Earth Observation for Monitoring and Observing Environmental and Societal Impacts of Mineral Resources Exploration and Exploitation

Reporting

Project Information

EO-MINERS

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Final Report Summary - EO-MINERS (Earth Observation for Monitoring and Observing Environmental and Societal Impacts of Mineral Resources Exploration and Exploitation)

Executive Summary:
The aim of EO-MINERS is to bring into play EO-based methods and tools to facilitate and improve interaction between the mineral extractive industry and society in view of its sustainable development while improving its societal acceptability.

EO-MINERS hence aims at integrating new and existing Earth Observation tools to improve best practice
in mining activities and to reduce the mining related environmental and societal footprint by:

• introducing innovative remote sensing tools to the mining industry,
• providing accuracy and quality measures for remote sensing products,
• demonstrating the application of Earth Observation in different case studies,
• fostering the dialogue between mining industry and environmental organisations based on EO-derived information and
generalising the obtained results to be used in operational mining applications in the future.

Methodological development have been carried out over three demonstration sites: the Sokolov lignite open pit in the Czech Republic, the Mpumalanga coalfield of South Africa and the Makmal gold mine in Kyrgyzstan.

The work started with the identification of the needs from the relevant stakeholders, i.e. mining industry, regulatory bodies and civil society (local communities, NGOs...) to evaluate the indicators and parameters to be taken into account in the assessment of the environmental, socio-economic and societal footprints of the extractive industry at each stage of a project, from exploration to exploitation and closure. Corporate level (extractive industry and relevant associations) as well as public level (regional, national to international) have been considered.

The development of meaningful indicators is a social and not an engineering process, which defines what to indicate for whom and why. It is then necessary to evaluate whether a proposed indicator can be related to quantities measurable by EO. Therefore, the development of indicators is a process iterating between stakeholder expectation and operational feasibility.

The selection of indicators to describe the status and impact of mining activities followed three different, but complementary, approaches:

• An expert elucidation process, where experts from the project contributed from their experience in the mining domain;
• Stakeholder interviews, both at national, regional, and site level, where all stakeholders, including civil society, NGOs, regulatory bodies, and industrials provide their own insight of the impact of mining and the ways to monitor them;
• Demonstration site investigations, where specific environmental and/or societal concerns have been highlighted and gathered in a Conceptual Site model

A total of around sixty indicators have been defined, of which more than a half can be either directly or indirectly monitored using EO methods, either by a single or a combination of methods. Indeed an indicator can be monitored through one or several parameters, each addressed by relevant EO methods, while, in some cases, a single EO method can be used in monitoring several parameters.

Once an indicator has been defined, a list of relevant measurable parameters is established, along with the potential to address them through EO techniques. For each parameter, the relevant EO data made accessible to the project are then listed, leading to the definition of EO-based GIS layers to be further used in the generation of a dedicated EO-based product, e.g. a map of potential surface drainage contamination by AMD minerals.

EO-MINERS general methodological approach

EO methods consisted in:

• Satellite data: conventional sensors like Landsat, SPOT and ASTER, very high resolution sensors
Satellite data: conventional sensors like Landsat, SPOT and ASTER, very high resolution sensors (WorldView_II),

Airborne data acquisition: hyperspectral airborne surveys, LIDAR survey, thermal infrared surveys (multi and broad band),

In situ measurements: field spectroradiometry campaigns (VNIR, SWIR, TIR), in situ point measurements (pH, temperature...), street dust sampling and analysis, information and/or measurements about vegetation, soils, surface and groundwater, dust...

Innovation consists in the juxtaposition and/or fusion of various EO data through models or data integration schemes which fit at best with i) site specific requirements, and ii) the parameters and indicators to be addressed as defined during the previous stage.

In the perspective of the societal acceptability of extractive industry, one of the major aim of the project being to define tools “opposable” during discussions between the parties involved in a mining project life, a particular attention is paid to the definition and application of protocols and standards to EO data and added value products that guarantee the “quality and objectivity” of data and products.

A selection of 31 products (15 for Sokolov, 9 for eMalalheni, 7 for Makmal) has been presented to the stakeholders during stakeholder triilogue workshops held at the demonstration sites. Products have been presented on form of paper printouts (posters) all available at the project web site, digital 2D and 3D (PDF) maps for use on PCs or mobile devices, 3D models and animations, and Google EarthTM files.

Discussions during the stakeholder workshop led to positive feedback, highlighting

- The attractiveness of tools that provide the information in an easy-to-use form,
- The benefit of spatially continuous and repeated measurements,
- The interest of the 3D presentation of EO Products, beyond the posters,
- The ability of maps and data to help develop a common language and base of communication between otherwise separate stakeholders

Project Context and Objectives:

The mining and extractive industry has played, and still play, a significant role in the development of many countries all over the world. The industry has been, and continues to be an important contributor to both national and regional economies and is critical to national defence. Mining, and the industries it supports, is among the basin building blocks of a modern society.

Most sectors, such as construction, chemicals, automotive, aerospace, machinery and equipment sectors depend on unimpaired access to raw materials, providing a total value added of € 1,324 billion, and employment for some 30 million people in the EU.

The world today is facing an increasing mineral resource demand. This was illustrated in 2007 by the European Commission Vice President Günter Verheugen, responsible for enterprise and industry policy, who said: “European industries need predictability in the flow of raw materials and stable prices to remain competitive. We are committed to improve the conditions of access to raw materials, be it within Europe or by creating a level playing field in accessing such materials from abroad”.

In recent years, the EU’s total material requirement has remained at a constantly high level – roughly 50 tonnes a year per head of the population since the middle of the 1980s. But in this time the weight of imports and their environmental impacts have considerably increased (EEA 2003).

The benefit of mining to those countries has been significant, but it has come at a cost to the environment. Early mining operations have left a historical legacy of negative environmental impacts that affect our perception of mining. As countries have matured, there has been increasing recognition that environmental protection is as fundamental to a healthy economy and society as is development. The challenge is to
protection is as fundamental to a healthy economy and society as is development. The challenge is to simultaneously promote both economic growth and environmental protection.

The bulk of this increase is attributable to ores, mineral fuels, metalware and products such as glass, ceramics and precious stones. These four categories account for most of the ecological impact of imports. More than half of these originate in the developing countries, while fewer resources are extracted in Europe itself. Numerous mines have closed in Europe during the last few decades, either because of natural exhaustion or because they were not profitable. With the closure of mines, environmental pressure has been reduced in Europe but raised in other regions. The environmental footprint of EU material consumption has shifted from Europe to other regions. One tonne of imports leaves behind an average of 5 tonnes in mining waste, emissions and erosion in the exporting country. This ratio has more than doubled over the past twenty-five years, and in the case of ores has quadrupled from 1:4 to 1:16 tonnes. The responsible management of Earth’s environment is one of today’s most pressing concerns and a central motivation for the Group on Earth Observations (GEO). Sound environmental management of mining activities can avoid high remediation costs, which frequently might drain public funds. Surface and groundwater pollution, soil contamination, and terrain instability all cause damage that can affect urban and sub-urban areas. Understanding and monitoring pollution processes in mining areas is therefore of concern to a very wide user community, including central government bodies or agencies, local authorities, industry, environmental groups and individual citizens. When also faced with legal and social pressures, the mining industry is interested to minimize the impacts on environment and society.

Because it significantly affects the quality of the human environment, mining nowadays is often perceived as only having negative social impacts; however, communities can benefit from surface mining activities and reclamation. From ore discovery and access, markets and capitals, worker safety, environmental issues, the scope of concern is moving towards taking communities and equity into account.

