GMES: FROM RESEARCH PROJECTS TO OPERATIONAL ENVIRONMENTAL MONITORING SERVICES

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ABSTRACT:

GMES is a political framework of the European Commission and – in practical terms - a joint initiative of the European Commission and the European Space Agency, designed to establish a European capacity for the operational delivery and use of information in support of Environment and Security policies. In this paper we report on several research projects bridging remote sensing and GIS in integrated workflows carried out by a liaison of several Geoinformatics institutions in Salzburg, Austria, on the overarching joint research framework and on the establishment of a GMES centre of excellence in Salzburg. We exemplify operational Geoinformatics workflows in an integrated remote sensing/GIS environment with foci on methodologies to extract information from remote sensing data and on services which integrate real-time information and deliver it to users and citizen.

1. GMES: WHAT DOES IT MEAN FOR THE REMOTE SENSING COMMUNITY?

GMES is a political initiative of the European Commission drawn up in Gothenburg in 2001 and poses a major challenge for remote sensing and Geoinformatics research in Europe. In practical terms, GMES is today a joint undertaking of the European Commission (EC) and the European Space Agency (ESA), designed to establish a European capacity for the operational delivery and use of spatial information in support of Environment and Security policies. Despite advances made in sensor technology, observing networks, data evaluation techniques and information technology, the production of the information needed for effective policy implementation in the environment and security field often remains below its full potential. Politically, it is of particular concern that Europe does not possess an independent capacity to assess the key drivers and impacts of change in these areas, or to evaluate its policy responses. The major components are the establishment of a European satellite monitoring capacity (GMES) and the installation of a global positioning system (Galileo).

GMES activities encompass a wide spectrum ranging from new satellites to dedicated service delivery. Space activities, through scientific research and especially through their direct applications, are acknowledged as strategic for their contribution to the construction of Europe and the competitiveness of the European Union in the light of the Lisbon-process (COM(2003) 673).

The GMES Advisory Council (GAC) endorsed several initial services (ESA/C(2005)73) according to EU policy priorities derived from GMES projects funded by the EC and by ESA, known as GMES Service Elements:

Marine and coastal environment (including pollution, oil spills);
Risk management (floods and forest fires);
Risk management (monitoring of subsidence and landslides);
Air pollution (local to regional scales);
European water quality;
European land use / land cover state and changes (including soil sealing);
Forest Monitoring;
Food security – Early warning systems;
Global change issues;
Maritime Security (maritime transport and coastal area surveillance, including ice monitoring aspect);
Humanitarian aid

The massive investments is expected to lead to the (pre-) operational validation of GMES services and products based on the integration and harmonisation of related observation data (both satellite-based and in-situ, including ground-based, ship-borne and airborne), starting with the so called 'Fast Track Services'. A number of GMES services will contribute to 'achieving by 2008 an operational and autonomous European capability', as expressed at the 2001 Gothenburg summit and in a subsequent Council Resolution. In November 2005 the Commission has confirmed its intention to move from concept to reality in supporting a variety of EU policies with geospatial information through GMES, and it has outlined the roles and responsibilities of EU institutions, the European Space Agency (ESA), and their Member States.

Very recently, interdependencies between environment, development, and conflict prevention have gained significant importance on the international agenda such as 'energy and climate security', and 'sustainable natural resources

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management'. Several recent studies highlighted major implications of global environmental change on national, regional, and global security: the Worldwatch Institute's "State of the World" Report 2005 on "Redefining Global Security", the speech by UK Foreign Secretary Margaret Beckett on "Climate Change and Security" in Berlin on October 24, 2006, the "Stern Review" on the economic dimensions of climate change and the upcoming report on climate change and security by the German Advisory Council on Global Change (WBGU) (to be published in 2007). These very recent developments have implications to the GMES framework. They underpin the importance of a European monitoring capacity but they also put climate protection and natural resource management into the broader context of foreign and security policy which will increase policy relevance of the whole GMES initiative.

