# The GMOSS experience

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***Abstract*—GMOSS (Global Monitoring for security and stability) is a Network of Excellence (NoE) in the Aeronautics and Space priority of the 6th Framework Program of the European Union lasting from 2004 to 2008. Being part of the "Global Monitoring of Environment and Security" (GMES) program, GMOSS aimed to integrate the European civil security research while assembling a critical mass of resources, activities, and expertise needed to ensure a durable integration of the participants' capacities for global monitoring using satellite earth observation. The activities carried out during these fours years were threefold: integrating activities, implementing a joint research program, and spreading of excellence. This paper summarizes these activities. The security issues considered by GMOSS are first presented. The GMOSS consortium is then described. In the next sections, the focus is successively put on GMOSS Test Cases, real-time exercises, training activities and Gender Action Program.**

## I. Introduction

Several initiatives have been made to assist governments in policy decisions about the environment, including better predictions of natural disasters, epidemics, the impact of energy choices, and variations in the climate. In particular, the GMES initiative, developed by the European Space Agency and the European Union in 1998, aims at supporting Europe's leading role in the global monitoring of the environment and provides support to policy makers in the fields of hazards and crisis management as well as security related aspects (see http://www.esa.int/). In this context, the NoE GMOSS, lasting from 2004 to 2008, has been created in order to address the Security component of GMES.

NoE are designed to strengthen scientific and technological excellence on a particular research topic through the durable integration of the research capacities of the participants. They aim to overcome the fragmentation of European research by gathering the critical mass of resources and the expertise needed to provide European leadership. NoE also have to spread excellence beyond the boundaries of its partnership.

New technologies have an impact on the way security issues can be addressed. Advances in the sensors technology in terms of spatial, radiometric, and time resolution, and advances in computer sciences with respect to data storing, access, and visualization enable to share and monitor earth observation data in a multi-scale and synoptic way. Sometimes EO is the only way to gather information on areas that are too dangerous, too remote or where other methods could be too intrusive.

With the increase of data produced and of the spatial resolution, automatic processing is not only becoming a necessity but also a challenging task. Indeed, higher spatial resolution introduce more variability in the signal and further geometric distortions due to the parallax effect produced by the satellite being closer to earth.

Dealing with security applications requires using heterogeneous data derived from EO data or not: geographical, economical and political data characterized by different scale, reliability, and completeness. EO data may also be heterogeneous in terms of sensors type (optic and radar) and of spatial resolutions; a multi-scale approach is often needed as precise information is required over affected/suspected areas while a coarse scale is useful for analyzing the situation, for planning operations and for identifying areas on which precise information is required.

The whole process leading to the delivery of products to the end users could be subdivided into the following chain ([6]):

1) Selection and tasking of suitable satellites; this includes dealing with specific situations such as bad weather conditions or the choice to use time series.
2) Download and assessment of the collected data; this point also involves gathering all contextual data, background information, and evaluating their reliability and completeness.
3) Pre-processing of satellite data like radiometric and geometric processing, given that few if not no field measures are available.
4) Thematic analysis such as feature extraction, change detection and classification, given that camouflage might make the task more difficult.
5) Fusion where analytical results are eventually merged together and/or with data coming from other sources.
6) Visualization in the form of multi-scale products (2D or 3D) provided to end-users.

Even though each task is already a challenge in itself, the fact that most of the time the whole chain should be accomplished rapidly is another challenge that experts in security applications have to face.

This paper offers a summary of the GMOSS experience; details can be found in [2] and in [3]. In the next section, the security issues and the GMOSS initial joint programme are presented. Providing products for security applications require experts in disciplines such as computer science, geography, statistics, and political science. The NoE GMOSS demonstrated the benefit of a multidisciplinary collaboration through the analysis of Test cases and the simulation of a crisis in real-time exercises. These two aspects are presented in section III and IV respectively. Section V then summarizes GMOSS training activities while the last section before the conclusion gives an overview of GMOSS gender action.

