EO-MINERS

Monitoring the Environmental and Societal Impacts of Mining
the EO-MINERS project

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GRSG Annual meeting
Frascati–7-9 December 2011
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 the society in view of its sustainable development while improving its societal acceptability.
Assess **policy requirements** at macro (public) and micro (mining companies) levels

- **Theme of indicators**
  - a. Land Use
  - b. Mass flows
  - c. Energy Flows
  - d. Air related
  - e. Water related
  - f. Transport
  - g. Geotechnical
  - h. Accidents
  - i. Social impacts
  - j. Regional development
  - k. Economic vulnerability

Define environmental, socio-economic, societal and sustainable development criteria and **indicators** to be possibly dealt using EO
Demonstrate the capabilities of integrated EO-based methods and tools in:

- monitoring,
- managing
- contributing to reduce the environmental and societal footprints of all phases of a mining project
Contribute making reliable and objective information about affected ecosystems, populations and societies, basis for a sound "trialogue" between industrialists, regulatory bodies and stakeholders.

The project will initiate and develop a sound "trialogue" between the three main groups involved based on reliable and objective information about ecosystems, populations and societies affected by mining activities.
## Who we are?

<table>
<thead>
<tr>
<th>Beneficiary name</th>
<th>Country</th>
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<tbody>
<tr>
<td>(BRGM) Bureau de Recherches Géologiques et Minières</td>
<td>France Coordination</td>
<td>Council for Geoscience</td>
<td>South Africa</td>
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<td>Mineral Industry Research Organisation</td>
<td>UK</td>
<td>KyrgyzAltyn</td>
<td>Kyrgyzstan</td>
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</table>
EO-MINERS Consortium

3 demonstration sites (CZ, ZA, KG)
EO-MINERS Sokolov lignite open pit demo site (CZ)

- AMD (Acid Mine Drainage)
- Impact on vegetation
- Coal fires
- Sediment (coal) Dust
- Landscape degradation
EO-MINERS Emalahleni (Witbank) coal field demo site (South Africa)

- The largest coal field in ZA
  - More than 60 x 60 km
- AMD (Acid Mine Drainage) affecting
  - Drainage system and wetlands
  - Urban areas
- Coal fires
- Dust
- Subsidence
- Landvalue degradation
- Uncontrolled urban sprawling
• Cyanide contamination
  – Surface waters
  – Groundwater?

• Employement 70% depending on mine activity
EO tools and methods

• **Satellite data**
  – Conventional optical sensors: Landsat Thematic Mapper, ASTER
  – Very high resolution optical sensors, such as Ikonos, Quickbird, WorldView_II, SPOT 5
  – Radar sensors, in particular for INSAR applications

• **Airborne data**
  – Airborne imaging spectroscopy (hyperspectral) survey
  – Airborne geophysics: radiometric, electromagnetic, aeromagnetic
  – Thermal infrared (multi and broad band)

• **In situ monitoring methods**
  – Time-lapse electrical resistivity tomography (ALERT)
  – Ground monitoring networks
  – In situ point measurements (reflectance, emissivity)
  – Field spectroradiometry campaigns
  – Information and/or measurements about vegetation, soil, groundwater and dust
  – Chemical Model and 3D characterization of the contaminated soils
Results

case histories

Field measurements:
1) reflectance and emissivity: QA (new Standards and Protocol)

Sokolov HyMap: 2009-2010, AIS 2011
1) Innovative Standards and Protocol
2) Thematic Mapping

Witbank TM:
1) Change detection
2) ALERT
Case History 1

Spectral Library: Emissivity

Derived from emission measurements with Spectro Radiometer SR5000
Case History II

Sokolov HyMap 2009-2010, AHS 2011

Hyperspectral QI/QA – (Innovative Standards and Protocols)

Thematic Mapping - (minerals, vegetation, man made objects)

Spectral based Change Detection (Innovative methods + Error Estimation)
Hypespectral QI/QA – Innovative Standards and Protocols

High performance – High Accuracy and Error Estimation

(2) $\Delta b_i = |b_{AP}(\text{noisy}) - b_{AP}(\text{noise-reduced})| = (SR+N) - (SR+N-N^*) = N^*$.

(3) $INI = \frac{1}{I} \sum_i \Delta b_i$.