2. GMES-RELATED RESEARCH

In order to achieve these objectives, substantial funds are invested, both directly through European organisations and through competitive research programmes. The main achievements for GMES to be accomplished by 2008, are the development and operational delivery of services e.g. for environmental monitoring (such as forest cover change), early warning for natural hazards (such as floods, drought), but also the provision of information for security related issues such as indicators for regional conflicts, the monitoring of migrations, borders, illicit trading of nuclear material and general reconnaissance for the deployment of the Rapid Reaction Unit of the EC.

Environmental monitoring in GMES is structured into three compartments: land, oceans and atmosphere. Already strong domains of remote sensing the data capture capabilities of space-borne and air-borne sensors will be integrated with in-situ measurements into observation networks.

During the past years, the effort to develop operational services in these fields is demonstrated by projects such as the GMES Service Element (GSE) Forest Monitoring funded by ESA and the Integrated Project GEOLAND supported under the 6th Framework Programme of the EC.

The GSE Forest Monitoring (GSE FM) consortium was set up to address the policy related demands for securing the ecological functions in the forestry and landuse sector. The first stage (2003-2004) consolidated services related to information needs of environmental policies such as the United Nations Framework Convention on Climate Change-UNFCCC.

Additionally, existing infrastructural systems and data sources were reviewed and utilised in order to develop forest monitoring services such as yearly carbon balance information, forest disturbance data, as well as products for practical forest and land use management.

A Service Portfolio of validated products and services was provided by the monitoring service and delivered standardised spatially referenced, quality products e.g. maps, that are cost effective, readily accessible and transparent to users, thereby promoting key applications and good governance within the forestry sector with sustainability as a paramount consideration (www.gmes-forest.info).

The ambition of the GEOLAND consortium is to develop and demonstrate a range of reliable, affordable and cost efficient European geo-information services for landcover and landuse monitoring, supporting the implementation of European directives and their national implementation, as well as European and International policies. Thus, the GMES initiative is considered a unique opportunity to integrate existing technology with innovative and scientifically sound elements into sustainable services. Within eight sub-projects, the 56 GEOLAND partners develop products and services, utilizing available Earth Observation resources in combination with in-situ measurements, and integrating them with existing models into pre-operational geo-information services. These will support international, European, national and regional authorities and institutions in fulfilling their increasing monitoring and reporting obligations - and help them to better manage natural resources (www.gmes-geoland.info).

Both initiatives will now be merged into the Fast Track Service Land to be consolidated in the course of the next years.

The security and stability aspect of the European Foreign and Security Policy, are addressed by the 'S' in GMES. As security strategies consider increasingly the security of the citizen as the central topic, the emphasis is shifting from national security – the traditional military domain – to human security. This process is accompanied, quite obviously, by a shift in observational requirements. The Network of Excellence GMOSS (Global Monitoring for Security and Stability, gmoss.jrc.it), started under the 6th Framework Programme, explores the opportunities and needs in this new field. GMOSS achievements will promote GMES research results and support European security policies. It is aiming at integrating Europe's civil security research to acquire and nourish the autonomous knowledge and expertise base Europe needs if it is to develop and maintain an effective capacity for global monitoring using satellite earth observation for applications such as population- and treaty monitoring.

Presently work by similar projects is collated into the Fast Track Service for Emergency Mapping and the development of a pre-operational service for security applications.
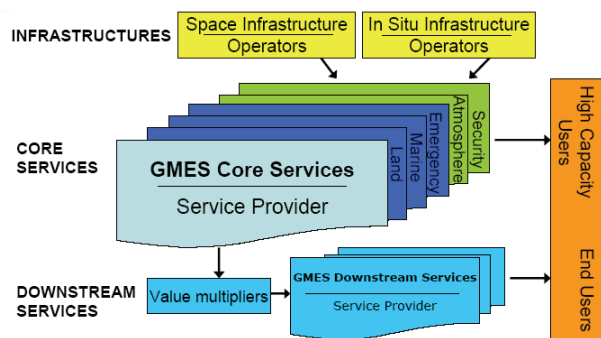

Figure 1. The general GMES framework towards the services (www.gmes.info)

Since the start of the 7th research framework programme (FP7) the roles between the EC and ESA are more distinct. ESA should manage the development of space infrastructures in accordance with the rules of the FP7 programme, integrating these activities with its own in this area. The Commission will manage the development of GMES services supported through FP7 and assure optimal integration of data from in-situ monitoring. After the completion of the ESA GMES Service Element projects, the further development and consolidation of such services will be the responsibility of the EC, as an integral part of its Space programme within FP7.