EO-MINERS is a Research and Technological Development project funded by the European Commission to help EC improve its raw material policy and better exploit mineral resources from the European territory and its mineral supplying countries. It also aims to demonstrate how to improve the capacity of Europe in implementing new mining sites, and to improve interaction between the mining industry and the society. The overall objective of the EO-MINERS project is to bring into play EO-based methods and tools to facilitate and improve interaction between the mineral extractive industry and society, for its sustainable development, while improving its societal acceptability.

The social acceptability of a mining project, from exploration to closure, is among the major key issues to be dealt with. EO-MINERS scientific and technical objectives are to: i) assess policy requirements at macro (public) and micro (mining companies) levels and define environmental, socio-economic, societal and sustainable development criteria and indicators to be possibly dealt using Earth Observation (EO); ii) use existing EO knowledge and carry out new work on demonstration sites to demonstrate the capabilities of integrated EO-based methods and tools in monitoring, managing and contributing to reducing the environmental and societal footprints of the extractive industry during all phases of a mining project and iii) contribute to making available reliable and objective information about affected ecosystems, populations and societies, to serve as a basis for a sound “trialogue” between industrialists, governmental organisations and stakeholders.

Given the vital role of the non-energy extractive industry in the EU’s economic development, an improved understanding of the environmental, socioeconomic and social impacts of mining is crucial. Earth Observation offers a unique opportunity and varieties of methods to collect and process spatial information to address, either directly or indirectly, monitoring and assessment of the impacts of mining at each phase of the mining cycle. It includes:
each phase of the mining cycle. It includes:

- Spaceborne and airborne imagery
- Ground and airborne geophysics
- Geochemistry
- In situ measurements
- Monitoring networks
- 3D modelling
- ...

EO-MINERS also addresses GEO (Group on Earth Observation) and GEOSS (Global Earth Observation System of Systems) process and tasks, by using the project outputs to define core elements of an environmental observing system and examining how this system fits in GEO and contributes to building GEOSS.

Project Results:

1. Description of the main Science & Technology results and foregrounds

The need to assess policy requirements and define societal and environmental criteria and indicators to be possibly dealt with using EO methods and tools was first addressed through an analysis of policies related to the environmental and social footprint of mineral industries. EO-MINERS then contributed by developing high level EO-based data products applicable to the different stages of mining activities within the life cycle of mining operations, over three demonstration sites:

- The Sokolov lignite open pit in western Bohemia, Czech Republic
- The Mpumalanga coal field, the largest coal field in South Africa, near the town of eMalahleni
- The Makmal gold mine and processing plant in Kyrgyzstan, near the town of Kazarman

These processes aimed to contribute to the development of generic EO data integration schemes, in particular in view of characterising affected ecosystems, populations and societies and prepare objective documents for industrialists, governmental organisations and stakeholders. To this end, the project continuously took care of robust and reliable standards and protocols that guarantee the repeatability of the methods deployed.

The overall methodological approach is illustrated below and described in more details in later sections.

2.1 Policy analysis and indicator definition

With respect to the first scientific and technical objective, the overarching task here was to identify information needs derived from policies to inform the selection of appropriate Earth Observation techniques and products.

EO-MINERS identified policies that address the environmental and social footprint of mineral industries or corporations, public authorities and civil society. Based on this policy analysis, expertise of the project consortium members, and targeted interaction in the form of interviews with stakeholders, specific information needs were derived that represent the basis for the development of indicators of the footprint of mining activities.

Different types of indicators that support the analysis of environmental and societal pressures and impacts related to mineral extraction have been identified, evaluated and developed. For the selection of applicable Earth Observation techniques, the project has identified and analysed policies of private companies, public authorities and civil society related to the footprint of mining industries. In this context, selected stakeholders at the South African, Kyrgyz and Czech demonstration sites have been interviewed. The aim...
Stakeholders at the South African, Kyrgyz and Czech demonstration sites have been interviewed. The aim was to have equal input from each component of the three stakeholder groups, i.e. authorities and regulatory bodies, industry, and civil society.

Appropriate indicators were selected for answering the information demanded by local stakeholders, e.g. via corporate sustainability reporting (CSR), and macro-economic indicators for governmental policy-making. These results were on the one hand undertaken to feed directly into the “trialogue” workshops organised by the project, while on the other hand they are also fed by results of the discussions during these “trialogue” events.

These analyses defined the demand for the development and application of Earth Observation products and services, respectively, and thus provide a reference frame for their applicability.

2.1.1 - Corporate policy analysis
Mining companies increasingly adopt corporate responsibility in both the societal and environmental realm as guidance for their actions.

The mining sector is a particularly interesting field with respect to corporate policies. Mines have a long tradition of setting specific corporate policies, namely with respect to health and safety issues, but also with respect to business protection and social aspects. Some mines are early examples of Corporate Social Responsibility (CSR), the mine owners having created a comprehensive set of infrastructure. Conversely, there are also numerous examples, where CSR has been completely perverted, resulting practically in bondage or servitude of the miners by forcing them into debt e.g. by exaggerated prices for daily necessities in company stores etc.

The ways that mining companies address environmental issues are not only determined by the local situation or the regulatory framework at the various levels, but also by the ways that mining companies place themselves into the world-wide context. It was noted that corporate policies strongly reflect the corporate setting, i.e. whether the corporation operates more locally or globally.

The results of the corporate policy analysis can be found in the project deliverable D1.1.1 entitled “Corporate Policies in a Mineral Extraction Context”.

2.1.2 - Policies in civil society
The significant socio-economic and environmental impacts that are often associated with mining operations have generated an increasing number of claims by civil society and regulators. These have resulted in a variety of new actual or perceived obligations on the side of the mining operators, who had been traditionally focusing almost exclusively on their economic profitability.

Civil society and their interest in and their attitude towards mining is very diverse. The emphasis that is given to any one of the different aspects may vary considerably even within these groups of stakeholders. Stakeholder views and agendas will be shaped by the performance of the mining operation with respect to these issues and in particular by specific events, such as environmental incidents. The attitude of external stakeholders is also significantly shaped by company policies and governance paradigms chosen.

The results of the corporate policy analysis can be found in the project deliverable D1.1.2 entitled “Civil Society Policies in a Mineral Extraction Context”.

2.1.3 - Public policies
The analysis of international and EU policy frameworks shows that there are a number of policy arenas relevant to EO MINERS:

- Sustainable Development: The political discourse about sustainable development is often rather general, relating environmental, economic and social problems to each other. It is thus primarily relevant for agenda-setting in the strategic policy environment of EO-MINERS.
- Resource Policies and Initiatives: The discourse about sustainable development is a key driver of
Resource Policies and Initiatives: The discourse about sustainable development is a key driver of resource policies. However, the relevant resource policy frameworks at international and at EU level put emphasis on different aspects. At international level, the focus is mainly on developing or transition countries. Social aspects like the management of resources and revenues and good governance are the main concerns of global initiatives. The emphasis on socio-economic and financial issues suggests that EO does not have a key function in this context. On the EU level resource policies are mainly about two central themes, i.e. a) decoupling environmental impacts from resource use and b) Security of supply. Primarily the first aspect is most relevant for EO-MINERS.

- International activities: Contributing to initiatives such as the Extractive Industry Transparency Initiative (EITI)
- General Environmental Policies: General environmental policies provide broad reporting, assessment and monitoring frameworks on any activity with the potential to impact negatively on the environment, including mining. At international level, the Kiev Protocol on the Pollutant Release and Transfer Register (PRTR) provides such a general reporting system. In the EU, the environmental acquis communautaire comprises several precautionary directives and regulations such as the Directive concerning Integrated Pollution, Prevention and Control (IPPC) and the Directive on the Assessment of the Effects of Certain Public and Private Projects on the Environment (Environmental Impact Assessment, EIA) which create information requirements related to mining activities.
- Specific Environmental Policies: There are a number of environmental policies, which address specific environmental qualities which can be affected by mining activities, such as the biological diversity of a site, air and water quality. The specific policies can also aim at specific risks of extractive activities, such as the release of waste, hazardous substances and other emissions.

