Status of European Geospatial Data Infrastructures

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ABSTRACT

Currently, geo-spatial data infrastructures (SDI) are being established with strong political support in many countries and regions around the globe. This is also the case for Europe. The implementation of policies at European and Member State level such as environmental thematic strategies on urban environment, soil protection and sustainable use of natural resources, regional policies, territorial cohesion and European spatial development perspectives, common agricultural and transport policies, or the UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, the UN Convention to Combat Desertification (UNCCD), and the UN Convention on Biological Diversity (UNCBD) and the UN Millennium Development Goals at international level need to be underpinned by timely, accurate, easily accessible, geo-spatial and environmental information, capable of being shared across European, national, regional and local political jurisdictions. In order to have such information in place the European Geo-Spatial Data Infrastructure (ESDI) has to be developed.

This paper gives a brief overview of the development of the ESDI starting at the beginning of this decade. The development is characterized by the fact that it is split up into two parallel lines. On one hand side the European Space Agency (ESA) and the European Commission (EC) are developing the project 'Global Monitoring for Environment and Security' (GMES). In a European Union (EU) Council Resolution of November 2001 the decision was made that an operational and autonomous European capability for GMES is to be achieved by 2008. The EC also outlined the strategic role of GMES in the development of the EU's role as a global actor, and identified elements for its implementation. As such GMES is to be the European contribution to the 'Global Earth Observation System of Systems' (GEOSS). On the other hand side the EC initiated INSPIRE (Infrastructure for Spatial Information in the EC) that aims to pool and improve the standard of geographical data generated in the various EU Member States (MS) to improve the planning and implementation of Community policies in the areas of environment, transport, energy and agriculture. The INSPIRE directive was adopted on 15 May 2007, and a Committee was established that is responsible for all decisions necessary for the implementation of the directive according to a schedule binding on all MS. The paper concludes that there is a strong need to combine both development lines in the near future in order to achieve a cost-efficient ESDI comprising harmonised data sets derived from space-borne and in-situ observations mainly from the National Geo-spatial Data Infrastructures of the EU MS.

1. INTRODUCTION

1.1. The SDI concept, originally developed in Canada at the beginning of the 1990ties (MacLaughlin, 1991), was further elaborated in a study conducted by the Mapping Science Committee of the National Science Foundation (USA) to the worldwide accepted SDI framework (NSC, 1993).

1.2. The SDI framework comprises the following organizational and technical components:

- *Networks* of the responsible institutions, which agree on and monitor the organizational regulations in order to be able to overcome the existing fragmentation of responsibilities, the redundancy or incomplete availability of the geodata as well as problems of identification, data access and data use. It is evident that great importance must be attached to an efficiently functioning organization and coordination of the whole SDI process.
- Basic geo-spatial reference and thematic data (*Geodata*) which describe the geography of a country in form of geo objects and geo-spatial structures by means of geometric, topologic, thematic and temporal attributes referring to a common geodetic coordinate system and harmonized semantical models. Standardized techniques for the acquisition and administra-

tion of the geodata are key for a successful SDI along with the metadata that constitute an important component since only these allow the required transparency and search of the available geodata and their quality.
- Internet-based communication networks with GeoPortals as nodes providing Geo Web *services* which enable the access to the metadata and geodata as well as to relevant methods of processing, evaluation, dissemination and visualization of the geoinformation derived from the geodata.
- Relevant common international *standards* and rules stipulating the interoperability of the geodata and geo Web services as well as conditions for licensing, purchasing and use of the geodata.

1.3. With regard to an efficient setup and effective use of a SDI the following *principles* have to be taken into account (known as INSPIRE principles, see 3.):
- For the area and the themes covered by SDI geodata shall be acquired and maintained only once, which means on that level on which the geodata are first required and efficiently maintained.
- Geodata available in a certain spatial and semantical resolution must be utilized for other resolution levels.
- It is a must that geodata from different sources can be combined with each other, so that multidisciplinary analyses are possible (interoperability of geodata).
- It must be possible, by means of registries/catalogue services, to easily find out which data are available, meet a specific applicational purpose, and on what conditions they can be obtained and used.
- Geoinformation must be visualized such that it can easily be understood and interpreted.
- For the provision of geodata acceptable rules shall be established which are no hindrance to their use (rights of access, use and protection).

1.4. The development of the ESDI started at the beginning of this century. It is characterized by the fact that it is split up into two parallel lines: GMES and INSPIRE. In the following chapters firstly GMES is briefly presented. This project aims at providing the EC, European Agencies, the European market as well as the MS with geodata primarily produced by space-borne earth observation (imagery and extracted object information). Secondly, the INSPIRE directive and its impact on building the national SDIs (NSDI) in Europe is briefly described. The NSDI will be underpinning the ESDI with so called in-situ data. Finally, the need to converge both lines of development is emphasized.

