Assessing Climate impacts on the Quantity and quality of WAter

Deliverable Data.5 : ACQWA Data Warehouse - month 12
Dissemination level: Public

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This deliverable is prepared from task 2.5 ACQWA Data Warehouse is order to organize and facilitate data exchange among partners. It is covering the following points:
1. Introduction

1.1 Presentation of the ACQWA project

As the evidence for human induced climate change becomes clearer, so too does the realization that its effects will have impacts on socio-economic systems and terrestrial ecosystems. Some regions are more vulnerable than others, both to expected physical changes and to the consequences they will have for ways of life. Mountains are recognized as particularly sensitive physical environments with populations whose histories and current social positions often strain their capacity to accommodate intense and rapid changes to their resource base. This proposal aims to assess the impacts of a changing climate, focusing on the quantity and quality of water originating in mountain regions, particularly where snow- and ice melt represent a large, sometimes the largest, streamflow component. There, they represent a local resource (freshwater supply, hydropower generation, irrigation), but in most cases also considerably influence the runoff regime of the downstream rivers and the related water availability. Such an influence is reflected mainly in the amount of surface water available for supplying irrigated agriculture and water supply systems, but also in the amount of groundwater recharge that can take place in river-fed aquifers. An increasing number of evidences of glacier retreats, permafrost reduction and snowfall decrease have been observed in many mountainous regions, thus suggesting that climate modifications may seriously affect streamflow regimes, in turn threatening the availability of water resources, increasing the downstream landslide and flood risk, impacting hydropower generation, agriculture, forestry, tourism and, last but not least the water dependent ecosystems. As a consequence, socio-economic structures of downstream living population will be also impacted, calling for better preparedness in developed countries and strategies to avoid the exacerbation of the already conflictual situation in many developing countries, like those in Central Asia and South America.

The goal of the project is to use advanced modelling techniques to quantify the influence of climatic change on the major determinants of river discharge at various time and space scales, and analyse their impact on society and economy, also accounting for feedback mechanisms (Figure 1). The focus will be on continuous transient scenarios from the 1960s up to 2050. In comparison to many existing studies, the limitation of the modelling horizon to mid of the 21st century allows to develop more realistic assessment of the progressive impact on the social, economical and political systems, which we expect to evolve typically in an adaptive mode on shorter time scales than the centennial ones, eventually shifting to new equilibria when forced abruptly.

The data required for the multiple model applications will be managed in the form of a “data warehouse” that will begin collecting and centralizing the data for the entire ACQWA community from the start of the project. The specification of data and the data formats will be defined in collaboration with the partners within the first 2-5 months of the project, and by the end of the first year, data will be available through the Internet for use in the different Work Packages. Additional data, such as remote sensing information, will be ready by the end of the second year, while the socioeconomic data required for many of the non-physical impacts studies will be brought online from the inception of ACQWA through to the end of the project. The data warehouse will be continuously updated and maintained for the entire duration of the project.
1.2 Presentation of Workpackage 2: Climate and Socio-Economic Drivers of Change

WP 2 will provide a quantitative description of the primary (or direct) driver, climate change (CC), and of the indirect (or secondary) driver, the socio-economic factors. Specifically:

1) the CC driver will be described by means of recent climatic scenarios for validation of models and large and regional scale scenarios respectively from GCMs and RCMs simulations according to selected IPCC emission scenarios;

2) validation of spatial and temporal extent of snow cover at global to local scale computed by spatially explicit models under different climate scenarios;

3) validation of timing and amount of runoff generated from snow pack at a fine temporal scale estimated under different climate scenarios;

4) the socio-economic factors will be quantified by means of scenarios of socio-economic developments, such as drivers of land use changes, drivers of energy demand, changes in agricultural policies, etc.
1.3 Scope and Purpose of the Task 2.5: ACQWA Data Warehouse

The complexity inherent to the chain of processes involved from climatic, to cryospheric and hydrologic models, all of them impacting on different compartments of human and natural systems, all this through different scenarios and across several regions, as described in the other project WPs, justifies the definition of a well organized data warehouse for the ACQWA project. Based on the long experience in managing data and metadata through the Internet from many international programs, developed by GRID-Europe as part of the Division of Early Warnings of UNEP, the first task of the ACQWA Data Warehouse (ACQWA-DW) will be to install and manage this data warehouse to:

- define standards of data exchange formats and needs among partners using existing international standards such as ISO19115 for metadata of geographic data;
- gather and distribute data (geographic layers, remote sensing images, climatic and hydrological time series,...) through the data warehouse;
- define a project data policy
- store data and metadata in a PostgreSQL relational database and PostGIS database searchable by the partners and the public (Geonetwork node);

The second main task is to build an Internet GIS MapServer (ACQWA IMS), in order to:

- visualize the outputs of the project on an Internet Map Server (ACQWA IMS);
- communicate results of the project through internet GIS web services (WMS, WFS, WCS, KML,...).

T2.5 will interact with all the other work packages. It will help in defining the structure of the outputs of WP2 (Climatic and socio-economic drivers of change) by matching the input needs of the models predicting changes in water quality and quantity (WP3) at the basin and local/point scales. Outputs from WP3 will also match the needs of the work package on impacts (WP4) through the ACQWA-DW. It will finally provide outputs from all work packages for Education and Outreach (WP5).

1.4 Scope and purpose of Deliverable Data.5

This document aims to provide a technical overview and basic concepts governing Spatial Data Infrastructures and associate topics in order to share this necessary knowledge with the partners involved in the ACQWA project and beyond to assist them to share and integrate spatial data sets more effectively.

The different chapters of the deliverable cover the following points:

- Spatial Data Infrastructure (chapter 4)
- Interoperability and standards (chapter 5)
- Global and regional SDIs initiatives (chapter 6)
- Organizations involved in developing standards for the GIS/SDI industry (chapter 7)
- Description of the relevant standards for the project (chapter 8)
- Description of the tools that implement those standards (chapter 9)

We conclude with some important recommendations (chapter 10).

This report is part of a set of guidelines and are linked with:
1.5 Contributors to the deliverable

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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-Europe since 2001 and is the focal point for Spatial Data Infrastructure (SDI). In 2008, he also started to collaborate closely with the envioSPACE laboratory where he begins a Ph.D thesis and works also for the FP7 ACQWA project. In ACQWA, he is task 2.5 leader on ACQWA data warehouse.

Anthony Lehmann:
Dr. Anthony Lehmann is the WP2 leader. 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 his 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.

2. Responding to our changing environment, the need for data sharing

Today we are living in a globalized world where everything is changing rapidly (growing population, environmental deterioration,...) and where communication means have taken a remarkable place in our life. Everyday we access an enormous and continuous flow of information and much of them refer to a position or a specific place on the surface of our planet, they are georeferenced.

In the last 30 years, the amount of georeferenced data available has grown dramatically following the evolution of the communication means and due to the rapid development of spatial data capture technologies such as Global Positioning System (GPS), remote sensing images, sensors,... (Philips et al., 1999) and over the last ten years with the advent of applications like Google Earth, we have seen that geoinformation has been incorporated and routinely embedded into business and workflows of agencies at all levels of government, as well as in the private sector (Booz et al., 2005).

Despite the fact that administrations and governments are recognizing that spatial information is important and must be part of the basic information infrastructure that need to be efficiently coordinated and managed for the interest of all the citizens (Ryttersgaard, 2001), this huge
amount of geospatial data is stored in different places, by different organizations and the vast majority of those data are not being used as effectively as they should.

Moreover at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, the so-called Agenda 21 resolution fosters the importance of georeferenced information to support decision-making and management on the degradation and threats that are affecting the environment (GSDI, 2004) meaning that the need for availability and access to appropriate information, development of databases and exchange of information are the conditions for creating the basis for a sustainable development and supporting the information management needs of implementing and monitoring sustainable development policies and goals like the UN Millennium Development Goals (UNGIWG, 2007).

Thus geospatial information is a critical element underpinning decision making for many disciplines (Rajabifard and Williamson, 2001) and is indispensable to make sound decisions at all levels, from the local to the global. Experiences from the developed countries show that more than two-third of human decision-making are affected by georeferenced information (Ryttersgaard, 2001).

However, geospatial information is an expensive resource, it is time consuming to produce, and for this reason it is of high importance to improve the access and availability of data, and promote its reuse. Many of the decisions that different organization need to make depend on good and consistent georeferenced data, available and readily accessible (Rajabifard and Williamson, 2001).

In 1998, the former vice-president of the United States, Al Gore, has presented its visionary concept of a Digital Earth (Gore, 1998), “a multi-resolution, three-dimensional representation of the planet, into which we can embed vast quantities of georeferenced data”. As of today this vision is clearly not fully realized, but gives us an interesting support to our purpose as it is still actual.

Talking about the geospatial data, Al Gore (1998) mentions that the difficult part of taking advantage of this vast amount of information will be “making sense of it, turning raw data into understandable information” because at the moment we have more information than we can handle and they are stored in “electronic silos of data” and remains mostly unused. He envisioned applications where “information can be seamlessly fused with the digital map or terrain data” allowing the user to move through space and time, but of course, to achieve this vision, a collaborative effort (from government, industry, academia and citizens) is needed.