These different arenas have their own historical development and stakeholders on different political levels, corresponding to specific information requirements. The results of the public policy analysis can be found in the project deliverable D1.2 entitled “Public Policy Analysis”. The deliverable D1.3 entitled “Report on Public, Corporate and Civil Society Policy Analyses” summarises the results of these three policy analyses.

2.1.4 - Identification of information requirements and operational indicators
The information, which is generally needed to adequately assess the environmental footprint of mineral industries, as well as its social implications, has been identified. For the different test sites this has been supported by an on-site mapping of information needed by local stakeholders by means of interviews and also during discussions in workshops organised by the EO-MINERS consortium. Meetings with local stakeholders in South Africa, Kyrgyzstan and the Czech Republic were organised at the test sites based on the support by the local EO-MINERS partners.

These interviews and assessments of the site-specific situation were the basis for selecting appropriate “micro indicators”, i.e. indicators applied on the local level. Specific information needs on the macro level were also identified. A recent development has been the development of the Europe2020 flagship initiative “Resource Efficient Europe”. The implications of the flagship initiative and the resource efficiency roadmap for the mining sector in general and more specifically for EO-MINERS were analysed and thus framed the planning of the European Triilogue. The identification of operational indicators included a multi-pronged approach, consisting of i) issues determined by expert knowledge, ii) examination of site-specific conceptual models for the three demonstration sites (see § 2.2.1 and deliverable D3.1) and iii) a semi-deliberative approach elucidating input from stakeholders outside the project team. The three processes ran in parallel, resulting in three...
input from stakeholders outside the project team. The three processes ran in parallel, resulting in three sets of indicators that then were analysed for their respective coverage. This process went through several loops of iterations in order to consolidate the set of indicators. The consolidated set of candidate indicators informed the process of EO product development and was subject to final stakeholder evaluations towards the end of the project (see deliverable D5.6). A complete list of indicators is provided in Annex 1, while Annex 2 provided the indicators relevant of each of the demonstration sites. The results of this step are presented in deliverable D1.4 entitled “Candidate Indicators for Mining-Related Environmental and Societal Impacts” and deliverable D1.5 entitled “Final Report on Information Needs and indicators”.

2.1.5 - Status quo of monitoring environmental indicators by Earth Observation

The aim here was to summarise what had already been achieved in this field at the start of EO-MINERS in order to learn from these lessons. An extensive literature survey was performed, including the two former complimentary projects: MINEO (www2.brgm.fr/mineo) and PECOMINES (http://viso.jrc.ec.europa.eu/pecomines_ext/). It led to an assessment of the technical advantages and disadvantages of measurement methods, which are required to populate the indicators or allow the development of EO products, respectively, including the assessment of available satellite, airborne, and ground sensors. The results are provided in deliverable D1.8 “Status quo of monitoring candidate environmental indicators by EO services”.

2.1.6 - Resonance analysis of selected indicators and EO services

The resonance analysis methodology has been specifically dedicated to match policies with indicators. It has been further developed for EO purposes and tested in the FP6 project Global Monitoring for Environment and Security (GMES) network of users (GNU). Resonance analysis collects empirical evidence on whether and how specific EO services or products can be related to phases of the policy cycle (e.g. agenda setting, implementation, and evaluation). On the basis of desktop research, stakeholder interviews and the trialogue workshops, assumptions about the function of EO services, which were developed by the project, in corporate and public policy-making have been tested. The results of this task could be seen as a contribution to the quality control of the project and for raising awareness on the potential of EO services and products for the mineral industry and for non-governmental stakeholders with regard to environmental and social footprinting. Results of the resonance analysis are discussed in Deliverable D1.6 entitled “Resonance Analysis of selected Earth Observation specifications”.

2.2 Use of existing knowledge and new development in monitoring and assessing mining impacts from EO

The fulfilment of the second scientific and technical objective of the project consisted of using existing EO knowledge and carrying out new developments on demonstration sites to:

- Further demonstrate the capabilities of integrated EO-based methods and tools to monitor, manage and contribute to reducing the environmental and societal footprints of the extractive industry during all phases of a mining project, from the exploration to the exploitation and closure stages.
- Contribute to making available reliable and objective information about affected ecosystems, populations and societies, to serve as a basis for a sound “trialogue” between industrialists, governmental organisations and stakeholders.
- Summarize and document the developed models and algorithms, as well as the results of the “trialogue” to establish a baseline for a compendium of best practice approaches that will assist the on-going and necessary dialogue between society and the mining industry.

Methodological developments have been carried out over the Czech, Kyrgyz and South African...
Methodological developments have been carried out over the Czech, Kyrgyz and South African demonstration sites, to allow observing, monitoring and where possible quantifying social and environmental footprint caused by the mining activity. Integration of satellite, airborne and in situ (see table below) monitoring methods and tools has been the unifying thread all along these developments.

In parallel, particular attention was paid to robust and reliable standards and protocols that guarantee the repeatability of the methods deployed.

The site-specific developments carried out intended to contribute to the development of generic EO data integration schemes, EO products and EO-driven environmental modelling scenarios adapted to various situations, whose reliability and objectivity cannot be disputed by parties involved in any stage of a mining project. Such products aim to characterise affected ecosystems, populations and societies and become an authoritative basis for a sound “trialogue” between industrialists, governmental organisations and stakeholders.

2.2.1 - Conceptual site model

The approach to assessing and predicting environmental and societal impacts of mining is based on the source-pathway-receptor framework, where there must be a linkage (i.e. pathway) from the source of a known or potential hazard to a receptor. The Conceptual Site Model (CSM) is one of the primary tools that can be used to support this assessment, by providing a framework where available information is collated and key linkages among system components are set out. Development of the CSM helps identify data gaps in the assessment process and guide further investigation.

A CSM can be used by all of the stakeholders, providing a framework to help communicate ideas and understanding of the site conditions in an effective manner. Mining or environmental engineers use them to understand the technical components of the environment, while they are also used to explain potentially complex situations to policy makers or members of the public.

Typically, a mining CSM should include consideration of the topics listed below:

- Site description
- Geology, topography
- Climate
- Hydrogeology
- Water Balance
- Geochemistry
- Distribution of receptors and exposure pathways.

Deliverables D3.1 (one per demonstration site) entitled “Report on site description and site conceptual model” provide a general description of the site and its impacts as well as the associated conceptual model.

2.2.2 - Relevant data collection and quality control

Once an indicator is defined, a list of relevant measurable parameters is established, along with the potential to address them through EO techniques. For each parameter, the relevant EO data to be collated and made accessible to the project are then listed. These include:

- Satellite imagery, either from archive imagery (e.g. Landsat TM, SPOT, ASTER, CARTOSAT) or resulting from specific tasking requests (e.g. WorldView_2);
- Airborne data acquisition surveys: hyperspectral, very-high resolution orthophOTOS, thermal imagery, LIDAR;
- In situ measurements and data acquisition during dedicated field campaigns;
- Existing publicly available data and GIS layers from various national or regional agencies and...
• Existing publicly available data and GIS layers from various national or regional agencies and organisations e.g. orthophoto mosaics, DEMs, land use maps, geological and hydrogeological maps and information, meteorological data, socio-economic data, etc.

A comprehensive list of data acquired within the project frame is provided in Annex 3, while deliverable D3.2 entitled “Data acquisition and validation” describes all data acquired together with associated metadata and copyrights.

Developments carried out during the project rely on data that fully comply with protocols and standards, e.g. data calibration, data validation and data quality assurance, from upstream (data acquisition phase) to downstream (the added-value EO-based product delivery phase) as well as through the processing chain (algorithms). Robust and reliable standards and protocols guarantee the repeatability of the methods deployed.