## II. GMOSS Consortium

GMOSS, coordinated by DLR, involved 22 Institutions and 13 associated partners shown in Figure 1, with quite different background, as some came from research (civil and military), companies and consultancies.

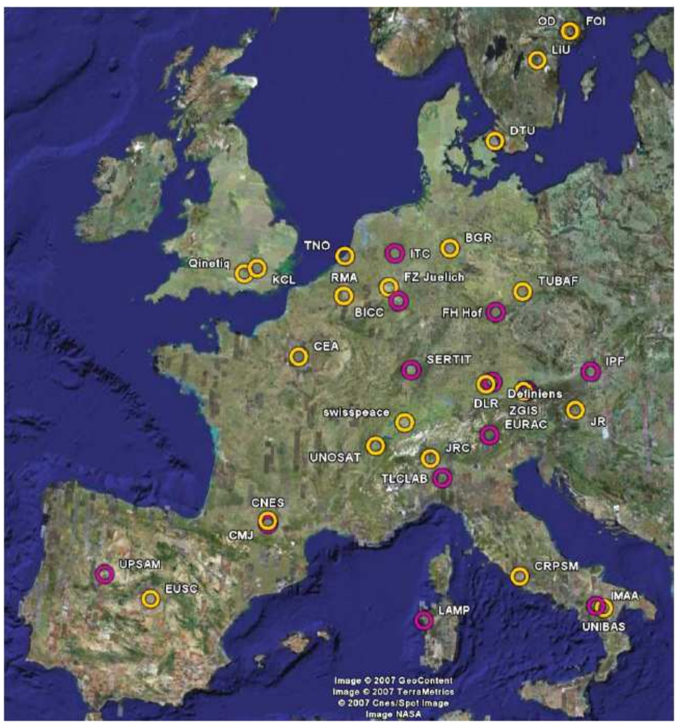


Fig. 1. GMOSS Partnership: contractors in orange, associated partners in pink (map based on Google Earth)

### A. Security issues

Security has been a key concept of two competing schools of (a) war, military, strategic or security studies, (b) of peace and conflict research that has focused on war prevention. Security issues are addressed by several EU Community policies (in particular the Common Foreign and Security Policy CFSP, and the European Security and Defence Policy ESDP) for areas such as sustainable development and climate change, civil protection, humanitarian aid, and safety research. Security is one of the basic needs of mankind, both individually and collectively. It is an important prerequisite for economic growth, investments and job creation as well as a powerful driving force for human ingenuity. With the end of the Cold War, Europe and the rest of the world faced new security challenges. The attack of September 11, 2001 added a perception of new vulnerabilities of industrialized countries. The distinction between hard military and soft non-military dangers, activities and priorities is blurred. The same applies to the traditional difference between internal and external security. Economic globalization has been challenged by transnational terrorism and international crime, and both created new security problems in the early 21st century. The sciences' traditional deep division into military research, isolated pockets of technological research, and the social and political sciences is coming into question.

On the one hand terrorism, proliferation of weapons of Mass destruction, regional conflicts, state failure, and organized crime, constitute the security threats recognized by the European Security Strategy [1]. On the other hand, climate change, natural hazards, environment degradation, poverty, under-development and diseases represent as many other threats affecting human security which no single state can master alone.

### B. GMOSS work program

GMOSS aimed to demonstrate how EO can help decision makers while addressing both types of threats. A NoE is a tool allowing much flexibility in its work program; the latter, built on each partner current interests is set up for 18 months every year. In its initial joint program, the NoE concentrated on the following applications: "Treaty monitoring", "Early warnings", "Damage assessment" and finally "Population and borders monitoring". The technological issues were embedded in technical work packages such as "Feature extraction", "Change detection" and "Data integration and visualization", aimed to address the specificities of the considered applications. The security aspects and the necessary background needed to deal with these specific applications were tackled by the "Issues and Priorities", "Responding to crisis", and "Scenario analysis" work packages.

Besides this application pillar, the GMOSS training and outreach pillar proposed summer schools each year, various technical seminars, a Gender Action Plan, and the publication of two books.