All the technologies and capabilities required to realize this vision and to build a Digital Earth are already available:

- computational science: even a simple desktop computer could process complex models and simulations and with the potential that technologies such as the Grid are offering new insights into the data, giving us the ability to simulate phenomena that are impossible to observe, and simultaneously to better understand data from observations.
- mass storage: storing tera-bytes of data on a desktop computer is actually no more a problem.
- satellite imagery: a lot of satellites are continuously observing the Earth offering high spatial and temporal observations.
- broadband networks: are already a reality giving the ability to connect different databases together.
- interoperability: this is a key point to allow communication and integration of distributed data, allowing the geospatial data generated by one software to be read by another.
• Metadata: are important as they describe the data, allowing a user to evaluate and discover the data before using them.

Even if all the technologies are ready, organizations and agencies around the world are still spending billions of dollars every year to produce, manage and use geographical data but they still do not have the information they need to answer the challenges our world is facing (Rajabifard and Williamson, 2001). These authors also highlight the facts that most organizations and/or agencies need more data than they can afford, they often need data outside their jurisdictions, and the data collected by different organizations are often incompatible. This inevitably leads to inefficiencies and duplication of effort, and thus it is evident that countries can benefit both economically and environmentally from a better management of their data (UNGIWG, 2007; GSDI, 2004).

In consequence, it is now essential to make these data easily available and accessible in order to give the opportunity to the user to turn them into understandable information with a clear and broad benefits for the society and the economy because "working together, we can help and solve many of the most pressing problems facing our society..." (Gore, 1998).

It’s clear that there are a lot of challenges to face, both tangible and intangible, when we start sharing data but we have to overcome them in order to improve our knowledge, share our experiences and try to build a better informed society. To achieve the goal of a sustainable development requires the integration of a large number of different types of data from different sources. Through agreed common standards and a clear political will, these data can be interchanged and integrated in an interoperable way, leading to a new collaborative approach to decision-making.

In conclusion, for Arzberger et al. (2004), ensuring that data are easily accessible, so that they can be used as often and as widely as possible is a matter of sound stewardship of public resources. Availability should be restricted only in certain specific cases like national security. He argues that “publicly funded research data should be openly available to the maximum extent possible”, because publicly funded data are a public good, produced in the public interest.

It seems to be the right time to really work together and to share our data in order to provide a state-of-the-art spatial data infrastructure for ACQWA project.

3. ACQWA Data warehouse

3.1 FTP site

A large FTP disk has been setup to allow the ACQWA partners to share their relevant data sets (upload and download).

To connect to this disk, a personal account will be provided to all partners. If you did not receive it please request it to Gregory Giuliani (gregory.giuliani@grid.unep.ch).

Once you are connected, the data is organized according to the following structure:
- ClimateScenarios
  - REMO (See task 3.1)
  - ...
- HydroScenarios
  - ...
- SocEcoScenarios
  - ...
- Rhone
  - HydroMeteo
    - Meteo
    - Streamflow
    - SoilMoisture
    - SnowIce
    - ...
  - RemoteSensing
    - Snow
    - Radar
    - Vegetation
    - SoilMoisture
  - Topography
    - DEM
  - Landuse
    - Geostat
  - Soil
  - SocioEconomic
    - Population
    - WaterDemand
    - Agriculture
    - Tourism
    - Economic

The structure used for Rhone is then repeated for the following spatial extents:

- Po
- Chile
- Kyrgyzstan
- Aragon
- FrenchPyrenees
- Switzerland
- Europe
- Global

PublicOutputs (read only)
- Rhone
- Po
Accessing the ACQWA Data Warehouse through the web

You can connect to the FTP site with the following URL:
https://netstorage.unige.ch/netstorage

Once connected, you can navigate through the different directories and can upload or download chosen files.

Accessing the ACQWA Data Warehouse on your desktop computer

With the same account used to access the FTP site via the web, you can now access the data warehouse directly on your desktop computer.

- on Windows XP & VISTA:
  - Download the NetDrive client in the private section of the ACQWA website: http://www.acqwa.ch/
  - Unzip the file
  - Install the client by double-clicking the “.exe” file (use the default options).
  - Double-click on the “.reg” file (this will install the right parameters to access the ACQWA Data warehouse).
  - The client is accessible directly in the menu “Start > Programs” or in the System Tray (near the clock on the lower-right of the screen).
  - Just click on the client, insert your username and password, click OK and now you are connected. The FTP site appears in the Windows Explorer under the drive N:

- on Mac:
  Go > Connect to server
type: smb://arves1.unige.ch
and click “OK”. After that a message will be prompt to ask you your username and password.
Chose the ARVES1.DATALAB6 folder.
Once connected you will find the same folders as on the web access.

- on Linux (Ubuntu):
  Places > Connect to server
Under “service type”, chose: Windows share and type:
Server: arves1.unige.ch
Click “OK” and fill the from with your username and password.
3.1 ACQWA project extent

Note that under the NETSTORAGE/ACQWADATA/WP2/Task2.5/AVAILABLE you will find shapefiles of the official extent for the project as defined on page 22 of the Document of Work (Annex1):

“The project will focus in the first three years out of five on two test areas:
1. the Rhone river basin up to the Lake of Geneva and
2. the Po river basin up to Pavia (Ponte della Becca), therefore including the Ticino catchment which partially shares the water divide with the Rhone basin.”

1. Rhone, proposed study area and watershed
   Coordinates (dd): 6.5/47.0  9.0/47.0
                    6.5/45.5  9.0/45.5

2. Po proposed study area and watershed
   Coordinates (dd): 6.0/47.0  9.5/47.0
                    6.0/43.5  9.5/43.5
3. **ACQWA proposed study area extent**

Coordinates (dd):

- 5.0/47.0 11.0/47.0
- 5.0/44.0 11.0/44.0

Partners working on these catchments are strongly encouraged to use one of these extents to favor and facilitate future exchange of data with other partners.

### 3.3 Data policy

A data policy was developed for the ACQWA project (see Annex 1) in order to set common rules on data exchanges in the consortium.

### 4. Spatial Data Infrastructure

#### 4.1 Definition, concepts and rationale

The term Spatial Data Infrastructure (SDI) is often used to describe the mechanisms or the enabling environment, that supports easy access to, and utilization of, geographical data and information (UNECA, 2005). This definition is quite reductive as it gives the idea that SDIs are essentially technical. The primary objective of SDIs is to provide a basis for geospatial data discovery, evaluation, and application for users and providers within all levels of government, commercial and the non-profit sectors, academia and citizens (GSDI, 2004).

This means that SDIs are more than just data repositories, they store data and their attributes, their related documentation (metadata), offer a mean to discover, visualize, and evaluate their fitness to different purpose, and finally provide access to the data themselves. In addition to these basic services, there is often additional services or softwares supporting the use of the data. Finally to make an SDI work efficiently, it is necessary to include all the organizational agreements needed to coordinate and administer it.

In consequence, following Masser (2005) and GSDI (2004), we can give a more complete definition of what are SDIs:

“A spatial data infrastructure supports ready access to geographic information. This is achieved through the co-ordinated actions of nations and organizations that promote awareness and implementation of complimentary policies, common standards and effective mechanisms for the development and availability of interoperable digital geographic data and technologies to support decision making at all scales for multiple purposes. These actions encompass the policies, organizational remsits, data, technologies, standards, delivery mechanisms, and fincancial and...
human resources necessary to ensure that those working at the national and regional scale are not impeded in meeting their objectives”.

Before going further in details, we have to explain the concepts underlaying the rational of SDI, in particular geospatial data and information (also named geodata or georeferenced data). A geodata describes a location on Earth, giving through its attributes a comprehensive picture of the physical world both in term of spatial and/or temporal extent. Geodata are extremely valuable as users can build spatial relationships between features and data. For example, just after a flood event, one can overlay remote sensing images with existing georeference data of settlements to evaluate the extent of the damage and then focus humanitarian assistance. In consequence, geodata has a key role to play in our knowledge-based economy affecting directly or indirectly different sectors like foresters, urban planners, police, telecommunications, environmental protection, ...

Fig.2: GIS and economy (Source: Geoconnections).
If previously geographical information was mostly presented in the form of paper maps, with the increasing means to capture information in digital formats, geospatial data are used and viewed within a Geographical Information System (GIS), this computer system is now capable of assembling, storing, manipulating, and displaying geographically referenced information (UNECA, 2005).

A GIS gives the ability to merge different existing information from different sources facilitating collaboration in creating and analyzing data. Due to these new possibilities of reusing existing data and working on collaboratively greater scale, new challenges arise. When anyone tries to create a new information based on different data or different formats, with different content and terminology, and perhaps different projection..., it is quite difficult to bring them together. Harmonizing geodata is a complex, costly and time-consuming task, but could be achieved by obtaining same agreement among data capturers before the work begins.

The growing recognition that once a geodata has been created it should be used as well in public and private sectors, as well as in business (Ryttersgaard, 2001) reinforces the need to store data into databases that are made accessible largely for different purposes (Philips et al., 1999). This leads to the concept that geodata could be a shared resource, which will be maintained continuously.