2. GLOBAL MONITORING FOR ENVIRONMENT AND SECURITY (GMES)

2.1. The political mandate for the GMES programme was expressed at the 2001 Gothenburg EU Summit, stating the need to "achieve by 2008 an operational and autonomous European capacity for global monitoring for environment and security". This was transformed into an Action Plan 2004–2008. GMES will provide critical environment and security information to European and national policy-makers. A secondary objective of GMES is to provide a coherent European contribution to international efforts such as the Global Earth Observation System of Systems (GEOSS), which was established in 2003 through an international Ministerial Summit. In 2005, the European Commission (EC) assumed political leadership of GMES and took responsibility for the development of services, including the definition and setup of a sustainable governance structure.

2.2. GMES comprises four main, inter-dependent, elements: services, space infrastructure, in situ infrastructure, and data integration and management.

2.2.1. Two main categories of GMES services are defined by scope and user type:

- The *Core Services* (CS) can be defined as common information capacities for Europe in the framework of the ESDI.
- The *Downstream Services* (DS) are tailored to specific requirements either at European level (for on-demand requirements or specific areas of interest) or at local/ regional/ national levels.

ESA and the EC began developing GMES information services as early as 2002. Under the ESA GMES Service Element (GSE), approved already in November 2001, ten service portfolios have been developed. Each responds to user needs in a specific sector of environmental or security policy. They address domains such as polar monitoring, forest monitoring, marine and coastal monitoring, flood, fire and geo-hazard risk assessment, air-quality monitoring and forecasting, and land-cover mapping and urban development monitoring, as well as information services to support humanitarian aid and development and food security actions.

A set of core services (CS) will be established first:

- The '*Marine Core Service*' includes monitoring of status and changes of physical and biological parameters of the sea as well as marine security. Geographical focus will be initially on European seas (borderlines are 200 N - 800 N latitude and 400 W - 550 W). Bathymetric data are needed as ancillary data both for open seas and for regular monitoring in shallow waters along the European coasts due to changes in sedimentation patterns and currents. In Europe, the numerous in-situ monitoring activities have to be streamlined and harmonised to get a coherent view on state and trends in European seas.

- The '*Emergency Response Core Services*' aims to provide European and worldwide support to Civil Protection, external relations, and humanitarian aid in the form of the provision of harmonised geo-spatial data and information (ancillary and vulnerability maps), monitoring tools for the duration of crisis (risk mapping), and models, scenarios, and tools for decision support (solution and services). Services require availability of information within short time frames and in high spatial and vertical resolution (scale 1:100.000 – 1:25.000 for ancillary data, 1:50.000 – 1:10.000 for risk/damage maps), and with a frequency of updates. Data are mainly procured by national and regional institutions. Especially for near real time data and forecasts costs for procurement depend on the business model currently applied in the different Member States.
- The '*Land Monitoring Core Service*' (LMCS) currently covers land-cover / land-use (LC/LU) change monitoring at continental and local scale, and will be extended to the global level. For Europe high resolution land cover mapping based on orthorectified satellite imagery will be provided on a regular basis. Land cover and land use changes in urban areas with >100.000 inhabitants will be monitored as part of the Urban Atlas project (EC DG Regio). Services for monitoring other environmental sensitive areas or hot spots will be based on very high resolution data. LC information provided by the LMCS will be used as well across other services i. e. emergency reponse.

2.2.2. ESA is responsible for the space infrastructure. This role comprises two basic functions:

- the end-to-end definition and implementation of the *space component*. Some of the elements will be provided through national entities (e. g. DLR) or Eumetsat;
- the development of space (Sentinel satellites) *and ground infrastructures* through ESA programmes, complementing national and Eumetsat contributions.

The EC undertook a series of large integrated projects within its 6th Framework Programme. These activities engaged more than 300 organisations from 35 countries as end users of GMES. Currently, among the missions identified as potential contributors are Cosmo-SkyMed, EnMap, Envisat, Jason, Meteosat, MetOp, Pleiades, Radarsat, RapidEye, SeoSat, Spot, TerraSar-X and TopSat.
A gap analysis, which analysed user requirements based on policy needs, enabled ESA and the EC to identify the key requirements for the GMES space infrastructure, and led to specific actions for the Sentinels and access to national missions. Five observation capacities have been identified that need to be developed for GMES:

- Sentinel - 1: high-resolution synthetic aperture radar (SAR) imaging;
- Sentinel - 2: high-resolution multi-spectral imaging;
- Sentinel - 3: global ocean and land monitoring;
- Sentinel - 4: geostationary atmospheric monitoring;
- Sentinel - 5: low-orbit atmospheric monitoring.