A protocol to assess the quality of the different field measurements and acquired EO data has been developed, taking already existing standards widely accepted and used into account. Quality assurance/quality indicators (QA/QI) are being developed for all available data, and the specific protocols for potential users have been gathered with alignment of the QA/QI developed within the framework of the EUFAR (European Facility for Airborne Research) project, the HYQUAPRO group and beyond.

Among other things, this includes development of a protocol for raw hyperspectral data quality indicators which include Radiance to Reflectance ratio (Rad-Ref), Radiance to Reflectance Difference Factor (RRDF) and Image noise Indicator (INI).

Deliverable D2.2 entitled “Data inspection” screens all the methods that were used to inspect remote sensing (satellite, airborne and proximal) data during the project.

2.2.3 - Data pre-processing
2.2.3.1 - Introduction

The goal of the EO-MINERS research project is to use EO tools to help identify mining-related environmental and societal footprints. In order to achieve this goal, the data collected have to be objective and accurate. The different data sets that have been collected using remotely sensed methods, integrated with in situ information, fulfil these criteria. From a Remote Sensing point of view, the different data sets can be grouped into different major groups:

• Hyperspectral remote sensing (imaging spectroscopy) for material detection and quantification,
• High resolution multispectral optical satellite and airborne data, covering different parts of the electromagnetic spectrum, used for precise mapping aspects, and medium scale optical satellite imagery used for mapping information on a regional scale
• Active satellite and airborne systems, like synthetic aperture data (SAR) and active systems that measures distance by illuminating a target with a laser and analysing the reflected light (LIDAR).

2.2.3.2 - Basic principle of optical remote sensing

Optical remote sensing and in particular Imaging Spectroscopy has shown the potential to assess not only general surface, land-cover and land-use properties over large areas, but also quantify selected parameters. This is accomplished by taking advantage of the characteristic interactions of incident radiation and the geo-physical-chemical properties of the surface and its cover types, which allows remote sensing-based approaches to study surface parameter patterns, their quantification and their possible changes over time. Those measurements can be transferred to large geographical regions of similar climatic and geo-physical and geo-chemical conditions after atmospheric correction has been applied.

2.2.3.2.1 - Reflectivity domain

Mapping Earth’s surface composition using optical remote sensing is based on the concept of reflectance and spectral signature. A target at the Earth’s surface illuminated by solar energy radiation (ETi) either
and spectral signature. A target at the Earth's surface illuminated by solar energy radiation \( \text{ET}(\lambda) \) either absorbs \( \text{EA}(\lambda) \) transmits \( \text{ETr}(\lambda) \) or reflects \( \text{ER}(\lambda) \) this energy, the energy budget being divided in these three quantities.

The reflectance is defined as the fraction of the total incident energy which is reflected by the target \( R = \text{ER}(\lambda)/\text{ET}(\lambda) \). The reflectance varies according to the wavelength and the nature of the target. The way radiation is reflected from a surface depends on the surface's characteristics. Measuring and plotting the variation of the reflectance with the wavelength for a given target makes possible to draw its spectral reflectance curve. Being a characteristic of the target, this variation represents its spectral signature.

These properties are responsible for the “colour” of the earth’s surface features on satellite images such as the ones used on Google Earth.

Each target hence presents distinctive spectral absorption/reflection feature(s) that enable its unique identification from spectral criteria, and are the basis for material identification, compositional analysis, abundance estimation and physical parameter retrieval.

Material identification and derivation of quantitative information is based on analysis of the wavelength position of the absorption features and parameters describing their shape, such as depth, width, symmetry...

2.2.3.2.2 - Emissivity domain

For the thermal infrared (TIR) domain the Earth surface itself is the radiation source. The surface's actual energy budget is dependent on a variety of material specific and environmental parameters such as heat capacity, heat conduction, evaporation, long- and shortwave irradiation, etc. This imposes a major problem as for n-spectral measurements (sensor bands) there are n+1 unknown (spectral emissivities plus temperature). Specific algorithms have been developed to separate emissivity and temperature in TIR spectral measurements.

2.2.3.3 - Principle of radar remote sensing

A Synthetic Aperture Radar (SAR) is a coherent mostly airborne or spaceborne side-looking radar system which utilizes the flight path of the platform to simulate an extremely large antenna or aperture electronically, and that generates high-resolution remote sensing imagery. Radar pulses can detect dielectric properties of the earth’s surface, and can distinguish texture. Particular benefits of this system are the ability to see through clouds (and at night time) and to detect features such as soil moisture and ground movement.

2.2.3.4 - Principle of LiDAR remote sensing

An airborne LiDAR (Light Detection and Ranging) system pulses a laser beam onto a mirror and projects it downward from an airborne platform, usually a fixed-wing airplane or a helicopter. The beam is scanned from side to side as the aircraft flies over the survey area, measuring between 20,000 to 100,000 points per second. When the laser beam hits an object it is reflected back to the mirror. The time interval between the pulse leaving the airborne platform and its return to the LIDAR sensor is measured. Following the LiDAR mission, the data is post-processed and the LiDAR time-interval measurements from the pulse being sent to the return pulse being received are converted to distance and corrected to the aircraft's onboard GPS receiver, IMU, and ground-based GPS stations. The GPS very accurately determines the aircraft's position in terms of latitude, longitude and altitude. The LiDAR sensor collects a huge amount of data and a single survey can easily generate millions of points totalling several terabytes. The initial LiDAR data can be further enhanced using additional post processing, some of which can be automated and some are manual. Further processing utilizes the multiple return signals from each laser pulse. By...
Some are manual. Further processing utilises the multiple return signals from each laser pulse. By evaluating the time differences between the multiple return signals the post processing system can differentiate between buildings and other structures, vegetation, and the ground surface. This process is used to remove surface features to produce bare earth models (DTM) and other enhanced data products.

2.2.3.5 - Main data preprocessing issues
2.2.3.5.1 - Atmospheric correction of hyperspectral imagery
The objective of any radiometric correction of airborne and spaceborne imagery of optical sensors is the extraction of physical earth surface parameters such as spectral albedo, directional reflectance quantities, emissivity, and temperature. To achieve this goal the influence of the atmosphere, solar illumination, sensor viewing geometry, and terrain information have to be taken into account. Although a lot of information from airborne and satellite imagery can be extracted without radiometric correction, the physically based approach offers advantages, especially when dealing with multi-temporal data and when a comparison of different sensors is required. In addition, the full potential of imaging spectrometers can only be exploited with this approach. One widely used physical model is the ATCOR software package. ATCOR can be easily adapted to new sensors once their data becomes available. Special features of ATCOR are the consideration of topographic effects and the capability to process thermal band imagery.

Atmosphere correction of hyperspectral data have been studied using different available methods. It was found that for vegetation and land, different attitude has to be taken and the merge of several methods is required. In this regard, a supervised vicarious calibration technique has been examined for the first time based on agricultural black net in different densities.

A new innovative method to inspect the quality of hyperspectral data has been developed. This inspection process is done on both the radiometric and reflectance data and is based on the Supervised Vicarious Calibration (SVC). Two physical indicators were developed for that purpose: RAD/REF (at-sensor Radiance divided by ground truth Reflectance) and RRDF (Radiance to Reflectance difference factor). Both are based on the radiance and reflectance response of selected ground targets. The SVC methods call to use “agriculture net” in different densities but other targets are also permitted.

Deliverable D2.3 entitled “Atmospheric correction protocol and validation results” details the methods and protocols followed for atmospheric correction of airborne hyperspectral data sets.