However, despite some obvious progress many scientific, methodological and technical challenges remain including:

- The interoperability of acquisition systems
- Questions of standardisation of data structures and interfaces
- Fusion of data from different sources
- The delivery of cost-effective, innovative, user-friendly services

3. OPERATIONAL MONITORING SERVICES I: AUTOMATED WORKFLOWS TO DERIVE INFORMATION IN SUFFICIENT RESOLUTIONS

GMES generically defines operational services which need to be established to
- inform the European Citizen and to serve his/her personal demand for environmental information
- provide guaranteed commercial services for professional users
- safety-of-live services for security critical applications
- search-and-rescue services for emergency operations
- public-regulated services

While the political goals were relatively clear from the beginning, the means to achieve these goals were defined only subsequently.

For many years users – and non-users - regarded spatial resolutions of Earth observation data as the main hindrances for operational applications (Blaschke and Strobl 2001) and requested finer and finer geometric resolutions. We can state today that the technical development of the late 1990ies and the new century has changed this situation significantly (for an overview see e.g. Ehlers et al. 2002, Jacobsen 2005). The use of multispectral, hyperspectral and Radar data is taken for granted in more and more applications (see e.g. Aplin 2004, Jacobsen 2005, Dell'Acqua and Gamba 2006, McCloy 2006) but operational Geoinformatics workflows in an integrated remote sensing/GIS environment are developed only recently (e.g. Tiede & Blaschke 2004). Although it is not possible to stick to only one workflow, scientists are increasingly working on generic and application-driven solutions as for instance within the GMES EU 6th Framework of Excellence "GMOSS" (Almer et al. 2004, Göbel et al. 2005, Tiede & Blaschke 2005, Lang et al. 2006a,b,c, Schöpfer et al. 2007)

The Centre for Geoinformatics Salzburg (Z_GIS) has developed methodologies to extract information from remote sensing data by using particular knowledge from existing spatial data. Starting with the definition of generic rule sets similar to a supervised classifications metainformation such as the bounding box of an image or the image centroid is straightforwardly utilized to automatically derive information from Spatial Data Infrastructures (SDI). The rule sets are then applied to other images taken by the same sensor through automated adjustments according to the metadata. These automated workflows build on image segmentation techniques (Blaschke et al. 2004) and have been successfully tested for medium-resolution data (Aster, Blaschke et al. 2006). They are now developed further to other sensor information.
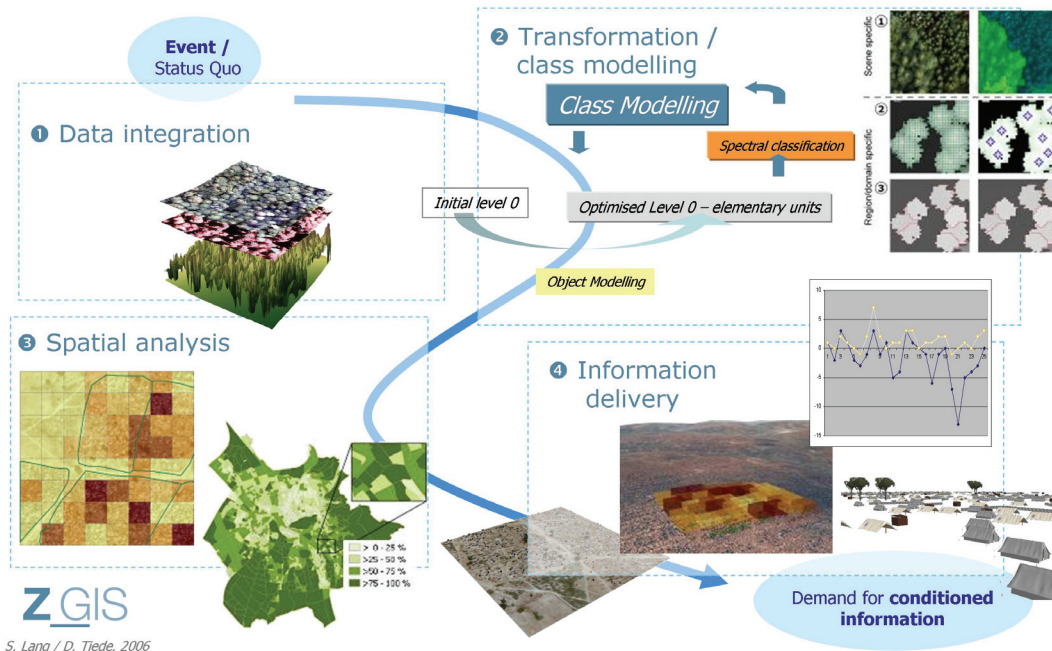