The sentinels were approved at the Ministerial Council in December 2005. Sentinel-1, -2 and -3 missions need two satellites each to meet the observation coverage and repeat cycle requirements. The Sentinels 1 and 2 will be launched around 2012, and it is assumed that the baseline technology for the satellites will remain stable for a long period, such as 15 years per satellite generation. The ground segment will control and exploit the ESA Sentinels-1/2/3 satellites and manage, plan and monitor the overall GMES space component, including access to the other missions.

2.2.3. The term in-situ infrastructure has been introduced for those infrastructures that provide observations that are not space borne, i. e. airborne, terrestrial and marine observations. These observations (data) are as important as the space observations. Such data are among others

- control points for the calibration of spectral and geometric properties of remote sensing images;
- training information for supervised image classification;
- ground truth data for the validation of the interpreted products;
- to complement space data in the monitoring, detection and understanding of environmental changes for parameters that cannot be derived from remote sensing data.

In addition ancillary data such as thematic maps and topographic maps and data bases, field campaigns and inventories, Digital Elevation Models (DEM) and digital orthoimagery round up the geodata sets defined in GMES.

2.2.4. A most important issue is data integration and management which, for the EU MS, is regulated through the INSPIRE Directive and the Implementation Rules (IR) to be adopted by the INSPIRE Committee. These are not binding on the EC, however, the EC has announced to use the IR , in a self-binding approach in order to achieve an interoperable ESDI (chapter 3).

2.3. Implementation of GMES Core Services

2.3.1. The EC organised major consultations with user organisations in Europe and is now dedicating significant resources of the 7th Frame-work Programme to develop three Fast Track Services (FTS) for the above described CS. For this purpose FTS Implementation Groups (IG) on marine, emergency response and land monitoring have been set up at the beginning of 2006. According to the Terms of Reference the IGs have to supervise and validate the implementation of the FTS, to report on its progress to the GMES management structure, and to improve user awareness of the FTS and consolidate and enlarge their user base. The groups have also provided an assessment of the Mission Requirement Documents (MRDs) of Sentinel - 1, -2 and -3.

Two other pilot services are planned: The Pilot Service Implementation Plan of '*Atmosphere*' will be outlined in 2007. It includes services for air pollution and climate change taking into account reactive, non-reactive gases, aerosols and UV/incoming radiation. Coupled weather – air pollution is envisaged for providing near real time pan-European atmospheric data. A service dedicated to *security* will follow.

The scope and the status of implementation of LMCS FTS is described in more detail in the following paragraph.

2.3.2. From the analysis of user's requirements of the GMES Land Monitoring Core Service three core service components have been identified:

- The *local component* will be focused on LC/LU mapping of sensitive or specific geographic or rapidly changing areas (e.g. urban areas, protected areas, agricultural parcels, coastal zones), and it will be based on very high spatial resolution (VHR) images (≤ 2.5 m) and on 3-5 years to an annual update.
- The *continental component* will include LC/LU mapping information all over Europe based on high spatial resolution (HR) images (10-20 m) and a temporal update of 3-5 years to annual one. In addition, more elaborated products or thematic information will be produced to address a wide range of European, e. g. environmental policies.
- The *global component* will include production of biophysical parameters at global scales and more elaborated products to support the EU international development co-operation policies and the implementation and monitoring of international conventions. This component will be mainly based on low (LR) or medium (MR) spatial resolution images (1 km-250 m) with a high time resolution from near real time monitoring systems to 5 yearly products (e.g. GLOBCOVER). The Global component will also be of major importance in the context of the GMES contribution to GEOSS.

Practical implementation of the *continental component* is steered by the European Environmental Agency (EEA) and conducted by its European Environmental Information Network (EIONET) made up of the European Topic Centre for Land Use and Spatial Information (ETC LUSI) and the National Focal Points (NFP, i. e. the national environmental agencies). The EEA Management Board endorsed a proposal to explore within the Corine Land Cover monitoring framework the possibility of moving to higher resolution and more frequent updates, initially for a selected number of land cover classes. Furthermore, an agreement was reached with the environmental user community, that built-up areas and forests will be mapped at higher resolution based on the outcomes of

relevant GMES pilot projects (Geoland, GSEs Land and Forest Monitoring). For the time being the implementation of the work plan for the *local component* is being prepared, and that for the *global component* has been intiated.