2.2.3.5.2 - Correction of geometric distortion in hyperspectral airborne surveys
Different approaches and methods to inspect geometric distortion have been developed. This was found to be a crucial stage when several flight lines are used to cover large areas. Comprehensive documentations exist and protocol how to apply these methods has been issued and used in all data sets within the EO-MINERS project.

2.2.3.5.3 - Completion of missing data in hyperspectral thermal infrared imagery
A new innovative method to complete missing data of hyperspectral sensor operating in the thermal region from other hyperspectral sensors that are active in the optical region has been developed. It terms SENTOS (Sensor to Sensor) and used the AHS data acquired over Sokolov area for demonstration.

2.2.3.6 - Data processing, data fusion, algorithm development
2.2.3.6.1 - Mineral mapping from VNIR – SWIR hyperspectral airborne imagery
Mineral detection and mineral mapping haven been demonstrated for the two demonstration sites Sokolov and eMalahleni. Both sites are characterized by active and closing open pit mines, dump sites and ancient mining remnants, responsible for Acid Mine Drainage (AMD). AMD is acidic water (pH <5.0) laden with...
mining remnants, responsible for Acid Mine Drainage (AMD). AMD is acidic water (pH <5.0) laden with iron, sulphate and other metals, that forms under natural conditions when geologic strata containing pyrite are exposed to the atmosphere or oxidizing environments. Much of the acid drainage worldwide is commonly thought to be associated with coal mining, but acid drainage can occur under natural conditions or where sulphides in geologic materials are encountered in metal mining, highway construction, and other deep excavations. Acidic waters are harmful to aquatic organisms and responsible for the mobilisation of heavy metals and their dissemination in the environment. This induces an adverse environmental impact on aquatic life, vegetation and soil fertility.

Spatial mapping of the source of acidification, its pathways and possibly affected areas are of key interest. In summary, mapping of the spatial distribution patterns of the various key minerals and mineral groups can support the evaluation of the soil quality, the risk assessment of possible contamination of surface and ground water bodies, the planning of specific remediation efforts or the assessment of the (future) economical usage potential of former mining sites.

AMD is commonly seen in eMalahleni area, with large pool of AMD formed above flooded mine workings, small dispersed seeps through residential areas with evidences in gardens, streets and potholes, AMD marshes formed in a number of residential gardens killing part of the garden vegetation. AMD also flow in small streams towards the Olifant River.

Using reference reflectance spectra collated on the field, VNIR – SWIR hyperspectral imagery enabled mapping various mineralogies associated with coal mining and in particular minerals typical of AMD. The presence of jarosite, a mineral stable at pH below 3, has been mapped in retention cells downstream of the main coal related industrial area (Ferrobank). Worth to note is jarosite mapped in the same location a year before acquisition of the hyperspectral imagery, using only VNIR high resolution imagery (WorldView_2 images).

The 2009 and 2010 HyMap airborne data of Sokolov, Czech Republic, was use to derive a set of image endmembers to be used for subsequent classification of soils and geological materials. Endmembers were extracted from the reflectance imagery that was not geo-corrected and had no cross-track illumination or BRDF correction applied. Of the 125 atmospherically corrected bands by using ATCOR, 14 of those occurring near the main 1.4 and 1.9 μm atmospheric water absorption features and noisy bands longer than 2.45 μm were removed from the data, leaving 110 bands. For endmember extraction no masking of the data was applied.

Sixty-five ground samples that were collected in 2010 that represent a limited number of soil, clay, and iron-oxide mixtures were used to help identify the endmember reflectance spectra derived from the images. Reflectance spectra of the samples were measured and compiled into a single library and then re-sampled to the 110 HyMap bands. This allowed for a direct comparison and evaluation with endmembers derived using endmember extraction tools. This allowed for endmember extraction to be applied to the full hyperspectral data set for both 2009 and 2010 simultaneously.

In Sokolov low-quality effluents are observed, in particular areas which have led to an acidification of soils and of surface waters.

Here also, hyperspectral imagery supports mapping minerals and mineral associations that are responsible for AMD and soil acidification, hence enabling the derivation of a predictive soil pH map. Diagnostic minerals of low (pH < 3) pH are pyrite, jarosite and lignite. Jarosite in association with goethite...
Diagnostic minerals of low pH (< 3) are pyrite, jarosite and lignite. Jarosite in association with goethite indicates increased pH (3 < pH < 6.5) while goethite alone characterises nearly neutral pH (pH > 6.5).

2.2.3.6.2- Mapping surface water parameters from VNIR hyperspectral imagery

Mapping surface water parameters, including estimated dissolved iron content, dissolved organic matter content (DOC) and estimated inorganic matter suspension have been carried out over the Sokolov open pit area. Linking spectral properties of surface water reflectance with specific chemical-physical parameters makes possible a semi-quantitative mapping of these parameters in the VNIR range of hyperspectral imagery.

2.2.3.6.3 - Mapping vegetation health status from VNIR – SWIR hyperspectral imagery

The biochemical composition of spruce needles with their longevity and exposure to environmental conditions is often used as a bio indicator of soil or air contamination. Particularly the contents of photosynthetic pigments are closely related to photosynthetic performance and can serve as early-warning symptoms of plant stress, before macroscopic changes are detected.

In Sokolov open pit area, physiological status of macroscopically undamaged foliage can be assessed from hyperspectral imagery and stress can be detected prior the symptoms are visually expressed. Reflectance spectra for each Norway spruce health class were calculated from the HyMap image data sets and stress-related trends changing canopy reflectance were identified. Changes in VIS/NIR reflectance can be explained by chlorophyll degradation on one site and carotenoid content increases on the other site, whereas changes in SWIR document falling water consumption as a reaction to the stress. The method proved suitable as the hyperspectral image classification results are in accordance with the statistical assessment of the biochemical properties of the sampled trees as well as with the geochemical properties of the forest sites.

2.2.3.6.4 - Change detection in mining areas from VNIR – SWIR hyperspectral imagery

Temporal changes are important in monitoring mining activities. Changes over two images acquired at two different dates can either be visible (spatial changes) or not visible (spectral changes). Applying dedicated change detection (CD) algorithms to hyperspectral imagery enables mapping land cover changes according to spectral characters. Such change detection highlights the progress of lignite exploitation to the west (any to coal) and overburden removal (any to clayey soil) to the west and its backfilling in the eastern part.

2.2.3.6.5- Mapping minerals from hyperspectral TIR imagery

Some minerals like quartz and silicates do not present specific absorption features in the VNIR – SWIR spectral range and can only be discriminated from their emissivity spectral signature in the TIR range. This information can be used to derive soil properties like fertility and acidity buffering capacity, which are relevant for localized reclamation efforts, assessing soil quality and selection of appropriate reclamation methods. In addition, the data can support evaluating the reclamation success; the yellow areas on the above image correspond to geotechnical engineering banks and trails. Beyond clay and quartz separation, processed thermal infrared data can be used to improve land-use/land-cover mapping approaches as many common minerals show distinctive spectral emissivity signatures in the thermal domain.

2.2.3.6.6- Mapping apparent thermal inertia from TIR hyperspectral imagery
2.2.3.6.6 - Mapping apparent thermal inertia from TIR hyperspectral imagery

Water content in soils is an important parameter in monitoring soil stability, a major concern in mining areas. As mentioned above, hyperspectral imagery in the TIR domain can provide information on surface emissivity and surface temperature.

A new technique to assess soil moisture was developed using the thermal and visible information acquired by the AHS airborne sensor. After processing the data the Apparent Thermal Inertia (ATI) was calculated on a pixel by pixel basis and correlation with the soil moisture values in selected areas was done. It was found that this simple method can provide soil moisture content.

The Apparent Thermal Inertia (ATI) of soils was retrieved from AHS airborne day and night surveys in the Sokolov area. High ATI values may indicate soils with high water content, whereas low values may indicate soils with low water content.