Figure 2. Workflow for high standard information delivery (Lang et al., 2006a, modified)

A general workflow for high standard information delivery (Lang et al., 2006a) is sketched out in Figure 2. It foresees an automatic transformation of imaged scenes into policy-relevant, i.e. conditioned information. That means image content is converted into high level information products, which is ready-to-use and relevant for decision makers. The workflow (see figure 2) integrates techniques of image pre-processing (georeferencing, segmentation), feature extraction and class

modelling, quantification and spatial dis-/aggregation, pseudo-realistic 3D visualisation and 3D analytical views. Depending on the aims or context of utilization we differentiate between two different product types. The first, pseudo-realistic visualisation is more oriented towards true depiction of e.g. a certain crisis area, complemented by figures, graphs and numbers describing the situation more quantitatively. This may be used to directly support relief actions or other fine-scale operations (ibid.). The other focus directs more towards an integrated representation of the entire situation, including data sets of several different scales, such as depicting the surrounding land cover, topography, political boundaries etc. The aim here is to provide a georeferenced set of data, which are either derived in the workflow as such or stemming from other sources. We use virtual globes as tools for seamlessly combining data on several scales, referenced on a globe and 3D enabled. Freely available virtual globes with high spatial resolution contextual data enable to disseminate analytical information derived EO data to a broad audience. Analytical 3D views are information layers on different spatial aggregation

(administrative or grid based units) using extrusion as a means for displaying the crucial spatial information (Tiede & Lang, in press). The magnitude of the variable is represented as an intensity value, expressed by height and supported by semi-transparent graduated colour. The workflow and its components are independent from the very sensor being used or algorithms applied. For investigating its compatibility we tested possible constraints of the workflow in terms of data material as well as feature extraction algorithms (Lang et al, 2006b).