Finally, another pillar was aiming at partners integration, through horizontal activities like staff exchange, infrastructure sharing, workshops, and standards — which was later extended to the benchmarking of techniques and algorithms.

## III. GMOSS Test Cases

The initial joint program had been built upon each partner's research program and domain of interest and despite the integration steps described above, after two years, the NoE felt the need of real-life problems within which the applications, the technical tools, and the security concepts could be co-addressed. The network thus set up several test cases in Kashmir, Zimbabwe, Iraq and Iran.

### A. Kashmir

Kashmir has been selected not only because it had suffered from natural disasters, but also because terrorism, nuclear proliferation, treaty monitoring and border monitoring constitute some major threats in this area. Kashmir, lying in the area of collision of the Eurasian and Indian tectonic plates, suffered from an earthquake the 8th October 2005. The Charter on Disaster Management was automatically triggered in response to this event, so that several institutions worked at the production of value added satellite image maps of the damaged region, based on Ikonos, QuickBird, SPOT4, SPOT5, Radarsat, Lansat TM, ASTER and SRTM images, delivered in the very next days.

GMOSS partners provided additional products that could be used in such type of events. Among the latter,

- A Digital Elevation Model (DEM) with higher accuracy, using three SPOT images. DEM are necessary to perform an accurate georeferencing.
- A method to derive indicators on the location of survivors, based on night-time images (OLS-DMSP), on which light fires, sign of the presence of the displaced people, can be detected.
- A method to detect the affected areas on medium spatial resolution images (ASTER: 15m resolution). At this scale, the damage due to earthquakes, wars, tsunami, are modifying the local image texture, which can be emphasized by an urbanization index computed before and after the event.

### B. Zimbabwe

Zimbabwe was chosen to demonstrate the use of remote sensing data to provide evidence for human right violations and to monitor progress made on reconstruction efforts.

Zimbabwe is undergoing a deep economic and political crisis. In 2005, the Zimbabwean government started the Operation *Murambatsvina* (Restore Order), a large scale campaign to forcibly clear slum areas across the country. Millions of people have been affected by this campaign; within 6 weeks between May and July 2005, already 700,000 people lost their home or livelihoods (see http://www.un.org/News/dh/infocus/zimbabwe/zimbabwe_rpt.pdf). When *Murambastvina* was still going on, the Zimbabwean Government officially launched a reconstruction effort, called Operation *Garikayi* (Reconstruction/Resettlement).

As far as damage assessment is concerned, GMOSS focused on a 25 km sized study area covering Harare, one of the most damaged place. Radar data (ASAR) from 2005 and 2006 have been used in a multi temporal composition, while Very High Satellite Resolution optical data (QuickBird) from 2004 and 2005 have been analyzed. Change analysis was done in two steps. In a first method, the changes in the spectral behavior of objects were statistically aggregated (by variances) and reported on regular grid cells (500m × by 500m) providing a rough change detection (see top of Figure 2); in another method, the automatic change detection MAD method was used to detect changes one scale further. In both cases, within areas characterized by large changes, that is, in Mbare and Glen Norah, in the suburb of Harare, fine-scaled change assessment has been done by visual inspection. This coarse-to-fine process avoids visually screening large areas.