SNR -

$L_s^*(\lambda) = \frac{E_A}{\pi} = \text{Constant}$

Radiance -

Mosaic integration (geometry + radiometry) -

GeoScore = SLRI * MILE
Sokolov - Thematic Mapping *(minerals, vegetation, man made objects)*

HyMap 2009
HyMap 2010
AHS/CASI 2011

2009, 2010, 2011 flights during the summer time
HyMap, AHS
Hyperspectral airborne surveys

HyMap: 126 bands VNIR, SWIR1, SWIR2

AHS: 80 bands 0.4 to 12.7 µm

HyMap 2009  HyMap 2010  AHS 2011 night flight
Hyperspectral imagery (HyMap 2010)
Coal Dust

Contamination coal spot in the environment (not known)
Hyperspectral imagery (HyMap 2010)  
Coal Dust - Ground Sampling

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<th>EPA Industrial (mg/kg)</th>
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Hyperspectral imagery (HyMap 2010)
Mineral Mapping
Hyperspectral imagery (HyMap 2010)
3D - Mineral Mapping

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<th>Class</th>
<th>Sq km</th>
<th>Percent</th>
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Elevation Change Detection

- CARTOSAT DEMs
- Difference 2009 – 2010
- Cyan = no deviation
- Difference = excavation or backfilling
Hyperspectral imagery (HyMap 2010)

AMD Mapping

• Exploitation of airborne imaging spectroscopy for mineral and vegetation mapping
Map of the Norway spruce canopy chlorophyll content

chlorophyll content was estimated by applying the $D_{719}/D_{704}$ regression model. E – Erika, H – Habartov, M – Mezihorská, S – Studenc. $C_{ab}$ – content of chlorophyll $a+b$ (g of pigment related to dry mass), A-J – 10 groups of 5 sampled trees.
Vegetation Health Mapping II

Health status classes for the trees without visual damage symptoms:
1 - the worst and 5 - the best result

Relative frequencies (%):
The entire Sokolov lignite basin area (top) and the individual sites Erika, Habartov, Mezihorská and Studenec (below).
Coal mine area progress in one year
Spectral based Change Detection II

(Innovative methods + Error Estimation)
Spectral based Change Detection

(Innovative methods + Error Estimation)
Similarity measures value span 2010

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<th>SAM</th>
<th>SID</th>
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<th>SCM</th>
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<tbody>
<tr>
<td>5 - Forest</td>
<td>6 - Grass</td>
<td>7 - Soil+Grass</td>
<td>8 - Soil</td>
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<tr>
<td>9 - Clay</td>
<td>10 - Water</td>
<td>11 - Asphalt</td>
<td>12 - Top roof</td>
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Spectral Based Change Detection
Witbank TM (2000-2010), ALERT 2011

• Change Detection
• 24/7 Monitoring System (subsurface monitoring system)
Landsat TM time series – Witbank (ZA)

- Evolution of mining and urbanisation along time
- Employment and urbanisation strongly dependant on mining

TM – Change detection (1989-2002 as an example)
24/7 Monitoring System (subsurface monitoring system)
Design specification (WITBANK)

- Site preparation/installation requirements communicated to CGS November/December 2010
  - Trenching
  - Power supply (solar/batteries)
  - Enclosure
- ALERT instrumentation designed by BGS
  - ALERT instrument
  - Sensors arrays
  - Comms.
Trenching and sensor installation

Sensor installation for trench ERT A. The ground conditions on site show significant variation away from (left image) and adjacent to (right image) the cut off trench. Individual electrodes, with a 2.5 m spacing are highlighted with red circles.

Completion of sensor installation

Closed trench (ERT B) after sensor installation

Portacabin after completion of security fence
Perspectives

- Potential of Remote Sensing together with EO techniques in assessing mineral industry footprint
- Capability of imaging spectroscopy (hyperspectral imagery) in mineral and vegetation mapping
- Potential of application to mining and oil & gas sectors is huge
  - Number of sites
  - Many isolated areas
- Preparation for Hyperspectral spaceborne data
  - VNIR – SWIR 1&2 (+TIR) spectral coverage
  - <10 µm spectral bands
  - high S/N
Thank you for your attention!

Contact: s.chevrel@brgm.fr (EO-Miners Leader and Coordinator)