2.3.3. Funding of GMES will be organized in a phased approach. Therefor several funding steps are planned during the period 2006–2013. So far on ESA's side, the 2005 Ministerial Council provided EUR257 million for the first phase. This is expected to be complemented by EUR430 million in 2007 for Phase-2 and, at the 2008 Ministerial Council, by the amount required to complete the build-up of the space component. ESA funds are complemented by EC funds. The EC foresees a total of EUR780 million through its 7th Framework Space Work Programme for 2007–2013. Future contributions will be necessary to cover the operational phase of GMES beyond 2013.
From 2008 onwards, pre-operational support of GMES services will start through coordinated and harmonised EO data provision from national, Eumetsat and other third-party missions (GMES contributing Missions). The GMES project got significant political support through the 'Munich Road Map' adopted during the German presidency on 17 April 2007.

3. INFRASTRUCTURE FOR SPATIAL INFORMATION IN EUROPE (INSPIRE)

3.1. INSPIRE is a legislative project that started in autumn 2001 in order to overcome the lack of co-ordination, of the use of standards, of incompatible information, of incompatible information systems, of fragmentation of information, of redundancy, of data specifications and infrastructure as well as the data policy restrictions in terms of pricing, copyright, access rights, and licensing policy. The draft directive was put forward by the EC in July 2004. After intensive negotiations between EC, European Parliament (EP) and European the INSPIRE Directive 2007/2/EC was published in the Official Journal of the European Union on 25 April 2007, and entered into force on 15 May 2007.

3.2. The directive lays down general rules for the establishment of the ESDI, for the purposes of environmental policies and policies or activities which may have a direct or indirect impact on the environment. The ESDI will be based on the NSDIs (e. g. GDI-DE for Germany) that are created by the MS and that are made interoperable and are supplemented with measures at Community level so that the ESDI is usable in a Community and transboundary context (EC 2007). As regards the content of the ESDI three Annexes define the themes that are needed to meet the requirements of policies in view.
Interoperability is according to the INSPIRE directive defined as the 'possibility for spatial data sets to be combined, and for services to interact, without repetitive manual intervention, in such a way that the result is coherent and the added value of the data sets and services is enhanced'. Interoperability will be achieved by the application of common Implementing Rules (IR) dealing with the metadata, network services, data sharing, interoperability of spatial datasets and services, and monitoring and reporting (interoperability of business models).
In close collaboration with stakeholders in the MS the EC started the drafting of the IRs in the Preparatory Phase (2005-2006). The work continues in the Transposition Phase (2007-2009) according to a work programme prepared by the EC-led INSPIRE Consolidation Team (CT).

3.3. The EC is responsible for coordinating the implementation of the INSPIRE directive at Community level and shall be assisted for that purpose by relevant organisations and, in particular, by the European Environment Agency. Each MS has to designate a contact point, usually a public authority, to be responsible for contacts with the EC in relation to the directive. The contact points

will be supported by coordination structures, taking account of the distribution of powers and responsibilities within each of the Member State.
Further development of the directive and the IR will be managed through a so-called Comitology process. For this purpose a Committee has been established by EC and MS. The Committee is among others responsible for the adoption of the IR. The development of these is conducted mainly by Drafting Teams (DTs) and related Thematic Working Groups (TWGs) both composed of experts from stakeholder organisations, and accompanied by European Commission services, Legally Mandated Organisations (LMOs), and Spatial Data Interest Communities (SDICs). After adoption the IR e. g. for metadata, geodata and services are immediately binding on the MS.

3.4. The implementation of the INSPIRE directive is mainly funded by operational budgets of the EC (Eurostat) and the MS. FP6 and FP7 funds are available for harmonization and integration of the data sets involved in both GMES and INSPIRE.

4. CONCLUSION AND OUTLOOK

The development of the ESDI is well underway, however it is split up for the time being into two parallel lines: GMES and INSPIRE. Although development of both initiatives started nearly at the same time GMES preparatory research projects primarily driven by ESA, EC DG Enterprise and space industry have already produced significant output (core services and downstream services) for the support of European policies. Additionally, the GMES LMCS FTS will deliver the products needed e. g. for UN reporting obligations by 2008.
Now, when the INSPIRE directive is put in force both projects need to work closely together as is foreseen in the GMES project (according to the so-called 'GMES diamond') in order to develop and run a cost-efficient ESDI. GMES core services should provide timely Earth observation data of large areas (Europe and worldwide) while within the INSPIRE framework the MS are mainly responsible for the in-situ data and ancillary data. The geodata from both sources need to be integrated and managed in such a way that application oriented 'downstream services' (application services) can provide useful and reliable information for decision-making.
There is a growing awareness for the need of integration of both development lines and a number of activities have already started to achieve this, among them the HUMBOLDT project ('Towards the Harmonisation of Spatial Information in Europe'). It is the goal of this project to support the harmonisation process and to create the basis for a sustained use of spatial data together with providing the basis for GMES application services by including their requirements.

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