The advantage of having geographical data in a digital form (UNECA, 2005; UNGIWG, 2007) are:

- easy storage,
- easy dissemination,
- facilitation of data exchange/sharing,
- faster and easier updates and corrections,
- ability to integrate data from multiple sources,
- customization of products and services.

As a result of the previous considerations the concept of the Spatial Data Infrastructure was developed in order to facilitate and coordinate the exchange and sharing of geospatial data (Rajabifard and Williamson, 2001), encompassing the data sources, systems, network linkages, standards and institutional issues involved in delivering geodata and information from many different sources to the widest possible group of potential users (Coleman et al., 1997).

The vision of an SDI incorporates different databases, ranging from the local to the national, into an integrated information highway and constitutes a framework, needed by a community, in order to make effective use of geospatial data (UNECA, 2005).

### 4.2 Objectives

Following Masser's definition (2005) and the different considerations highlighted in the previous section we can list different objectives underpinning SDIs:

- The overall objective of an SDI is to maximize the reuse of geospatial data and information.
- SDIs cannot be realized without coordination (especially by governments).
- SDIs must be user driven, supporting decision-making for many different purposes.
- SDIs implementation involves a wide range of activities, including not only technical topics such as data, standards, interoperability, and delivery mechanisms, but also institutional arrangements, policies, financial and human resources.
− The term infrastructure is used to promote the idea of a reliable and supporting environment, analogous to a road or a telecommunication network, facilitating the access to geoinformation using a minimum set of common practices, protocols, and specifications (GSDI, 2004). This allows the movement of spatial information instead of goods.
− SDIs are all about (UNGIWG, 2007):
  − re-use: of data, technical capabilities, skills developed, invested effort and capital.
  − sharing: “sharing-not-wearing” the costs of data, people, technology,... helping to realize more rapid returns on investment.
  − learning from others: avoiding the pitfalls experienced by others.
− Avoid duplication efforts and expenses and enables users to save resources, time and effort when trying to acquire or maintain datasets (Rajabifard and Williamson, 2001).
− SDIs are “about working smarter, not harder” (UNGIWG, 2007).
− Implies to scale from specific and monolithic (data-centric) towards independent and modular (service-oriented) information systems.
− Integrate these systems together into an information highway which both links together environmental, socio-economic and institutional databases and provides a movement of information from local to national and global levels.
− To encompass the sources, systems, network linkages, standards and institutional issues involved in delivering spatially-related information from many different sources to the widest possible group of potential users.

Altogether these objectives intend to create an environment that foster activities (fig.3) for using, managing and producing geospatial data and in which all stakeholders can co-operate with each other and interact with technology, to better achieve their objectives at different political/institutional levels (Rajabifard and Williamson, 2004).

### 3.3 Components

Masser (2005) identifies the most important stakeholders with special interests in geoinformation/SDIs matters and shows the diversity both in terms of size and resource of the large numbers of players involved:
− Central government organizations,
− Local government organizations,
− Commercial sector,
− Non-for-profit/non-governmental organizations,
− Academics,
− Individuals.

Thus the temptation will be to create a centralized “one-size-fits-all” spatial database, in order to provide all the information needed by a country or a specific community of common interest. But as reported by UNECA (2005), UNGIWG (2007) and GSDI (2004) the existence of geodata and information does not alone ensure that it is used for decision-making. Different other factors are important to consider in order to ensure that information will be effectively used and reused:
To be used, people need to know that the data exist, and where to obtain it.
− They need to be authorized to access and use the data.
− They need to know the history of the data capture, in order to interpret it correctly, trust it and be able to integrate it meaningfully with data coming from other sources.
− To know if the data depends on other data sets, in order to make sense of data.

In consequence, to leverage the full potential of geospatial data, an SDI must be made of different components to allow users to find, discover, evaluate, access and use these data, namely:
− A clearly defined core of spatial data.
− The adherence to known and accepted standards and procedures.
− Databases to store the data and accessible documentation about the data, the so-called metadata.
− Policies and practices that promote the exchange and reuse of information.
− Adequate human and technical resource to collect, maintain, manipulate and distribute geospatial data.
− Good communication channels between people/organizations concerned with geodata, allowing the establishments of partnerships and share knowledge.
− The technology for acquiring and disseminating data through networks.
− Institutional arrangements to collaborate, co-operate and coordinate actions.

But as stated by Rajabifard and Williamson (2001), there is an important additional component represented by people. This include the users of geospatial data but also the providers and any other data custodians. For these authors, people are the key to transaction processing and decision-making. Facilitating the role of people and data in governance that appropriately supports decision-making and sustainable development objectives is central to the concept of SDI.

In order to meet the requirements of all stakeholders involved, an SDI must (Coleman et al., 1997):
− be widely available,
− be easy to use,
− be flexible,
− form the foundation for other activities.

In summary, Rajabifard and Williamson (2001) suggest that an SDI cannot be seen only as composed of geospatial data, services and users but instead involves other issues regarding interoperability, policies and networks.
This shows that an SDI is by nature really dynamic as people who want to access data must interact with technological components (fig.4).

### 3.4 SDI hierarchy

As a result of the fact that SDI initiatives range from local to national and regional levels (Crompvoets, 2003; Masser 2007) and they all aim to promote economic development, to stimulate better government and to foster environmental sustainability (Masser, 2005), Rajabifard (2002) proposed a model of SDI hierarchy that is made of inter-connected SDIs developed at different levels (from local to global). Each SDI of a higher level is primarily formed by the integration of geospatial datasets developed and made available by the lower level (fig.5).

![SDI hierarchy diagram](Source: GISCafe)
Such a hierarchy has two views: in one hand it is an umbrella in which the SDI at a higher level encompasses all the components of SDIs at levels below. On the other hand, it can be seen as the building block supporting the access of geospatial data needed by SDIs at higher levels. The SDI hierarchy allows to create an environment in which users working at any level can rely on data from other levels and integrate geospatial data from different sources (Mohammadi et al. 2007). Such a hierarchy is envisioned by regional and global initiatives like INSPIRE and GEOSS, that will be further discussed.

For Masser (2006), the SDI hierarchy poses the challenge of a multistakeholder participation in SDI implementation because the vision of a bottom-up vision differs a lot from the top-down that is implicit in most of the SDI literature. 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.

3.5 SDI evolution and (emerging) trends

Different authors (Masser, 2005; Crompvoets, 2003) have studied the diffusion and evolution of SDI around the world and show that driving forces behind SDI initiatives are generally similar:

- promoting economic development,
- stimulating better government,
- fostering environmental sustainability,
- modernization of government,
- environmental management.

They all agree on the fact that, as of today, a critical mass of SDI users has been reached as a result of the diffusion of SDI concepts during the last ten to fifteen years. This provides a basic network of people and organizations that is essential for future development of SDIs.

Rajabifard et al. (2001) find that the first generation of SDIs, based on a product model, gave away to a second generation at the beginning of the years 2000, the latest is characterized by a process model. Indeed, the first generation of SDIs were product-based, aiming to link existing and future databases while the second generation, aim to define a framework to facilitate the management of information assets allowing reuse of collected data by a wide range of people and/or organizations for a great diversity of purposes at various times. For Masser (2005) this evolution emphasis the shift from the concerns of data producers to those of data users and the shift from centralized structures to decentralized and distributed networks like the web.

The process-based model emphasizes the communication channel of knowledge infrastructure and capacity building towards the creation of an SDI facilitating cooperation and exchange of data and knowledge (Rajabifard and Williamson, 2001). They also highlight the fact that the characteristics of the social system strongly influence the approach taken to implement and develop a Spatial Data Infrastructure. They propose key issues and strategies to be considered for the design process:

- development of a strategic vision and associated implementation strategy,
- recognition that SDI is not an end in itself,
- key institutional strategy is to have all coordinating processes administered by one group.

Today’s effort on the technical development of SDI components clearly focus on the exchange of geodata in an interoperable way (Bernard and Craglia, 2005) through services that allow efficient
access to spatially distributed data. The shift towards an infrastructure offering services to answer requests rather than a “simple” network allowing to find, view and exchange geodata is highlighted by the concept of web services and the related Service Oriented Architecture (SOA).

Web services are a “new paradigm” (Comert, 2004) where different systems or providers offer some services for certain user groups, allowing an easy access to distributed geographic data and geoprocessing applications. The web services emphasize the necessity that systems involved could talk to each other and the provision of this talk should be easy and cost-effective for businesses to profit. In other words, web services relay on interoperability.

Web services enable the possibility to construct web-based application using any platform, object model and programming language. A service is no more than a collection of operations that allows users to invoke a service, which could be as simple as requesting to create a map or complicated as processing a remote sensing image.

In summary, web services are for application-to-application communication over internet and are based, in general, on open standards like XML (Comert, 2004). SOA is the basic principle concept supporting web services development. It promotes loose coupling between software components so that they can be reused (Sahin and Gumusay, 2008). In a SOA, the key component is services. They are well defined set of actions, self contained, stateless, and doesn't depend on the state of other services.