4. OPERATIONAL MONITORING SERVICES II: DAY-TO-DAY ONLINE SERVICES

From an end user point of view, remote sensing and in-situ information need to be seamlessly integrated and reliably available in appropriate spatio-temporal resolutions. Beyond the examples from research projects only few operational services yet exist.
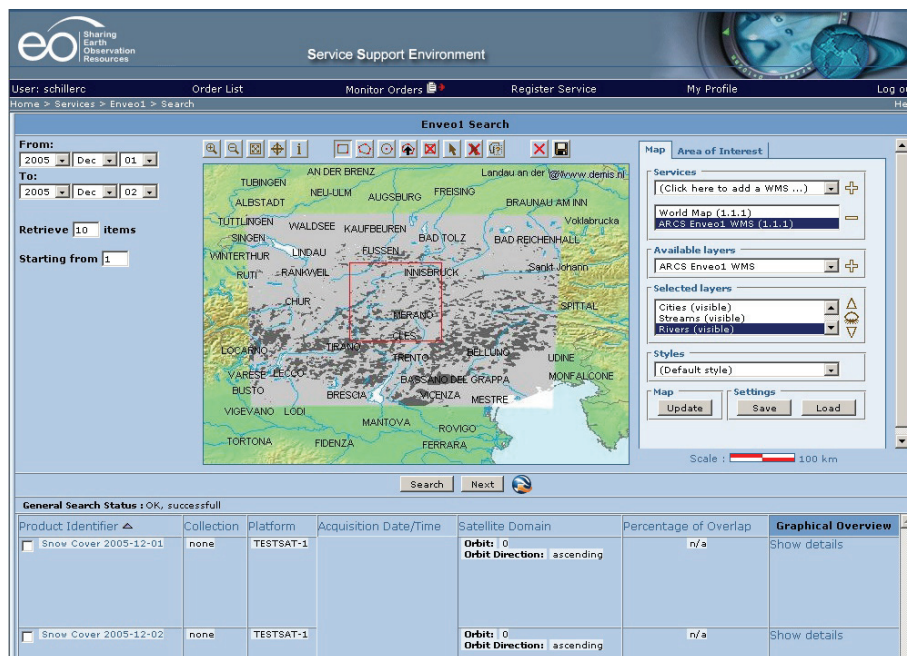

Figure 3. Operational GMES service: alpine snow cover map

4.1 Alpine Snow Cover Maps

One small but conceivable example is a service currently transferred from a testing into a fully operational level. It presents regular estimates of alpine snow-coverage from the central alpine area. The service has been developed by ENVEO GmbH e.g. to support electricity providers to estimate potential water runoff from melting snow. The regular update of the Snow Cover Maps ranges between 3 and 10 days, depending on the season. The originally offline model is implemented as an online service delivery within ESA's (European Space Agency) Service Support Environment[1] (SSE) by ARC in the frame of ESA's "New Earth Observation Services Integration into SSE" contract.

The SSE follows the "one-stop-shop" philosophy for service and data providers, which can offer their services globally to potential customers. But it also represents a trend-setting portal providing the platform and specialised tools to allow regular service providers to participate in global market by giving easy access to the new web-service technologies. Web-services are supposed to be searchable, modularised, and therefore combinable into new services (service chaining).
The fully operational Snow Cover Map service will soon be released (December 2007). Registered customers can then enter SSE and visually browse through already existing Snow Cover maps (Fig. 3). They can select the desired dataset (time) as well as an area of interest (AOI). If a valid account, with ENVEO GmbH, for data delivery exists the image(s) can be ordered and will be immediately delivered online to the customer either via FTP or WCS (Web Coverage Service) ready to be integrated into their GIS system.

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[1] http://services .eoportal.org

Currently datasets are only generated for the central alpine area. However, the service data coverage can be extended to other areas if customers show their interest. Such extension can be envisioned in the frame of GMES e.g. for the Baltic Sea region, where melting snow river runoff is of interest as a major source of nutrient input[2].

4.2 Real-time sensor webs

A major challenge is the full integration of real-time in-situ information and remote sensing information in a geo-aware environment. This will require an appropriate supply of input data from both space and in-situ observation systems. It will be necessary to identify effective ways for doing this, in a reliable way and with a guarantee of long-term continuity, at least building the technical base for such a goal. The aim is also to support the future development of an appropriate European capacity in this context, coupled with a perspective of long-term sustainability.

The goal of the project Real-time Geo-awareness (RTGA) is to establish a real-time GIS services framework based upon open web service standards for sensor measurements integration (Open Geospatial Consortium [OGC] Sensor Web Enablement [SWE] Framework) into server based geo-processing environments (Web Processing Services [WPS]) serving indicator-based environmental monitoring services in distributed infrastructures, as illustrated in the following figure (Fig. 4).
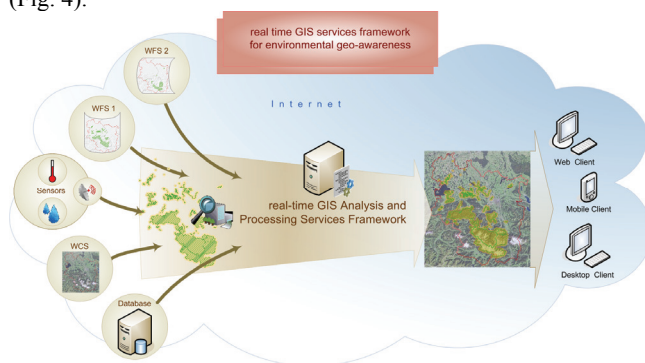