2.2.3.6.7 - Mapping urban footprint from radar imagery

Mining often is associated with uncontrolled urban sprawling. Effective planning requires a reliable current extent of urban areas. In developing countries often no official records are available and heavy informal settlement regularly occurs.

The objective of the Global Urban Footprint (GUF) initiative is to generate a global high-resolution binary mask of urban areas (i.e. built-up) from very high resolution SAR data acquired in the framework of the TanDEM-X Mission. The GUF will serve as a basis for the analysis of human settlements worldwide.

The German TerraSAR-X add-on for Digital Elevation Measurement (TanDEM-X) mission collected two global data sets of very high resolution (VHR) synthetic aperture radar (SAR) images between 2011 and 2013. Such imagery provides a unique information source for the identification of built-up areas in a so far unique spatial detail. In particular, with respect to optical sensors, the weather-independent, day and-night data acquisition capability and the low sensitivity toward atmospheric effects of SAR systems make them particularly suitable to provide temporally and radiometrically consistent global data coverages.

2.2.3.6.8 - Exploitation of high resolution DEMs derived from optical satellite imagery

Digital Elevation Models (DEMs) are required for several tasks like generation of orthoimages, generation of contour lines and for many geographic information system applications, including spatial risk assessment. DEM based on spaceborne systems are a cost effective alternative in comparison to more expensive airborne surveys.

Stereo satellite sensor systems, as WorldView-II take advantage of its motion over its orbit to change its viewpoint. In order to still image the same area, the satellite slightly changes its attitude (de-pointing capabilities). In a typical setup, the satellite will, slightly before overpassing the area of interest, rotate and acquire an image of the land-strip in front of him. Just after having bypassed it, it will be rotated backward and takes a second image from its new position. This de-pointing capacity is critical, hence limiting stereo-imagery to satellite being able to rotate along their track.

Tailings dams leakage might be responsible for the release of contaminated water into the environment and contamination of downstream surface waters. The downstream flow from the Makmal tailings dam in Kyrgyzstan, displayed in red on the following image, has been computed using a specifically designed flow accumulation algorithm, applied to a 1 meter resolution DEM derived from a WorldView-II satellite stereo.
accumulation algorithm, applied to a 1 meter resolution DEM derived from a WorldView_II satellite stereo pair. It clearly shows that the potential contamination of the surface drainage by leakage from the tailing dam should not affect the town of Kazarman, but may however contaminate the Naryn River downstream. Tailings dam failure and associated mud flows represent a major threat in mining areas and have been responsible in the past for many casualties. Modeling the downstream extension of a possible mud flow would be a valuable tool in securing downstream populations and ecosystems as well as in implementing new tailing dams. The brown area represents the maximum possible downstream extension of a 5-meter thick mud flow resulting from the failure of the tailings dam. It has been computed by taking into account a constant thickness of 5 metres, whereas in reality the thickness should decrease with distance from the source, depending on the mud viscosity. According to this model, only the most western part of the Kazarman urban area might be affected by the flow. It shows however a large area of the floodplain might be affected, leading to potential grassland contamination by tailings mud.

2.2.3.6.9 - Exploitation of very-high resolution DTMs from LiDAR airborne survey

The main advantage of LiDAR compared to DEMs based on space borne optical stereoscopic systems is it provides information on the ground surface elevation (i.e. a Digital Terrain Model, DTM) while the latter ones provide a digital elevation (DEM) of the first hit only (e.g. top of canopy or building elevation). LiDAR hence is suitable for mapping terrain models, detecting subtle surface elevation differences and providing advanced topographic information.

LiDAR DTMs are of particular interest in mining areas where they provide invaluable quantitative information on terrains modified by the mining activities, such as subsidence, mining-related engineering works, waste volume calculation, etc.

Very high resolution DTMs enable computation of accurate drainage pattern, being of natural or anthropogenic origin. Mining areas, where topography has been considerably modified, can take benefit from such patterns.

The LiDAR data collected over the eMalahleni test site have been used to derive:
• an image showing areas of internal drainage within the study area (in blue)
• a run-off model showing the surface water flow pattern (in purple).

A comparison of these two data sets makes possible determining the water ingress potential within the Mpumalanga mining area. The left image shows an area where a relatively large surface area contributes run-off to the underground mine workings, making this an area with a high potential for water ingress and the generation of acid mine drainage. The right image shows an area where an artificial trench acts as a cut-off trench, diverting surface run-off away from the underground mine workings.

2.2.3.6.10 - Mapping thermal anomalies from Thermal Infrared airborne survey

Uncontrolled combustion of coal is a serious problem on a global scale. Since coal can easily be oxidized and often has a prominent “self-heating” capacity, many coal types have a tendency to combust spontaneously once sufficient oxygen is available and natural cooling is prevented. The rapid expansion of often insufficient controlled small-scale coal mining activities and the increasing amount of not adequate closed down and now abandoned coal mine sites are supposed to have led to an
amount of not adequate closed down and now abandoned coal mine sites are supposed to have led to an increase of human-induced coal fires.

According to the National Database of Derelict and Ownerless Mines, based on the Council for Geoscience's SAMINDABA (South African Mineral Deposits Database) database, there is close to 150 coal deposits in the Mpumalanga Province which had been mined in the past, but which was no longer mined and operating mines. Thus, these coalfields need to be not only inventoried at regional and local scales through rapid and cost effective methods, but also assessed, monitored and secured, wherever appropriate.

Thermal infrared cameras can be used on ground to locate otherwise invisible and monitor coal fires, in particular regarding underground coal combustion, as well as in temperature measurements. FLIR cameras mounted on board of airborne platforms have been used in identifying areas of underground combustion, and, if possible, identifying areas of contaminated groundwater flow. Thermal airborne survey carried out over the Mpumalanga coal field has been able to identify areas of active coal combustion as well as identifying areas of mine water seepage. In the survey flown, seepage areas showed up as zones of elevated temperature, due to two factors:

• The survey was flown in the early hours of the morning, before sunrise. Under these conditions, water saturated soil will have cooled slower than dry soil due to its higher thermal inertia and heat capacity.
• In some cases, water is heated by underground coal fires, resulting in persistent higher water temperatures, the effect of which can be measured using thermal sensors.

Analysing dust collected in the neighbourhood of mining activities provides information about aerial pollution plumes around mining areas.

The map below shows the result of statistical method called factor analysis, which groups elements with similar spatial distribution into one single variable, called factor. Five factors were extracted, and one of them, named factor 4, possibly reflects the amount of coal dust in the atmosphere. It joins the distribution of following elements: Be, Li, As and Al into a single variable. Higher factor score means higher impact. Such results can be useful for monitoring of impacts and for planning of measures which prevents the mobilisation of dust.

Deliverable D3.3 entitled “Presentation of algorithms” describes the processing steps used for the different data sets, while deliverable D2.4 entitled “Thematic accuracy and validation” presents the methods used to validate the thematic data and the thematic accuracy of the processing results. Deliverable D 3.4 entitled “Report on methodological developments for site footprint and risk analysis, considering possible “generic” aspects” explains possible risks and risk assessment strategies.

2.2.4 - From indicators and data processing to EO-based products

It was recognised that single EO datasets rarely meet a particular need for environmental or societal information in isolation, but that it is necessary to integrate several different types of measurement. This step examined how the EO datasets (from space, aircraft and in-situ) acquired and processed during the previous stages could be fused and/or integrated into one (or several) products to meet the environmental
previous stages could be fused and/or integrated into one (or several) products to meet the environmental indicators identified and the environment concerns documented in the Conceptual Site Models.