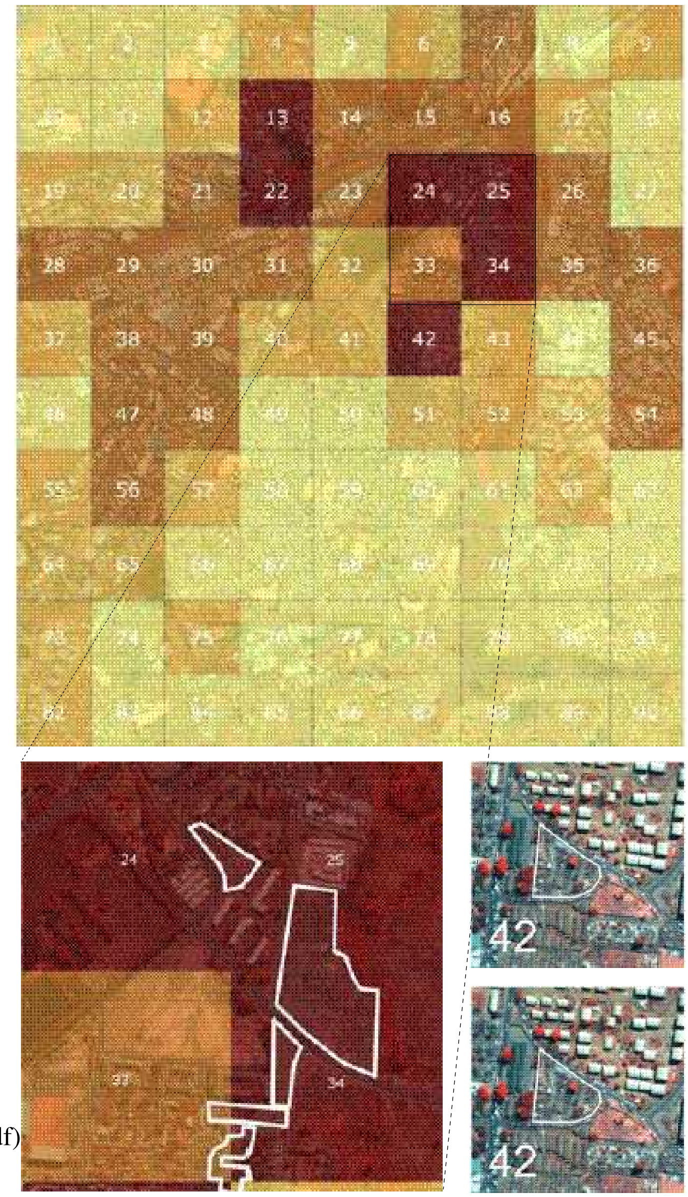


Fig. 2. Top: aggregated change of urban area between 2004 and 2005; dark value indicates higher standard deviation, i.e a higher likelihood of change. Bottom left: manual delineation of destroyed area overlaid with the corresponding high variance cells. Bottom right: identified destructed area in cell # 42 before (top) and after (bottom) (from [5]

As far as reconstruction is concerned, Operation *Gariyaky* has been analyzed in the Hatcliffe area.

### C. *Iraq*

The Iraq test case has been chosen for demonstrating the use of EO for monitoring pipeline attacks and the unstable situation in Baghdad.

Attacks on the oil infrastructure are studied using hot spots observations from satellites with a high temporal resolution (SEVIRI, MODIS). High resolution optical imagery can be used to observe the impact of attacks on the environment. These observations are compared with reports about pipeline attacks. Geo spatial trends and social-political aspects are studied using geographical (GIS) data about pipelines, land cover, population density, and ethnic distribution. Such a GIS-based analysis can indicate which pipelines are most vulnerable to terrorist attacks.

The Baghdad region is studied by monitoring the developing situation during and after the war in 2003 using (radar) change detection. Radar images can observe the Earth's surface even when smoke or clouds are present and can efficiently monitor changes. Also 3-dimensional data extracted from high resolution optical satellites are studied. The 3-dimensional data are used for situational awareness and to characterize changes obtained with the radar. The changes are related to damage, infrastructural change and economical activity.

Other work comprises a GIS based study of cancer incidences in Iraq after 1991 and GIS development and webGIS server issues for data integration.

