desktop Components,
- Data base Model (Geodatabase organized for data of Annex 1).

Server components

This chapter describes both server components : ArcGis Server extension and Geoportal Server.

ArcGis Server Extension is a Server Object Extension (SOE) providing INSPIRE View and download services.

- Inspire View services

  As a reminder, these are services designed to view a map by asking a server to generate an image, specifying the layers and style of data representation desired.

  The technical Guide of View Services INSPIRE recommends the use of WMS services 1.3 (ISO19128:2005).

  INSPIRE Directive introduces additional features compared to standard WMS. It corresponds in particular to associate metadata describing the view service and the different layers.

  The directive requires that metadata can be accessed via a "GetCapabilities" on the WMS and via the discovery services.

  The Implementation Guide states that view services must be able to return their descriptions (Capabilities) exceptions and their messages in different languages.

  The LANGUAGE parameter in WMS requests is then used to specify the language in which you want to access the service.

  According to ESRI, the ArcGIS for INSPIRE offers these additional required capacity level of ArcGIS Server.

  When publishing ArcGIS Server services, you must choose the WMS capabilities and INSPIRE View.

  INSPIRE view services published by ArcGIS Server offer style SLD required by the default directive (INSPIRE: DEFAULT). The administrator can add its own SLD.

  Coordinate systems available in the visualization services INSPIRE published by ArcGIS respected the list of CRS specified by the Directive.

  A visualization service INSPIRE is foremost an ArcGIS Server service, which means it can continue to be consumed by customers without going through the ESRI WMS interface.

- Download services

  As a reminder, this allows to download the spatial and tabular description of the entities of the map.

In version 1.0, ArcGIS for INSPIRE implements download services according to the recommendations of the "Draft Technical Guidance for INSPIRE Download Services 1.0" which recommends the use of WFS 1.1.

An implementation based on the standard WFS 2.0 (adopted in November 2010) is available in a minor update to ArcGIS for INSPIRE to meet the "Draft Technical Guidance for INSPIRE Download Services 2.0".

ArcGis Server extension provides these two types of download services:

- Pre-Defined Dataset

  This option provides access to a subset of the initial dataset by creating filters at the WFS service at the time of its publication.

  The client application can then retrieve this subset by a simple request WFS "GET". When publishing with ArcGIS, you can choose to publish this download service with optional features "INSPIRE Predefined Dataset".

- Direct Access Download

  This is a WFS service with generally larger data but enable client applications to specify filter conditions to retrieve the entities that meet specific criteria (attribute, spatial, temporal, ...).

  When publishing with ArcGIS, you can choose to publish this download service with standard features "INSPIRE Feature" (= Direct Access Download).

Geoportal Server providing INSPIRE Discovery Services

As a reminder, these are types of network services for research and consultation in a metadata catalog: the "Discovery Services".

The portal (website) of this catalog provides access to search functions, discovery, visualization, metadata and related resources.

INSPIRE Discovery Services are web services enabling users via the exchange of standardized messages (OGC CSW 2.0.2), to query a metadata catalog and get back information on resources in the search criteria.

It should be noted that the process of exchanging messages can also be used to synchronize between two servers (also known as harvesting) all or part of their metadata catalog.

The standard Geoportal Server to publish its metadata catalog as prerequisites INSPIRE (CSW 2.0.2 ISO AP with profile 1.0).

The metadata catalog is also accessible to other interfaces (REST, OpenSearch, HTML, GeoRSS, KML, ...). This helps facilitate the integration of research tools to the catalog in any application (office, mobile or web).

Geoportal Server also offers the ability to reference metadata catalogs exposed as OAI standards, or WAF CSW and / or harvesting of metadata.

Finally, the Geoportal Server provides a Rest API of the metadata catalog, so it can return a result from a query (expressed as a URL) resulting from any page of a site web.

Desktop Components

Desktop components are of two types: some are part of an integrated extension to the license for ArcGis Inspire and others are for free download.

- ArcMap tools provided by Arcgis for Inspire license:
    - A wizard to add Inspire layers (from the Geodatabase Inspire) (feature "Add Layer Inspire")
    - An interface for editing the metatdata of a Inspire view service (feature « Editing the Inspireviewservice property »).
- ArcCatalog tools provided by Arcgis for Inspire license: they allows to manage the services (View, download like described before).
- "Publish Client" tool, free extension for ArcCatalog 10, allows transmission of metadata from ArcCatalog to Geoportal Server.
- The Add-In "CSW Client", free extension for ArcMap 10, allows acceed with ArcMap to INSPIRE Discovery services and display the metadata for these resources.

In this case, this tool allows also to add the INSPIRE view service corresponding directly to the map.

- The Add-In "WMC Client ", free extension for ArcMap 10, allows acceed with Arcmap at files Web Map Context with extensions ".cml", "wmc", or "xml" for grouping maps from Web Map Services.

Database model

Currently the geodatabase data model corresponding to Annex 1 is the only one available. It is supplied in XML format is to be imported into a geodatabase to generate the structure.

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ABBREVATIONS & ACRONYMS

CERN: Centre Européen pour la Recherche Nucléaire

CSW: Catalog Service for the Web

EGEE: Enabling Grids for E-scienceE

EO: Earth Observation

GEO: Group on Earth Observations

GEOSS: Global Earth Observation System of Systems

GDAL: Geospatial Data Abstraction Library

GIS: Geographic Information System

GML: Geographic Markup Language

GPL: General Public Licence

GPS: Global Positiong System

GRID: Global Resource Information Database

INSPIRE: Infrastructure for Spatial Information in the European Community

ISO: International Organization for Standardization

IR: Implementing Rules

IT: Information Technology

JSON: JavaScript Object Notation

KML: Keyhole Markup Language

OAI: Open Archive Initiative

OASIS: Organization for the Advancement of Structured Information Standards OGC: Open Geospatial Consortium

OWS: OGC Web Services

RDBMS: Relational DataBase Management System

REST: Representational State Transfer

RPC: Remote Procedure Call

RSS: Really Simple Syndication

SDI: Spatial Data Infrastructure

SDK: Software Development Kit

SOA: Service Oriented Architecture

SOAP: Simple Object Access Protocol

SOS: Sensor Observation Service

SQL: Structured Query Language

SWE: Sensor Web Enablement

UN: United Nations

UNEP: United Nations Environment Programme

UNGIWG: United Nations Geographical Information Working Group

URM: Uniform Resource Management

VGI: Volunteered Geographic Information

WAS: Web Service Authentication

W3C: World Wide Web consortium WMS: Web Map Service

WFS: Web Feature Service

WCS: Web Coverage Service

WSDL: Web Service Description Language WSS: Web Security Service

WPS: Web Processing Service

WPVS: Web Perspective and View Service WTS: Web Terrain Service

XML: eXtended Markup Language