There are three components on the web services architecture: service provider, service requester and service broker and three operations: publish, find and bind. A SOA relates the three components to the three operations to allow automatic discovery and use of services.

In a traditional scenario, a service provider hosts a web service and “publishes” a service description to a service broker. The service requester uses a “find” operation to retrieve the service description and uses it to “bind” with the service provider and invoke the web service itself (fig.6).

SOA is the underlying concept for an interoperable environment based on reusability and standardized components and thus is of high importance for SDIs allowing applications and related components to exchange data, share tasks, and automate processes over the Internet (OGC, 2004).

The OGC web services are, by far, the most important and relevant web services for our purpose and they will be discussed in details in an upcoming section of this deliverable (paragraph 6.1).

With the advent of web services into the SDI community new trends/opportunities could be foreseen:
Actual SDIs are lacking of analysis capabilities, an essential task to turn data into understandable information. This means that the processing of the geospatial data is done in general on desktop computers and thus limit the analytical capacities caused by the huge execution time that geoprocessing tasks require to process a vast amount of data. With the recently introduced Web Processing Service and the promises of high storage and computing capacities offered by Grid infrastructures, new opportunities are emerging within geosciences communities (Padberg and Greve, 2009).

Semantic web developed vocabularies (called ontologies) for geospatial data with the goal to increase understanding of such data by machines, allowing automated process through web services (Boes and Pavlova, 2008; Vaccari et al., 2009).

Web services are one aspect of the Web 2.0 revolution. The web 2.0 refers to a second generation of internet based services, that let people to collaborate and share information (Boes and Pavlova, 2007). GIS is also taking advantage of the web 2.0 revolution, highlighted by the fact that, for example Google Maps opened some of the more straightforward capabilities of GIS to the general public (Goodchild, 2007) and allowing, with other tools, the general public to create and generate news sources of data and information. This phenomenon is also know as Volunteered Geographic Information (VGI) (Boes and Pavlova, 2007; Coleman et al., 2009, Craglia, 2007). VGI offers new opportunities and perhaps will influence in a near future the development of SDIs and the production of data.

Finally, it is necessary to mention that building an efficient SDI is almost impossible without partnership because a single agency is unlikely to have all resources, skills or knowledge to undertake the development of all aspects of SDI (UNECA, 2005; UNGIWG, 2007). This is why different authors (Williamson et al., 2003, Rajabifard and Williamson, 2004) stress the importance of the capacity building component in the SDI implementation process.

### 3.6 Benefits

To conclude, we can highlight some of the (expected) benefits that SDIs can offer:

- universal (anywhere and anytime) access to geodata and related information,
- services and applications to discover and access distributed data sources,
- integration of different geospatial information to provide seamless view,
- seamless combination (chaining) of data, services and related applications,
- geospatial data update and maintenance made easy,
- sharing and reuse capabilities,
- collaborative activities,
- wide-scale interoperability, agreeing on open and common standards,
- development of partnerships, collaboration between different stakeholders.

The Canadian Geospatial Data Infrastructure (CGDI) claimed that developing applications using such an infrastructure allows to:

- Reduced costs: Applications can be built by reusing existing services.
- Reduced complexity: Service interfaces hide the underlying complexity.
- Less costly integration and interoperability: Standard interfaces simplify interconnection and integration.
- Direct access to current, authoritative source data.
Finally an effective and working SDI leads to:

- Informed decision-making: easy access to current information, knowledge and expertise.
- Efficiency: standards and specifications, as well as access to services, reduce duplication of effort.
- Usability: providing reliable access to geospatial information to all levels, from the citizens to governments.
- Economic growth.

We would not depict SDIs as a “perfect tool” that solves all the problems. It's evident that SDIs represent a great opportunity and a framework with great perspective but as Masser reminds us (2005), SDIs can facilitate access to data to a wide range of users only if profound changes in “sharing spirit” take place. He also mentions the fact that building an SDI is a long term process. In order to be fully operational such a process depends on sustained and commitment.

In addition, there are several others issues that could limit the implementation of SDI concepts such as: collaboration, funding, political stability, legislation, priorities, awareness, copyrights, privacy, licensing, capacity building and cultural issues. These are all clear challenges that EnviroGRIDS will have to face.

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<td>Copyright,</td>
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Table 1: Integration issues (Williamson et al., 2006)
To conclude this section, it is important to keep in mind that data sharing and related SDI developments rely first on individuals (Craig, 2005) that have generally things in common. First, their idealism, their sense that better data will lead to better decisions. Second, their self-interest: by sharing, they got something in return even if it is intangible, they are viewed as cooperative partners, and finally they are involved in a professional culture that honors serving society and cooperating with others.

In other words, without people, SDIs cannot be built, and successful SDI would not exist.

4. Interoperability and standards

4.1 Definition and concepts

Previously, in section 2, we have seen that we are living in a world that is changing rapidly with communication means that are taking an increasing place in our everyday life. This communication revolution is mostly based on the Internet, whose successes are due to interoperability. Interoperability is “the ability of a system or a product to work with other systems or products without special effort on the part of the customer.” (OGC, 2004). This means that two or more systems or components are able to transmit or exchange information through a common system and to use the information that has been exchanged.

When systems are interoperable, it gives the user the ability to:
- find what he needs,
- access it,
- understand and employ it,
- have goods and services responsive to his need.

As of today, in a climate of economic constraint, interoperability and standardization have never been so important because a non-interoperable system impedes the sharing of data, information and computing resources (OGC, 2004), leading organizations to spend much more than necessary on data, software and hardware. Moreover being non-interoperable increases the risk for a system or an infrastructure to not deliver its expected benefit and in consequence to lead to a user disappointment and system failure.

In order to achieve interoperability, there are two approaches:
- adhering to standards
- making use of a “broker” of services that can convert one product’s interface into another product’s interface, “on the fly”.

One good example of the first approach is the Web, where standards like HTTP, TCP/IP or HTML have been developed by organizations that wish to create standards to “meet everyone’s needs without favoring any single company or organization” (OGC, 2005).

The great advantage of interoperability, and that is why it is an essential building block for the GIS and SDI industry, is that it describes the ability of locally managed and distributed heterogeneous systems to exchange data and information in real time to provide a service (OGC, 2004). This allows the users to maximize the value of past and future investments in geoprocessing systems and data.

As a response of the need of GIS standards to support interoperability, the OGC aims to tackle the non-interoperability caused by the diversity of systems creating, storing, retrieving, processing and displaying geospatial data in different formats. In addition to this, software
vendors often did not communicate among themselves to agree on how data should be structured and stored and how systems must exchange information, leading inevitably to a non-interoperable environment, isolating geospatial data in “electronic silos” and resulting in expensive duplication of data and difficulty in sharing and integrating information (OGC, 2004).

The OGC (2005) has pointed out the general user needs:

- need to share and reuse data in order to decrease costs (avoid redundancy collection), obtain additional or better information, and increase the value of data holdings.
- Need to choose the best tool for the job and the related need to reduce technology and procurement risks (avoid being locked in to one vendor).
- Need to leverage investment in software and data, enabling more people to benefit from using geospatial data across applications without the need for additional training.

The OGC believes that responding to the users needs of interoperability will have a profound and positive impact in the public and private sectors, opening the doors of new business opportunities and new human activities.

In summary, interoperability enhances: communication, efficiency and quality for the benefit of all citizens allowing them to access data in a good, consistent and transparent way.

### 4.2 Types of Interoperability

When we talk about interoperability, there are two types of interoperability (OGC, 2004):

- syntactic (or technical): when two or more systems are capable of communicating and exchanging data, they are exhibiting syntactic interoperability. Specified data formats and communication protocols are fundamental. In general, XML or SQL standards provide syntactic interoperability. Syntactical interoperability is required for any attempts of further interoperability.

- Semantic: Beyond the ability of two or more computer systems to exchange information, semantic interoperability is the ability to automatically interpret the information exchanged meaningfully and accurately in order to produce useful results as defined by the end users of both systems. To achieve semantic interoperability, both sides must defer to a common information exchange reference model. The content of the information exchange requests are unambiguously defined: what is sent is the same as what is understood (eg. explaining why INSPIRE is producing data specifications).

Different types of geoprocessing systems (vector, raster, CAD,...) producing different types of data, different vendors geoprocessing systems using internal data formats and producing proprietary formats, different vendors systems using proprietary libraries and interfaces and reducing the possibilities of communication between systems... are all causes of syntactic non-interoperability while different data producers using different metadata schemas and/or different naming convention, etc... lead to semantic non-interoperability.

The World Wide Web and its associated technologies offer a great opportunity to overcome both syntactic and semantic non-interoperability because it is an almost universal platform for distributed computing and it provides facilities to semantically process structured text. The web is thus a key enabler for interoperability by increasing the access to geospatial data and processing resources and in consequence also increase the value of those resources (OGC, 2004).

To ensure an effective interoperability, it is not only a matter of technology but also and often it requires a change of philosophy, of spirit to go “open”. This is classified under human or legal/policy on the following table summarizing the different types of interoperability.
Table 2: Different types of interoperability.