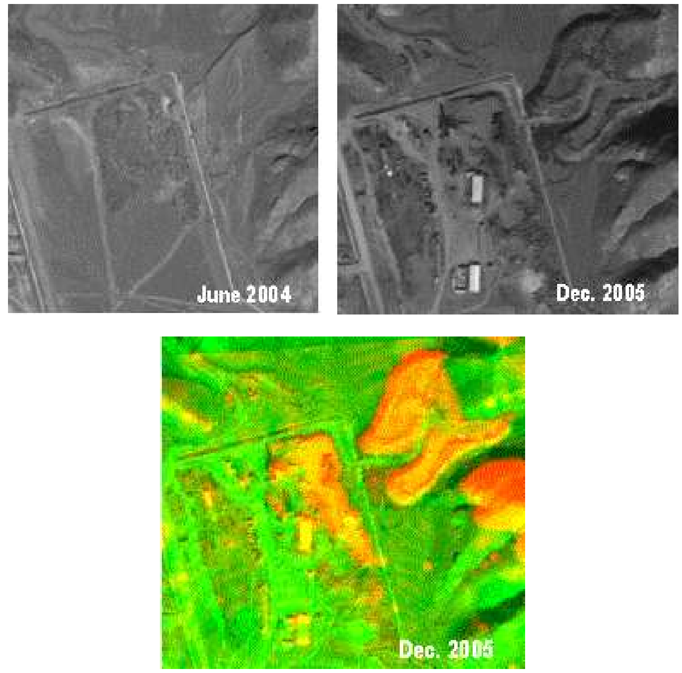


Fig. 3. Top: Two images of different dates. Bottom:combination of Orthoimage (green) and difference of two digital surface models (red). Maximum height difference is 10 m

### D. *Iran*

Finally, the test case in Iran has been chosen to investigate whether satellite imagery analysis could give indications on the civil or military purpose of the Iranian programme. Iran claims its nuclear ambitions are peaceful. However, its facilities have the appropriate scale to produce fissile material for nuclear weapons. The UN Security Council has repeatedly legally required Iran to suspend its enrichment and reprocessing activities, without success so far ([4]).

GMOSS researchers aimed at monitoring the development of some relevant sites in Iran: Arak, Bushehr, Esfahan, Natanz and Saghand, investigating which are the significant features of nuclear facilities/activities/processes identifiable from space and how to extract and visualize them. For example, thanks to the comparison of stereo pairs of Esfahan taken in June 2004 and November 2005, one partner was able to highlight the excavation of 103000 cubic meter (7 football fields, 3m hight), testifying some subsurface constructions, as shown on Figure 3. Such stereo analysis also shows the new buildings. Automatic object-based classification also show the development of new buildings.

## IV. GMOSS Real time Exercises

At the GMOSS Kickoff meeting, real-time exercise had been proposed as a tool for integration, for assessing the capability of EO and specific tools in some security applications, and for analyzing the whole process leading to the delivery of appropriate products to end users. Three of such exercises have been proposed to the NoE GMOSS. This section summarized the second one called GNEX'06. A complete description of the simulation can be found in [6].

The exercise aimed at testing Earth Observation Technology in a crisis situation in which some factors such as management, process control and communication play a key role. In this 33 hours simulation, three teams mixing GMOSS partners were working in parallel to answer a fictitious information request by the European Commission on a nuclear leakage scenario within Europe, resulting in locally heterogeneous low to intermediate ground contamination. The teams composed of about 20 researchers each (on average) were provided with satellite imagery as well as further geo-information and were mandated to extract and provide up to date information on infrastructure, urban areas and land cover. The information was generated in form of maps, reports and statistics over the fictitious contamination area crisis. The foreseen end-users, involved at an early stage in the scenario and tasks definition, were the nuclear safety experts of the German Nuclear reactor remote monitoring system of the Ministry of environment of Baden-Wurttemberg.

Each team had one pre-defined coordinating organization operating a coordination point. The three coordination points were in different geographical location, spread over Europe. They all used a different way to involve the participating partners: participants had the choice to send a representative at the team location, have a team working at the home institution, or even invite some partner to their institution.

In order to assess the exercise and follow the process, the management team had planned an expert evaluation of the products, an observation program during the exercise, an after-action review by the participants, two half day workshops, and some internal discussions.

The products delivered by the teams differed both in the content and in their visualization. As far as the land cover is concerned, all used different classification, which made the comparison difficult. The results of the urban land cover were compared to the CORINE DATA (derived from Landsat data with a re-sampled size of 25m and a minimum size per land-use unit of 25ha), showing an underestimation by 29% for one team and an overestimation by 24% for another. No cartographic standards had been used nor even recommendations in terms of color schemes, map layers, etc., which make the results difficult to view with other traditional products.