Figure 4. Real-time GIS Services Framework

Real-time geo-processing services facilitate the transformation of vast amounts of sensor measuring data into geographic information layers using interpolation methods like IDW (inverse distance weight), spline or kriging that can be integrated in real-time analysis models.

In the near future, spatial data shall be provided via standards-based web services (cp. the INSPIRE initiative launched by the European Commission). This effort depends on a standardised storage of and access to complete, accurate, and current spatial data, without regard to geographical, political or technological boundaries. With these requirements in mind, the project focus was posed on the "geographical integration" of real time sensor measurements - geographically aggregated - into ArcGIS Server Geo-Processing Services. The project outcome will be a modular framework for the real-time geo-analysis and processing of live sensor measurement data combined with other distributed spatial information layers in within complex geo-web services. This enables situational awareness in a geographic context, which is crucial for applications in

environmental monitoring, protection of critical infrastructures or different kinds of security applications.

In the context of such operational services it will be necessary to provide also the means for more effective ways of data exchange, in a reliable way, encompassing the development of data management infrastructures that support the different services and whilst ensuring interoperability. The GMES service elements should also act as pilots for the ongoing INSPIRE Directive implementation and may act as test-beds for INSPIRE.

5. OUTLOOK AND RESEARCH NEEDS

The status of GMES has rarely – if ever – been assessed critically. Main sources of reference include official documents by the European Commission and outcomes of EU-funded research projects.

Remote sensing data	Applications (examples)	GMES service domains	Frequency/ coverage
Geo-stationary satellites	Meteorology, climatology, early warning of environ. Disasters, oil spills etc.	Atmosphere	>hourly/ global
Low resolution optical imagery (~1km)	Environm. Hazards (floods, fires ....)	Emergency (alert), (Security)	Daily/ continental, global
Medium resolution optical imagery (~250m)	First information for many applications including environm. hazards and man-made catastrophes, more detailed information often required	Land, Emergency (early warning)	Daily/ continental, global
High resolution optical imagery (~10-30m)	Most Applications	Land, Marine, Emergency	On demand/ swaths of 60-180 km
Very high resolution optical imagery (~1-5m)	Built-up area monitoring, technical hazards	Land, Emergency	On demand/ swaths of 10-20 km
Radar	Geo-hazards, snow and ice, maritime, oil pollution	Land, Marine, Emergency	On demand/ swaths of 10-50 km

Table 1. Satellite remote sensing, applications and typical spatio-temporal coverages

In the 7th EU Framework Programme research has to explicitly focus on future GMES services, both during their pilot phase and when fully operational. This requires an appropriate supply of input data from both space and in-situ observation systems. It can be expected that the major industrial players leading the GMES service elements and Fast track services will demarcate the technical means to reach these goals. Scientists are somewhat concerned if this will necessarily lead to the most appropriate and scientific sound solutions or to 'industry-feasible' workflows. History shows how much single technical decisions can influence decade of future development as, for

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[2] http://www.esa.int/esaEO/SEMQFOUXJUE_environment_0.html

instance, with the short term decisions on the instruments of the first publicly available satellite sensor known as Landsat 1. It will be necessary to identify the most effective way to develop operational GMES services. Based on our joint experiences in research and in operational service development, we plea for linking this process to academic research in order to define scientifically sound and reliable workflows which shall guarantee a long-term continuity. While the political goal is clear – to establish an appropriate autonomous European monitoring capacity - the aim must also be to achieve methodologies acknowledged by a worldwide scientific community, coupled with a perspective of long-term sustainability.

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