As expressed by the OGC (2004) “if an organization does not fully embrace the tenets of interoperability and interoperable architectures, then long-term success in integrating geospatial processes into an organization's overall business processes may be problematic”.

In consequence, organizations will need:

- commitment to interoperability and geospatial standards,
- commitment to collaboration,
- commitment to define a geospatial interoperability and information framework that meets the requirements of the organization,
- commitment to the collection and maintenance of geospatial metadata,
- commitment to training and education

Through all these commitments, an organization will be truly interoperable, maximizing the value and reuse of data and information under its control and will be able to exchange these data and information with other interoperable systems, allowing new knowledge to emerge from relationships that were not envisioned previously.

4.3 Interoperability enablers

To enable effective interoperability, we have already seen that the Internet and standards are probably the most important components at a technical level but here are a lot of other possible enablers, both human and technical, that could help an organization to promote its commitment to interoperability:

- web and networks,
- standards,
- infrastructure,
- metadata,
- support for multiple: languages, views, data formats, projections, datums,...
- sharing of best practices,
- cooperation and collaboration,
- business models,
- business agreements,
− policy framework,
− copy and access rights,
− authorization,
− ...

Altogether they will contribute in a way or another to a successful implementation of the geospatial interoperability by reaching a consensus between the users’ need for compatibility with the autonomy and heterogeneity of the inter-operating systems (OGC, 2005).

4.4 Standards

Standards are documented agreements, used in public contracts or international trade, containing technical specifications or other precise criteria to used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose (Ostensen, 2001). In other words, standardization means agreeing on a common system (OGC, 2005).

The existence of non-harmonized standards for similar technologies contribute to the so-called “technical barriers to trade”, avoiding a user to share data, information or services.

Although developing standards is a long and complex process, involving many organizations, based on a consultative approach and aiming to find a consensus between all the parties involved (UNECA, 2005), organizations and agencies are increasingly recognizing that standards are essential for improving productivity, market competitiveness, export capabilities (GSDI, 2004) lowering maintenance and operation costs over time (Booz et al., 2005; Craglia and Nowak, 2006; Almirall et al., 2008).

We can summarize the functions of standards as follow:
− help to ensure interoperability,
− promote innovation, competition, commerce and free trade,
− increase efficiency,
− make things work,
− affect every aspect of our life (widespread use of standards).

4.5 Benefits

After discussing what are standards and interoperability, we can give an overview of the (expected) benefits of a truly interoperable architecture.

1. Allow share and reuse of data: gives access to distributed and heterogenous sources of data.
2. Avoid data duplication: data are collected and maintained at the most appropriate place.
3. Reduce the costs: of maintenance, of operations and of course of production.
4. Integration: As Mohammadi et al. (2007) shows multi-source data integration could only be achieved with an effective interoperability.
5. Reduce the complexity: through common knowledge, standards offer a set of rules that every data provider can follow, understand and become familiar with. Moreover when a user share a data in a standardized way, another will be immediately able to use it.
6. Increase efficiency.
7. Vendor neutral: avoid the fact to be locked in to one vendor.
8. Improve decision-making: offering standardized access to a vast amount of data and information and to used them as effectively as they should.
9. New opportunities and knowledge: open the doors to new activities and relations that wasn't foreseen before.

Finally, as OGC (2005) stated:

“Changing internal systems and practices to make them interoperable is a far from simple task. But the benefits for the organization and for those who make use of information it publishes are incalculable”.

5. Initiatives

Different initiatives at the regional and global level are influencing and promoting the creation of Spatial Data Infrastructures and the use of open standards. They all are concerned about data access, harmonization, standardization, interoperability, seamless integration and services. They coordinate actions that promote awareness and implementation of complimentary policies, common standards and effective mechanisms for the development and availability of interoperable digital geographic data and technologies to support decision making at all scales for multiple purposes. These actions encompass the policies, organizational structures, data, technologies, standards, delivery mechanisms, and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives.

5.1 Infrastructure for Spatial Information in the European Community (INSPIRE)

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

The Infrastructure for Spatial Information in the European Community, namely INSPIRE, is of particular interest for the EnviorGRIDS 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 (EU, 2007). 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 (EU, 2008). 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 (EU, 2008):

- inconsistencies in collection of georeferenced data: geodata are often missing and/or incomplete, or are collected twice by different organizations.
- Lacking of documentation, description (metadata) of the data.
- Geodata are often incompatible and thus cannot be combined.
- Infrastructures used to find, access and use geodata 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 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 thus: “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”. (EU, 2004)

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

INSPIRE is based on common principles (EU, 2007):

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 Stated 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 endorse 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 (EU, 2008).
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 (fig.7). Thus users will spend less time and efforts to integrate data delivered within the INSPIRE framework.

The Directive (EU, 2007) 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 a 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. For Luraschi et al. (2009) because the geoportal does not store or maintain data and metadata, 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 (EU, 2008), Member States shall establish, operate and provide access to the following network services (fig.8):

- 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.

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5.2 **Global Earth Observation System of Systems (GEOSS)**

Website: [http://www.earthobservations.org](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, 2005). GEO is a 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.

5.3 United Nations Spatial Data Infrastructure (UNSDI)

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

The United Nations Spatial Data Infrastructure is 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 provide 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).

5.4 Global Monitoring for the Environment and Security (GMES)


The GMES is a European programme, coordinated by the European Commission and European Space Agency, for the implementation of a European capacity for Earth observation with the
objective to monitor and better understand the environment and thus contribute to the security of every citizen. This initiative aims at providing decision-makers and other users who rely on strategic information with regard to environmental and security issues an autonomous, independent and permanent access to timely, reliable and accurate data and services.

The objective is to integrate data on atmosphere, oceans and continental/land processes giving an overview of the state of health of our planet and to deliver information through five thematic areas (served by different services) covering:

− land,
− marine,
− emergency,
− atmosphere,
− security.

allowing policy and decision-makers to prepare legislation (at different level) on environmental topics and to monitor the implementation of such laws.

To gather data and information on Earth Observation, GMES proposes to build and infrastructure around four components:

− space: environmental satellites
− in-situ measurements: ground-based and airborne sensors.
− data harmonization and standardization,
− services to users.

Like various other data sources, Earth-observation-based services already exist in Europe but are dispersed and fragmented at national and regional level avoiding a sustainable observation capacity (meaning that long-term availability of information is not guaranteed). In consequence, GMES is the answer of the European Commission to develop a reliable and sustainable Earth Observation system and also contributing the the GEOSS initiative.

GMES stated that “By securing the sustainability of an information infrastructure necessary to produce output information in the form of maps, datasets, reports, targeted alerts, etc…, GMES helps people and organisations to take action, make appropriate policy decisions and decide on necessary investments. GMES also represents a great potential for businesses in the services market, which will be able to make use of the data and information it provides according a full an open access principle.” (GMES, 2009).

5.5 Global Spatial Data Infrastructure (GSDI)

Website: http://www.gsdi.org

The mission of the GSDI Association, a world-wide inclusive body of organizations, agencies, firms and people, is to “promote international cooperation and collaboration in support of local, national, and international spatial data infrastructure developments that will allow nations to better address social, economic and environmental issues of pressing importance” (GSDI, 2004).

Its purpose is to focus on communication, education, scientific, research and partnership efforts to support all societal needs for access to and use of spatial data.

This is an association, guided by a board and funded by membership fees, to:

− serve as a point of contact and effective voice for those in the global community involved in developing, implementing and advancing spatial data infrastructure concepts,
foster spatial data infrastructures that support sustainable social, economic, and environmental systems integrated from local to global scales, and

- promote the informed and responsible use of geographic information and spatial technologies for the benefit of society.

The GSDI community aims to truly develop and achieve the goal of a Global Spatial Data Infrastructure relying on international and open standards, guidelines and policies to enhance data management and access, and support global economic growth, and associated social and environmental objectives (UNGWIG, 2007), through interoperable standards-based services, systems, softwares and products that operate in a web-based environment.

This vision is guided by five goals (Stevens, 2005):

- Continue to promote and develop awareness and exchanges on infrastructure issues for all relevant levels from local to global.
- Promote and facilitate standards-based data access/discovery through the Internet.
- Promote, encourage, support, and conduct capacity building.
- Promote and conduct SDI development research.
- Collaborate with others to accomplish its Vision and Goals.

To support this vision, the GSDI association acts as a platform and offers a vast choice of publications, conferences, workshops, projects and programs allowing people interested in SDI to learn, exchange, share their knowledge and expertise, because capacity building is one of the key points of SDIs.

6. Standards organizations relevant for GIS/SDI

In the field of geomatics there are several organizations involved in publishing standards to effectively achieve the goal of interoperability. Such standards are increasingly important in the geospatial community allowing the increase of interoperability between systems and data and thus to “geo-enable” the Web.

6.1 Open Geospatial Consortium (OGC)

Website: http://www.opengeospatial.org

The Open Geospatial Consortium (OGC) is a non-profit, international, voluntary consortium of more than 380 companies, government agencies and universities that is leading the development of standards for the geospatial community. Its approach is based on a member-driven consensus process to develop open and publicly available standards and software application programming interface for the geospatial community (UNGIWG, 2007). These standards offer to the developers the possibility to create complex georeferenced information and services accessible to a wide variety of applications and share data in a standardized and interoperable way.