It was necessary to establish a mechanism to assess the data and to consider and decide what EO-based products would be made. Throughout the project, a very extensive product development matrix was generated and maintained for each of the three demonstration sites, which tabulated the stakeholder-driven indicators with the environmental parameters derived from the Conceptual Site Models (CSM) along with the EO data available to the EO-MINERS project.

The matrix clarified which input layers were required to make each possible EO-based product, and stipulated deadlines for data delivery, including their format and the partners responsible. The matrix was used within the project as a decision-making tool to determine the range of EO-based products that were made in EO-MINERS in response to the stakeholder requirements. Furthermore, it helped to prioritise which products were made. It was a transparent method to explain which products were made, and why. It is important to note that EO-MINERS did not make a product relating to every indicator at each site. This was not possible due to limitations of resources, EO data and time within the project duration.

Nevertheless, the generic approach developed (conceptual site models, indicators and the required EO data) can easily be adapted for additional indicators or time series analyses, which could not be targeted in detail during the project life time.

In total, 22 integrated products were developed, based around the thematic areas of land use, air quality, water quality and geohazards. Annex 4 lists all of the products and the associated Indicator, along with the primary EO datasets used to construct the product.

Initial interviews with the stakeholders highlighted that there was a wide range of expertise and understanding. Some already had experience of EO datasets and were users of GIS software while others had no experience of any EO data whatsoever. In order to make the EO-based products understandable to the wide range of stakeholders several product formats we developed. The product formats that were delivered include:

• Paper maps (A0 and A3)
• Digital maps (two-dimensional GeoPDF format)
• 3D PDFs
• Google Earth visualisations (KML/KMZ format)
• Digital 3D visualisations (in GeoVisionary™ format)
• Animated fly-throughs

The EO Products were presented to the stakeholders at workshops at the mining sites in the Czech Republic, South Africa and Kyrgyzstan (see 3.3.1). The presentations included displays of the paper maps as well as live demonstrations of, and interactions with, the full range of digital products. In order to provide an overview on the EO product development achievements, a printed booklet was prepared and distributed for each demonstration site that showed the diverse EO products presented at the workshops.

Deliverable D4.1 entitled “Earth Observation Product Review” details all the approach and presents the matrix and all developed EO-based products.

2.2.5 - Modeling urban sprawling

Interpretation of medium resolution satellite (Landsat Thematic Mapper) imagery over the period 1989 – 2002 – 2010 shows a strict correlation, in eMalahleni and Middelburg municipalities, between development of mining activity and urban sprawling, without being able to understand the type of relation yet.

The activity here aimed at defining a conceptual model to simulate mining related urban sprawl of the
The activity here aimed at defining a conceptual model to simulate mining-related urban sprawl of the eMalahleni municipality, with more detailed aspects on social and economic criteria to be considered. The spatial dimension would have enabled taking into account demography while time series would enable the simulation of the dynamic evolution of urban sprawling. The level of detail to be considered regarding the spatial dimension has been the most pressing concern as it depends on the level of detail of the relevant data collated. Unfortunately, very few of the required data could have been made available to the project and in particular no time series of socio-economic data have been made accessible.

The work hence consisted in building a minimal model which features essential (extensions, constraints...) functionalities. The objective is thus not to present a directly operational result for experts or policymakers but rather to lead to a demonstration of the potential of the approach as well as the deriving tool in terms of simulation of this type of problem.

The first step consisted in calibrating the model using 2002 and 2010 data (2002 in brown, 2010 in blue). In second step, possible urban extension was simulated for 2025 from the model.

Deliverable D4.2 entitled “mine site simulation platform” describes the methodology and the results of this simulation.

2.2.6 - EO-MINERS and GEO

The key objective of this activity was to advocate the expansion of the GEOSS to include observation systems and applications relevant to minerals issues. During the project period, the focus was on securing the inclusion of Minerals Tasks in the next GEO Work Plan, 2012-15. To this end, text was submitted on minerals during the Work Plan review, both by EO-MINERS partners and GEO Members. The aim was to ensure that the minerals-related Task(s) already appearing in the draft Work Plan were retained and the text improved to reflect minerals issues better. This was supported by lobbying to include minerals in the Work Plan and by a series of workshops and presentations at GEO European Project Workshops, Work Plan Symposia and Plenaries, that culminated in a EuroGeoSurveys presentation during a EuroGeoSurveys side-event at the GEO Plenary VIII in Istanbul, November 2011. The Work Plan was adopted by GEO Members and Participating Organisations at the Istanbul Plenary, November 16th - 17th 2011 and included two Tasks on minerals issues:

- SB-05 (Impact Assessment of Human Activities), Component C2 (Impact Monitoring System for Geo-Resource Exploration and Exploitation) focused on pollution and waste aspects
- EN-01 (Energy & Geo-resources Management), focused on exploration and exploitation

EO-MINERS and its Partners are noted as a contributor to both of these tasks and the coordinator has been appointed as Point of Contact for the Task SB-05-C2. The diagram below shows where these Tasks fit into the new GEO structure, both reporting to the Societal Benefits Implementation Board.

EO-MINERS maintained its high level of engagement with GEO after this significant change was achieved. As a result, it is among the 8 projects mentioned in the 4-pages GEO Fact Sheet Brochure that was distributed at the GEO X Plenary and Ministerial Summit Ministers in Geneva, January 2014 and among the projects of key achievements included in the GEO "Report on Progress" 2011 - 2013.

Looking to the future, several partners’ ongoing activity within GEO has led to them being invited to either co-chair or participate in the GEO Working Group of Coal and Environment (WGCE) that held its first meeting during the GEO X Plenary in Geneva, January 2014.
Meeting during the GEO X Plenary in Geneva, January 2014.

GEO aims to build a GEOSS that meets all the critical observational requirements of its societal benefit areas. Without question, this now includes minerals and related mining impacts. This leads to a new set of EO requirements being placed on GEOSS. EO-MINERS has shown what these are and this information can be used to describe the earth observing system necessary for minerals applications. Doing this is revealing as it is clear that some of the required components only exist on aircraft platforms or as part of a short-lived spaceborne experiment. EO-MINERS work on this sets out a clear agenda for GEOSS to develop in this application domain. If we are to measure and monitor minerals in the environment, a key requirement is to have continuity of spaceborne hyperspectral sensor systems.

Potential Impact:
The third objective of EO-MINERS focuses on dissemination, promotion and capacity building actions in order to provide bodies involved and interested in impact assessment of mining activities as well as all other interested parties with the results of the project work. Further, it also concentrated on developing means for a sound “trialogue” between the three main groups involved, the industry, governmental organisations and other stakeholders (e.g. NGOs). This “trialogue” intends to assist towards the reconciliation of interests in order to reach common agreement upon actions to deal with environmental and social impacts of mining activities.

3.1 Trialogue activities
The trialogue methodology was finalised and agreed among the project partners. In principle, the trialogue dealt with any kind of stakeholder interaction activities in the sense that the outcomes of such events were considered in the conclusions of the trialogue of EO-MINERS. Therefore, the EO-MINERS trialogue comprised two parts:
a) Trialogue related to the European level (“European trialogue”), aiming at determining the way of presenting the project contribution to policy requirements, and,
b) Trialogue related to each of the mining sites under investigation, so-called “Site-specific trialogue”, describing the current situation specific for the particular site, including problem identification and the EO-MINERS product-type response.