The teams had to provide quality statements, necessary to decision makers to estimate which products to use and how to use them in their decision-making process. But all teams failed in giving such an information.

The nuclear safety experts nevertheless appreciated the high level of detail of the map products, that would facilitate their work in a real event. All teams proposed additional products aiming at a better visualization of the results, but this was not seen as relevant for the experts.

The exercise highlighted the standard and quality issues in security applications.

## V. GMOSS Training activities

GMOSS put in a variety of efforts to reach out to other GMES projects, experts outside of the European research area and end users. GMOSS considers other GMES projects in implementation as scientific end users, which need to be exposed to the results and concepts developed by the network. The network intends to engage partners of respective consortia in training measures as a way to stimulate the exchange of expertise. Users from the communities-of-practice are involved in training events (such as GNEX, summer schools and seminars) to increase the awareness about the benefits of using spatial information for decision making in security situations. The activities of the training program cater not only for outreach, but also strongly facilitate the integration within the partnership. The year 2007 may serve as an example: following the presentation of the test cases in an integrated analysis framework during the Review Meeting in The Hague (April), the third Summer School on 'Early Warning and Monitoring of Agreements' in Madrid (September), and a Seminar on 'Environment and Conflict' in Bonn (October) provided platforms for exchange between different communities. It is by these 'interfaces' that the network attracted a substantial number of institutions from sectors such as policy analysis, science and technology and service providers to apply for associated partnership. The implementation of near-real time exercises (GNEX'06, '07) is a clear indicator for the progressing integration within GMOSS. So, in the end, the concept of gaming under realistic scenarios as a tool for problem analysis and validation was broadly accepted by the participants, from GMOSS and outside.

## VI. GMOSS Gender Actions

"Gender" describes the sexually defined roles of men and women in a social and cultural context. To support the goals of research excellence and economic competitiveness the EC has set a strategy of gender mainstreaming in 1996.

The objectives of such a strategy are threefold. A first objective is to increase the participation of female researchers in research projects at all levels. A 40% participation of women at all levels is foreseen. A second objective is to orient research so that it addresses the needs of both women and men. A third objective is to support research which gives an understanding on the gender question itself.

Thus, as all FP6 projects, the NoE had to fulfill a Gender Program. With respect to the second objective, GMOSS organized a Gender and Security Workshop focusing on the perspective of women in conflict, post conflict reconstruction and peace building. With respect to the third objective, an artistic exhibition composed of photographic portraits, artworks and answers to a questionnaire, illustrated how some GMOSS scientists — both men and women— conciliate a rich private life beside their professional work.

## VII. Conclusion and the way forward

Even though working in a highly competitive environment, the GMOSS community was able to build the confidence and mutual trust required to evaluate individual and/or joint achievements (algorithms, tools, work flow) by establishing procedures for validation and benchmarking through test cases, and GNEX.

Partners are now aware of each others institutional capacity, activities and expertise.

At the end of GMOSS funding period, there is a recognition that the stability of livelihoods is in many ways influenced by environmental factors as well as governance. Safeguarding human security then certainly requires to extend existing scenarios by incorporating the global and climate change dimension. This should also include investigations into the linkage of security & health and security & migration.

The analysis of scenarios — and the evaluation of information products afterwords — show that EO expertise alone is not sufficient. Therefore, the integration of the socio-political domain has to be continued and deepened by incorporating social sciences as "full" partners.

By using the flexibility of the NoE wisely, GMOSS has paced towards a "European Think Tank for the development and benchmarking of new tools and methodologies for the application of EO technology in the security domain". The challenge for a future network is to flower out by acting as an advisory group for decision makers in security applications and to further develop the benchmarking concept as support for the operational GMES Core Services.

## Acknowledgment

The authors would like to thank all GMOSS researchers for sharing their results.

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