The OGC standards are based on a generalized architecture presented in the Abstract Specification and Reference Model (OGC, 2007). On top of the Abstract Specification, there is a set of standards that have been developed and/or proposed to serve specific needs of the Geographical Information community in order to be interoperable.

These standards are mostly based upon the use of the http protocol to interact through messages over the Internet. In the last two years, the OGC members have been looking with interest to a more common approach used in the Service Oriented Architecture using SOAP
protocol and WSDL bindings. There is also work in progress around the Representational State Transfer (REST) protocol for web services.

The OGC is also closely working with the International Organization for Standardization (ISO) through a partnership with the ISO Technical Committee 211 (TC211) to promote and endorse the OGC standards to a higher level of standardization becoming part of the ISO 19100 series. For example, the WMS or the GML are now ISO standards.

The OGC vision is the realization of a full societal, economic and scientific benefits of integrating electronic location resources into commercial and institutional processes worldwide. Its mission is to serve as a global forum for the collaboration of developers and users of spatial data products and services, and to advance the development of international standards for geospatial interoperability.

More specifically the OGC aims to (http://www.opengeospatial.org/ogc/vision):

− Provide free and openly available standards to the market, tangible value to Members, and measurable benefits to users.
− Lead worldwide in the creation and establishment of standards that allow geospatial content and services to be seamlessly integrated into business and civic processes, the spatial web and enterprise computing.
− Facilitate the adoption of open, spatially enabled reference architectures in enterprise environments worldwide.
− Advance standards in support of the formation of new and innovative markets and applications for geospatial technologies.
− Accelerate market assimilation of interoperability research through collaborative consortium processes.

It must be noticed that the OGC and its members want to help users and developers to make usage of OGC's standards offering them different resources (technical documents, training, best practices,...) through the OGC Network (http://www.ogcnetwork.net/).

6.2 International Organization for Standardization (ISO)

Website: http://www.iso.org

The International Organization for Standardization (ISO), the world's largest developer, publisher and promoter of international standards, is a non-governmental organization made of a network of more than 160 countries representatives (one per country) with a central secretariat based in Geneva (Switzerland) that coordinates the system.

Even if the main focus of ISO is the development of technical standards, they have an important impact on the economy and the society because many members are coming from a governmental structure or from the private sector. Therefore, ISO is an ideal place to build consensus and solutions that meet the needs and requirements from both the economy and the society.

Within the ISO system there is a Technical committee (http://www.isotc211.org/) whose main area of interest are the Geographical information and the Geomatics aiming to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth.

At the present day, they have more than 55 standards in the field of the Geographical information specifying methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations.
6.3 The World Wide Web Consortium (W3C)

Website: [http://www.w3.org](http://www.w3.org)

The World Wide Web Consortium (W3C) is an international consortium where members, organizations, staff and the public work together to create and develop Web standards, protocols and guidelines. Since 1994, the W3C has published more that 110 Recommendations (the W3C standards) aiming to "lead the World Wide Web to its full potential by developing protocols and guidelines that ensure long-term growth for the Web", accommodating the growing diversity of people, hardware and software and ensuring the core principles and components of these standards would be supported by everyone.

For the W3C it is crucial to reach the goal of the "web interoperability" allowing the Web to reach its full potential by using technologies that must be compatible with one another and allowing any hardware and/or software to access the Web. By publishing open and non-proprietary standards, the W3C seeks to avoid market fragmentation and thus Web fragmentation.

Therefore the W3C engages in education and outreach, develops software and interoperable technologies that support this mission and acting as an open and vendor-neutral forum for discussion about the Web.

6.4 Organization for the Advancement of Structured Information Standards (OASIS)

Website: [http://www.oasis-open.org/](http://www.oasis-open.org/)

The Organization for the Advancement of Structures Information Standards is a non-profit, global consortium (with 5000 members coming from more than 600 organizations in 100 countries) that drives the development, convergence and adoption of open standards for the global information society, the so-called e-business. OASIS produces different web standards concerning the following categories: Web Services, e-Commerce, Security, Law & Government, Supply Chain, Computing Management, Application Focus, Document-Centric, XML Processing, Conformance/Interop, and Industry Domains.

7. Standards description

ISO and OGC are providing a lot of different specifications regarding geographical data but in the context of the EnviroGRIDS project we propose to concentrate on those that are mostly used in the geospatial community. The aim is to place the first building blocks of a regional SDI for the Black Sea catchment.

The general aim of these standards is to abstract data delivery mechanisms from physical storage formats and offer services that could be consumed by applications through different interfaces.

The OGC defines a general architecture for the geoportal (OGC, 2004) called The Geospatial Portal Reference Architecture. It provides the basis for an open, vendor-neutral portal that is intended to be a first point of discovery for geospatial content in the context of designing and implementing the Spatial Data Infrastructures. The Geospatial Portal Reference Architecture is founded on the tenants of a Service Oriented Architecture (SOA). An SOA is an architecture that represents software functionality as discoverable services on a network yielding the following benefits:

- Easier extension of legacy logic to work with new business functionality
- Greater flexibility to change without the need to constantly re-architect for growth
- Cost savings by providing straight-forward integration.
The Geospatial Portal Reference Architecture specifies also four services that are needed for creating a interoperable and standardized geoportal (fig.9):

- **Portal Services**: provide the single point access to the geospatial information on the portal. In addition, these services provide the management and administration of the portal.

- **Catalog Services**: used to locate geospatial services and information wherever it is located and provide information on the services and information if finds to the user.

- **Portrayal Services**: used to process the geospatial information and prepare it for presentation to the user.

- **Data Services**: used to provide geospatial content and data processing.

To implement and deploy these different service classes, the OGC propose to use web services that are applications running on a computer connecting to a remote web service via a URL allowing access to distributed data and services. As stated by the CGDI "Web service architectures provide a distributed environment in which you can deploy and invoke services using standard Internet protocols. In this context, a service is a collection of operations, accessible through one or more interfaces, that allows you to evoke a behavior of value to you." (http://www.geoconnections.org/publications/Technical_Manual/html_e/s4_ch10.html#10.1)

Using such a Service Oriented Architecture (SOA) provides a distributed computing platform over a network, typically the Internet, allowing to publish standardized services no matter how it is implemented or on which platform it is executed. This is leveraging the full potential of the interoperability and thus web services to be seamlessly coupled, reusable and available for a variety of applications.

A traditional open web service must have the ability to describe its capabilities and provide a standard way to communicate with it, enabling applications and other web services to communicate and interoperate. Through OGC standards, different GIS softwares and/or
components can interoperate, work together and exchange information over a network by means of agreed standards.

For example, when two softwares implement the same OGC standard, they can immediately work together without the necessity to develop new components to translate from one file format (used in one software) to another file format (used in a second software). This means that in a SOA environment that implement OGC standards, a user can access in a transparent way to data stored in different databases, with different formats, and running on different Operating Systems.

Without interoperability and standardization accessing and integrating different data sources is really difficult or in the worst case impossible. This leads to a fragmentation of geospatial data sources and limit organizations to work only within a single software package.

**7.1 Catalogue Service for the Web (CSW)**


The Catalogue Service defines an interface to publish, discover, search and query metadata about georeferenced data, services and related resources. CSW uses queryable properties, which enable clients to search for geospatial resources by subject, title, abstract, data format, data type, geographic extent, coordinate reference system, originator, publisher, purpose,...

![Fig.10: GeoNetwork, a catalogue system using CSW.](image)

**7.2 Web Map Service (WMS)**

The Web Map Service defines an interface that allows a client to retrieve maps of georeferenced data. In WMS context, a map means a graphical representation (jpeg, gif or png files) of a geospatial data meaning that a WMS service doesn't give access to the data itself. It is used for mapping purposes and can be combined with other WMS services.

### 7.3 Web Feature Service (WFS)

OGC Web Feature Service specification: [http://www.opengeospatial.org/standards/wfs](http://www.opengeospatial.org/standards/wfs)

The Web Feature Service defines an interface that allows a client to retrieve and update features of georeferenced data encoded in Geography Markup Language (GML). The main difference between WMS and WFS is that WFS gives direct access to the geometry and the attributes of a selected geospatial data, meaning that a user can work with a dataset provided by WFS. In brief, the WFS is the specification to access vector datasets.

### 7.4 Web Coverage Service (WCS)


Like the WFS allows a client to access vector datasets, the Web Coverage Service allow a client to access raster datasets. By rasters we mean data that are represented as a matrix of cells in continuous space organized in rows and columns where each cells contains a value. Thus WCS service provide access to different types of gridded data such as Digital Elevation Model (DEM), remote sensing imagery, etc... It must be noted that WCS gives only access to the raw data and does not have transactional capabilities.

### 7.5 Web Processing Service (WPS)


The two previous discussed standards are focusing on data accessibility: WFS allows a client to access vector data while WCS allows a client to retrieve raster data.