3.1.1 Site specific trialogue
The site-specific trialogue workshops were held at:
• Sokolovska uhelna open-cast lignite mining area, Czech Republic, in March 2013, split between the mining company and general stakeholders;
• Mpumalanga coal field around eMalahleni (Witbank), South Africa, in April 2013 as a “all in one” workshop;
• Makmal gold mine, Kazarman, Kyrgyzstan with local stakeholders and mining company and, in Bishkek with national stakeholders, in June 2013.
The participants of the site-specific triologues were provided with the results of the interviews made during the site visits and the derived site-specific indicators. Results of EO measurements (field measurements, remote sensing, etc.) were prepared for presentation as well as EO-MINERS products available at that time. The set of actions was completed with a moderated discussion to retrieve the general perception of the stakeholders and their perception of indicators, suitability of EO measurements and EO products. All this served as input for the trialogue workshop and helped the moderator(s) to give an introduction into the problems to be tackled and to moderate the discussion. The workshop itself ran 100% in local language (simultaneously translated to English and vice versa).

A summary of the stakeholders' feedback highlighted several clear outcomes:
A summary of the stakeholders’ feedback highlighted several clear outcomes:

- The products were well received, with comments that they are attractive tools that present the information in an easy-to-use form.
- It was noted that the products are appropriately sophisticated, responding to the diverse user needs.
- Beyond the paper maps and posters, the use of 3D technology was “much appreciated” to help describe the often complicated 3D nature of the system being monitored.
- They served the purpose of informing the trialogue, as epitomised by the quote “The maps and data are able to help developing a common language and base of communication between otherwise separate stakeholder discourses, among civil society and administration (and ideally also mining sector).”
- Confidence in the results was raised (particularly in Kyrgyzstan) where independent, often international sources, were thought of as more trustworthy.
- Some stakeholders recognised that long-term monitoring (often encompassing seasonal variability) is required, and that the products need to be updated appropriately over time.
- Limitations of the EO Products were also identified:
  - The first related to the health impacts of the measurements. This was a lesson that was learnt during the project and the products were adapted not only to provide quantified measurements but also to state clearly if the measurements registered could pose a health risk to the local population. This was still not sufficient to appease some stakeholders who requested that medical practitioners should be included in order to take relevant blood or tissue samples.
  - Secondly, whilst no local stakeholder mentioned this issue, an attendee at the GEO & Minerals Workshop (Brussels, 2013) raised the issue that the project did not address the exploration phase of the mining lifecycle. This is a result of the fact that we had to replace the test site in Chile with the site in Kyrgyzstan, therefore none of our test sites were actively involved in exploration.

The positive feedback from stakeholders is clear evidence that EO-MINERS has successfully demonstrated the development and application of EO Products to the mining sector at the three test sites. In spite of the numerous EO Products developed (we produced twenty-two EO Products in a range of formats), we were unable to address every indicator, but that was expected at the outset of the project.

The tools and methodology developed in EO-MINERS are exportable to other sites worldwide. Furthermore, new data sources (in situ, airborne and satellite) are constantly becoming available (e.g. EO-MINERS used WorldView-2 to map AMD, and WorldView-3 will have improved spectral resolution) and these will increase even further the number of social and environmental issues (indicators) that can be monitored, as well as increasing the confidence in the measurements gained compared to those achieved currently with existing sensors. The financial cost of producing the EO-Products has not been calculated because this is a research project. Nevertheless, it is expected that costs will be reduced in future with streamlined methodologies and the new range of sensors. This include the upcoming fleet of ESA’s Sentinel sensor systems, whose data sets will be free of charge aiming in stimulation and supporting wider use and the development of further service elements within Copernicus and beyond.

A summary of trialogue activities and results is provided in Deliverables D5.6 (one per site). Deliverable D3.5 entitled “Feedback on interaction with stakeholders and capacity building” reports on feedback from stakeholders.

3.1.2 European trialogue

The European trialogue has to be seen in a wider policy context (Europe 2020 Strategy, flagship initiative for a resource efficient Europe (common vision to support a long-term perspective for an efficient use of natural resources)). It provided a platform for interaction between all stakeholders at the European level.
Natural resources. It provided a platform for interaction between all stakeholders at the European level that are directly and indirectly related to the minerals sector (e.g. industry, policy makers, professional associations, governments and authorities, NGOs, environment agencies, etc.). This also included groups dealing with the environmental and social effects of mining. The target groups comprised among many others the Copernicus (former GMES), GEO (Group on Earth Observation), the Raw Materials Initiative and ETP-SMR (European Technological Platform for Sustainable Mineral Resources).

Three trialogue activities, all combined into a meeting held between 18-19 September, 2013 in Brussels, were proposed at European level, addressing different target groups: the GEO community, the Member states and the industry:

1. The “Minerals and GEO” workshop consisted of presentations from GEO and EO-MINERS, followed by a panel discussion. It was stressed that sustainable mineral resources have risen up the agenda in Europe and internationally, and discussions focused on the following:
   - How should initiatives like GEO evolve to reflect that?
   - What kind of observing system is needed to support these changes?
   - And how can we work through initiatives like Copernicus to realise the key elements of that observing system?

2. The “Resource Flows and Economics” (MFA) workshop consisted of presentations from DG ENV, International Resource Panel and Italian Institute for Environmental Protection and Research. It was followed by a panel discussion focusing on:
   - The contribution of EO methods to the development (population) of Resource Efficiency macro/meso scale indicators - with a particular focus on mining activities
   - At which scale are the potentials highest? How could indicators benefit from EO data regarding: accuracy, timeliness, costs?
   - The applicability of EO methods to improve the current material accounting schemes, on European flows, on global material flows

3. The “EO-MINERS project” (best of locals) workshop focused on presentations about the EO-MINERS approach and product developments together with the stakeholders’ feedback from the site specific trialogue workshops. The discussion centered on:
   - the potential contribution of the EO-MINERS developments to the policy requirements and policy developments,
   - their effectiveness in monitoring, meeting high environmental standards, and contributing to the improvement of public acceptance
   - their applicability at local, regional and global scales.

The people attending represented a very good mixture of the stakeholders addressed. The following key messages were obtained:
   - Objective, reliable and verifiable data are key to discussion
   - Results must be transformed into applicable services
   - Tools must be easy to use
   - Project didn’t consider economical based indicators
   - EO has a major role in sustainable development
   - EO can have an important role when delivering data quicker than established mechanisms
   - EO must have a clearly define application
   - The term ‘indicator’ caused intensive discussion, because different groups understand the term
3.2 Dissemination activities
The results of the work undertaken the EO-MINERS project need to be made known to related and also other interested parties. To this effect, a wide variety of dissemination media were proposed including written, oral and visual presentations in order to inform and actively involve governmental organisations, industry and societal groups during the project as well as in its aftermath. A lot of presentations were given at related external events or conferences or at special events. The purpose was to inform the public about general project achievements. Targeted audience was the industry and their trade organisations and governmental organisations. Society organisations did participate as well but they were not the main focus due to the more technical content of the presentations. These groups were addressed by other means (see trialogue activities).
Several scientific papers have also been issued. They were published in international journals and in this way increased the dissemination of project results.

The project web site was another means of dissemination. The project web site is populated with a lot of results and other materials so that the “outside world” can have access to the EO-MINERS achievements. The project issued a series of non-technical leaflets and a promotional video to address the general public (all downloadable at http://www.eo-miners.eu/additional_material/publicity_materials.htm).
Specifically, towards the end of project, the results of the project and its achievements and consequences are collated and presented in a book/brochure edited within the frame of the project and published using an established publishing house (Deliverable 5.5 entitled “Guide for Good Practice”)

3.3 Exploitation of results
There are no protection measures foreseen. The results obtained in the project will be used in the day-to-day business of the project partners and form the basis for further development of EO products. Other organisations who view the products and results may wish to produce similar outputs for other mine sites. Details of any IP related issue are reported in the project deliverable D5.7 entitled “Final Plan for the Use and Dissemination of Foreground”.

List of Websites:
EO-MINERS - Home page : http://www.eo-miners.eu/
Contact: webadmin@eo-miners.eu ian.martin@miro.co.uk

Related documents

! final1-final-report-technical.pdf

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