Now we need to extend our capabilities in order to process data available using the recently introduced Web Processing Service (OGC, 2007) that provides access to processing and calculations on geospatial data. A WPS service can offer, through a network access, a vast number variety of GIS functionalities ranging from a simple calculation to complex models. It acts as a sort of middleware between the client and the process that runs the calculations. It allows users to know which process are available, to select the requires input data and their formats, to create a model and run it, to manage processes (status, storage for the output, ...) and to return the output once the computation is completed.

### 7.6 ISO 19115


The ISO 19115 standard defines (with more than 400 metadata elements, 20 core mandatory elements) how to describe a georeferenced information and provide information about the content, the identification, the quality, the spatial and temporal extent, the access and rights and the spatial reference.

This standard is applicable to:
the cataloguing of datasets, clearinghouse activities, and the full description of datasets.

4 geographic datasets, dataset series, and individual geographic features and features properties.

The main applicability of ISO19115 is for digital data but its principles can be extended and applied to other forms of geospatial data such as maps, charts and textual documents as well as non-geographic data (ISO, 2003).

### 7.7 Keyhole Markup Language (KML)


The KML format is an XML based language schema for describing geographical objects in web-based viewer (the so-called geobrowser). It has been developed and popularized by the Google Earth application and due to its success was turned into an OGC standard.

### 7.8 Geographic Markup Language (GML)


The GML is a very complete XML based language used to describe all the geographical features and objects and provides a standard mean for representing geographical features (properties, relationships, geometries, ...). GML differs from KML as it is not only used for data visualization (which is the main focus of the KML specification) but serves also as a modeling language as well as an open and interoperable exchange format over the Internet, it is mostly used in the Web Feature Service to send geographical features between servers and clients.

The real advantage of using GML is that all the world of XML technologies is available meaning that information stored in a GML file could be easily shared with other information and then specialized application domains could reuse, extend and/or refine GML components in an application schema in order to develop a specific data model.

### 8. Tools

After reviewing the set of OGC and ISO standards relevant for our purpose it is important to present a selection of tools that implement those standards allowing the user to produce standardized and interoperable web services. Note that none of these softwares integrate all the standards at once instead each of them are somehow building blocks of a Spatial Data Infrastructure following the OGC Reference Architecture (OGC, 2004; OGC, 2008).

#### 8.1 OGC web services

**8.1.1 Mapserver**

*Website:* [http://www.mapserver.org](http://www.mapserver.org)

*Supported OS:* Windows/Linux-Unix/Mac

MapServer is an open source geographic data rendering engine and development environment for building WebGIS applications and sharing data through OGC standards. It can run as a CGI program or via Mapscript which supports several programming languages.

MapServer is now a project of OSGeo and is maintained by a growing number of developers from around the world.

Mapserver main features are:
advanced cartographic output: scale, labels, reference map, classification, ...
- support for different scripting and development environments: PHP, Python, Perl, Java and .NET
- Cross-platform support: Linux, Windows, Mac, Solaris, ...
- OGC web services: WMS (client/server), WFS (client/server), WCS, GML, SLD, SOS, ...
- Multitude of raster and vector formats: GeoTiff, shp, PostGIS, ArcSDE, ... via GDAL/OGR
- Map projection support: up to 1000 projection through the Proj.4 library.

### 8.1.2 Geoserver

**Website:** [http://www.geoserver.org](http://www.geoserver.org)

**Supported OS:** Windows/Linux-Unix/Mac

Geoserver is an open source server designed to publish data from different major data sources using OGC standards and allowing the users to share their data. Unlike Mapserver, Geoserver has no mapping capabilities, it is only used for publishing data in an interoperable and standardized way.

Geoserver is a community-driven project sponsored by OSGeo.

Geoserver main features are:
- java-based.
- support of WMS, WFS, WCS and KML specifications.
- Various raster and vector formats: PostGIS, Oracle spatial, ArcSDE, DB2, MySQL, shp, GeoTiff, ECW, MrSID and Jpeg2000.
- Through standard protocols produce: KML, GML, shp, GeoRSS, PDF, GeoJSON, JPEG, GIF, SVG and PNG.
- Editing capabilities using WFS-Transactional.
- Includes an OpenLayers client for previewing data layers.

### 8.1.3 Deegree

**Website:** [http://www.deegree.org/](http://www.deegree.org/)

**Supported OS:** Windows/Linux-Unix/Mac

Deegree is an open source framework, sponsored by OSGeo, offering the main building blocks of an SDI. Its entire architecture is developed around OGC and ISO standards.

Deegree main features are:
- java-based.
- support of WMS, WFS, WCS, WPS and CSW.
- Storage formats: PostGIS, Oracle, shp, GML, jpeg, gif, png, bmp, geotiff.
- Simplified installation and configuration.
- SLD support.
- Envisioned support of Sensor Observation Service (SOS) and Web Terrain Service / Web Perspective and View Service (WTS/WPVS).
– Security implementation using Web Authentication (WAS) and Web Security Service (WSS).
– Built-in web-geoportal.

8.1.4 PyWPS


*Supported OS:* Linux-Unix

PyWPS is an implementation of the Web Processing Service specification. The great advantage of PyWPS is that it has been written with a native support of GRASS GIS software, meaning that accessing to the GRASS modules via web interface should be really easy. Process can be written using either GRASS or other programs like R, GDAL or PROJ.

PyWPS main features are:

– support of WPS specification.
– Simple configuration files.
– Method for custom process definition.
– Support for multiple WPS servers.
– Python based

8.1.5 52 north WPS

*Website:* [http://52north.org/maven/project-sites/wps/52n-wps-site/](http://52north.org/maven/project-sites/wps/52n-wps-site/)

*Supported OS:* Windows/Linux-Unix/Mac

52north WPS is another implementation of the WPS specification that aims to create and design an extensible framework (with plug-in mechanism) for providing, orchestrating and executing processes as well as Grid computing on the internet.

52north WPS main feature are:

– java-based
– support of WPS specification.
– Pluggable framework for algorithms and XML data handling and processing frameworks
– Build up on robust libraries (JTS, geotools, xmlBeans, servlet API, derby)
– Supports full logging of service activity (exception handling, storing execution results, ..)
– Clients: basic implementation for accessing the WPS & plug-in for uDig and JUMP.
– WPS invocation: synchronous/asynchronous, http-get, SOAP, WSDL
– Supported data types: GeoTiff, ArcGrid, GML.

8.1.6 ArcGIS Server


*Supported OS:* Windows

ArcGIS Server is part of the ArcGIS family and is the component to provide web-oriented and OGC standardized spatial data services. Since the version 9.2, ArcGIS Server includes also the
Spatial Data Engine (ArcSDE) that geo-enabled databases and allows the user to store their data into popular database system like PostgreSQL or Oracle.

ArcGIS Server main features:

- .NET and Java frameworks.
- ArcGIS Server services can be consumed by web browsers, mobile devices and desktop clients.
- Full implementation of WMS, WFS (basic and transactional), WCS, KML specifications.
- Services: mapping, geocoding, geodata management, geoprocessing, virtual globes, network analysis.
- SOAP and REST API.
- Additional SDKs to build web applications: JavaScript, Flex, Silverlight, ...

8.2 Metadata editor and catalog system

8.2.1 GeoNetwork Open Source

Website: [http://geonetwork-opensource.org/](http://geonetwork-opensource.org/)

Supported OS: Windows/Linux-Unix/Mac

GeoNetwork is an open source project, sponsored by the UNSDI (UNGIWG, 2007) initiative and supported by several UN agencies (FAO, UNEP, OCHA and WFP) as well as the OSGeo. GeoNetwork implements both the Portal component and the Catalog database of a Spatial Data Infrastructure (SDI) defined in the OGC Reference Architecture (OGC, 2004) allowing a user to search, discover, evaluate, publish, manage and edit metadata on spatial data and related services through the internet.

The main goal of GeoNetwork is to improve the accessibility and thus enhance the data exchange and sharing in a standardized and consistent way between the organizations to avoid duplication, increase the cooperation and coordination of efforts in collecting data and make them available to benefit everybody, saving resources and at the same time preserving data and information ownership.

Main features of GeoNetwork are:

- Instant search on local and distributed geospatial catalogues
- Support of CSW, Z39.50 and OAI protocols.
- Uploading and downloading of data, documents, PDF’s and any other content
- An interactive Web map viewer that combines Web Map Services from distributed servers around the world
- Online map layout generation and export in PDF format
- Online editing of metadata with a powerful template system
- Scheduled harvesting and synchronization of metadata between distributed catalogues
- Groups and users management
- Fine grained access control.
8.3 Data storage

8.3.1 PostgreSQL/PostGIS

Website: http://www.postgresql.org/ & http://postgis.refractions.net/

Supported OS: Windows/Linux-Unix/Mac

PostgreSQL is a popular and powerful open-source relational database management system (RDBMS) allowing the user to store data and their relations in the form of tables.

A RDBMS itself cannot store geographical information and thus for geo-enable a database system like PostgreSQL it is necessary to install a middleware to add support for geographic objects into the database. Two softwares are able to work in conjunction with PostgreSQL and add specific tables and functions that extend the capacities of a traditional RDBMS:

- PostGIS: follows the OGC Simple Features Specification for SQL (OGC, 200x).
- ESRI ArcSDE: that implements the powerful geodatabase system.

PostGIS main feature are:

- Geometry types for points, linestrings, polygons, multipoints, multilinestrings, multipolygons and geometry collections.
- Spatial predicates for determining the interactions of geometries.
- Spatial operators for determining geospatial measurements like area, distance, length and perimeter.
- Spatial operators for determining geospatial set operations, like union, difference, symmetric difference and buffers.
- Powerful spatial indexes for high speed spatial querying.
- Index selectivity support, to provide high performance of query plans for mixed spatial/non-spatial queries.
- No support (for the moment) of raster data.

8.3.2 PostgreSQL/ArcSDE

Website: http://www.esri.com/software/arcgis/geodatabase/storage-in-an-rdbms.html

Supported OS: Windows/Linux-Unix

ArcSDE is the second software that could “geo-enable” a RDBMS and implements the powerful concept of the geodatabase allowing to store either vector and raster data in a central data repository for easy access and data management. It can be be leveraged in desktop, server and mobile applications and is the common data storage and management system of the ArGIS family of softwares products.

In the latest version 9.3 of ArcGIS Server, ArcSDE is now a component of that and offers an integrated environment. Geospatial data is managed as a database accessible by the users using a desktop client and can be easily published on the internet. It allows query, mapping, analysis and editing in a multi-user environment.

ArcSDE main features are:

- Store a rich collection of spatial data in a centralized location.
- Apply sophisticated rules and relationships to the data.
- Define advanced geospatial relational models (e.g., topologies, networks).
− Maintain integrity of spatial data with a consistent, accurate database.
− Work within a multiuser access and editing environment.
− Integrate spatial data with other IT databases.
− Easily scale storage solution.
− Support custom features and behavior.
− Support DB2, Informix, SQL Server, Oracle and PostgreSQL.

8.3.3 File system
The simplest way to store data is probably under a file system arborescence. The inconvenient is that the arborescence must be well structured and self-explainable in order to rapidly find the desired data. We do not recommend to use file system because it is a complex and not efficient system to manage and maintain geographical data. The only advantage is that a user can see a small increase in performance when accessing data but this advantage disappears as soon as he works in an environment where there is a concurrent accesses.

8.4 Web Mapping

8.4.1 Open Layers
Website: http://openlayers.org/
Supported OS: Windows/Linux-Unix/Mac
OpenLayers is an open-source JavaScript API for creating web-mapping applications. Main features are:
− load map data from many sources: WMS, WFS, GeoRSS, ...
− Support for displaying geographic features, with markers and popups
− Easy mouse/keyboard navigation.
− Layers selection.
− Easy build configuration, designed to help build OpenLayers into other applications
− Javascript API to allow full control over OpenLayers-powered map from within Javascript on a web page.

8.4.2 Mapfish
Website: http://www.mapfish.org
Supported OS: Windows/Linux-Unix/Mac
MapFish is JavaScript API and web-mapping framework using the latest web 2.0 technology and integrates different components like OpenLayers, ExtJS and GeoExt.

8.4.3 Google Maps
Website: http://code.google.com/apis/maps/
Supported OS: Windows/Linux-Unix/Mac
Google Maps and its JavaScript API are free services provided by Google and allow developers to embed Google Maps into their web pages using their own data. The API provides a number of
functionalities for manipulating maps, adding content and allowing to create simple and robust maps applications.

### 8.4.4 Mapserver

As already discussed in the section 8.1.1 MapServer can produce OGC web services but has also cartographic capabilities using different scripting languages like PHP, Perl or Python.

### 9. Conclusions and Recommendations

### 10. ACQWA developments

In order to give the best visibility for the output data of the project, the ACQWA Geoportal is currently under development.

This Geoportal is accessible through the URL: [http://acqwa.grid.unep.ch](http://acqwa.grid.unep.ch) and will be made of four parts:

- **acqwaCatalogue**: allows users to collect, register and maintain description of geospatial data by providing a metadata editing tool as well as different search functionalities. This catalogue will be like a Google for the geodata of the ACQWA project, improving the accessibility and enhancing the exchange of a wide variety of geodata.
- **acqwaViewer**: allows users to visualize and query selected geodata on a map as well as a set of base layers such as DEM, Rivers, etc... This mapping module will also implement basic functionalities like zoom in/zoom out, pan, measurements and print.

- **acqwaDatabase**: will present the geodatabase used to store the output geodata of the project.

- **acqwaServices**: will describe the different OGC web services that allow users to access data in a standardized and interoperable way. At the moment only a WMS service has been set up and is accessible at the following URL: [http://212.203.125.202/ArcGIS/services/ACQWA/ACQWA/MapServer/WMSServer](http://212.203.125.202/ArcGIS/services/ACQWA/ACQWA/MapServer/WMSServer)

Further webservices like WFS, WCS, KML will be available in the coming months.

To complete the task and to fulfill the requirements we have, being part of the GEOSS Work Plan 2009-2011, the acqwaCataolgue and the acqwaServices will be registered into the GEOSS Common Infrastructure (GCI) and in consequence output data of the ACQWA project will be also available and accessible through the GEOSS portal that 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 information and analyses on the environment.

*fig.xx: the acqwaViewer showing snow cover maps.*
ANNEXES

ACQWA DATA POLICY

1. Scope of this document
This document describes the key issues relating to the supply, custody and use of data in the ACQWA project through the ACQWA Spatial Data Infrastructure (SDI) and Max Planck Institute database on climate scenarios outputs.

2. Principles
The overall policy is designed to serve the following aims:

- Timely, easy and free access to the SDI by the ACQWA community;
- maximum use of the SDI, for data exchange within the ACQWA community;
- maximum use of the SDI, for presenting the results of ACQWA 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. Max Planck Institute World Data Center for Climate (WDCC)

- MPI will develop a project data base containing climate model results carried out within the ACQWA project.
- Use will be made of the existing infrastructure at the World Data Center for Climate (WDCC). For example, the data from the EU-FP6 “ENSEMBLES” project is regularly updating its climate data base with results from the ensembles GCM and RCM simulations. The ACQWA data base will provide links to these already existing data sources.
- Specific climate scenarios focusing on the near and mid-term future (in practice until 2050) carried out within the present study will be stored in the data base and shared within the consortium for the project time and to the broad scientific community at the end of it.
• The data will be available in a user-friendly manner, accessible through the Internet.

4. The ACQWA Spatial Data Infrastructure (ACQWA-SDI) and metadata standards

The UNIGE-GRID-SDI will contain the data and metadata stored according to international standards (e.g. ISO 19115) and fed on a continuous basis by the partners through a web interface. The SDI website will be operational from January 2009.

The SDI contains the metadata and the listing of data owners (ACQWA 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.

• All WP leaders are to communicate to the SDI management which data and derived products are to be produced and provided to the SDI.
• All WP leaders must inform the SDI management on any data from the database that they will use within their planned activities.
• All modules/WP leaders are to enter the relevant information described above on-line through the ACQWA official website.
• All modules/WP leaders are to provide documentation to their databases through the ACQWA official website.
• Additional information might be sent by the WP/module leaders to the SDI management as deemed necessary.
• Access to the SDI for the purpose of adding would be restricted on the basis of password privileges granted only to WP/module leaders.

After completion of the project, UNIGE-GRID will maintain the SDI until a specific date to be determined by the ACQWA Management Board in accordance with a working agreement between partners.

5. Data access

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

• The scientific teams and partners will always have free and unlimited access to the metadata of SDI. However they are not permitted to exchange, to sell nor to give away data outside the ACQWA community without permission of the data owner.
• After completion of the project and completion of planned scientific publications, metadata included into the SDI shall be freely available to the scientific community.
• Observations collected in the frame of or developed within ACQWA and the model output remain with the data owners who are encouraged to facilitate the work of ACQWA by making them available to the scientific teams and partners of ACQWA.

6. 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.

7. GEOSS special clause

The societal benefits of Earth observations cannot be achieved without data sharing. ACQWA 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.
REFERENCES


Bernard L., Craglia M. (2005) SDI - From Spatial Data Infrastructure to Service Driven Infrastructure, Workshop on Cross-learning on Spatial Data Infrastructures (SDI) and Information Infrastructures (II), 8p.


http://www.egy.org/files/ROI_Study.pdf


http://www.isde5.org/al_gore_speech.htm


http://dewa03.unep.org/sdi-ea/system/files/BUILDING_SPATIAL_DATA_INFRASTRUCTURE_AT_C.doc


http://repository.unimelb.edu.au/10187/1247


http://www.geoinfo.aist.ac.th/download/SCOSA2007/1_DrAbbas/4-SDIDevelopmentCapacityBuilding.pdf


http://www.fig.net/pub/proceedings/nairobi/ryttersgaard-TS1-1.pdf


http://www.isprs.org/congresses/beijing2008/proceedings/2_pdf/5_WG-II-5/03.pdf


http://geoinfo.uneca.org/sdiafrica/default1.htm


http://repository.unimelb.edu.au/10187/1171

