Remote Sensing in Europe: Status analysis and trends focusing on Environment and Agriculture

Dr Ioannis Manakos
Researcher

Center for Research and Technology Informatics & Telematics Institute
My special thanks for the invitation and the chance to introduce and discuss my ideas and experiences with you to Prof Maria Petrou, Director, CERTH-ITI
...from space to place

ioannis Manakos, Dr.
how decisions here may be supported by activities up there or how geoinformation may support environmental & agricultural management

int.@ EARSeL, Secretary General [www.earsel.org]

loc.@ CERTH-ITI, Researcher [www.iti.gr]
...a few words about the speaker

ioannis Manakos, Dr.

BSc Geology (RS - GIS - Physical Geography)

MSc Agriculture (RS - GIS - ES - Erosion)

PhD Forestry (RS - GIS - Precision Agriculture)
A scientific networking platform fostering the exchange of ideas and experiences while utilizing remote sensing products and methods for tackling contemporary challenges in the following fields:

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<th>Forestry</th>
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1. Considerations
2. Policy making in Europe
3. Remote Sensing challenges
4. Remote Sensing in practice
5. Remote Sensing platforms/ sensors
6. Examples – Projects
7. Trends and Outlook
Remote Sensing in Europe: Status analysis and trends focusing on Environment and Agriculture

...considerations

http://fathersdaypictures.blogspot.com/2011/03/keeping-family-happy.html
Linkages between Ecosystem Services and Human Well-being

© 2005 Millennium Ecosystem Assessment
...objectives

Major: Quality of life

Supportive:
- Food security
- Conservation of the natural resources
- Reduction of risks & threats
- Sustainable Rural and Urban development

Challenge:

Special adjustment for the human – environment interaction surface

in 4D: x, y, z, space and t, time
Indirect:

- Demographic
- Economic
- Sociopolitical
- Science & Technology
- Cultural & Religious

Direct:

- Changes in Local Land Use & Land Cover
- Species introduction or removal
- Technology adaptation & use
- External inputs
- Harvest & resource consumption
- Climate change
- Natural, physical and biological drivers

**NEED for Spatial Information**

...socio-economic dimensions and drivers of LUCC

The human footprint – The earth from another perspective

Meat consumed per person and day, 2005 (www.worldmapper.org)
...socio-economic dimensions and drivers of LUCC

The human footprint

Brazil, Amazon basin, viewed from Google Earth at two different snapshots in time.

http://earthobservatory.nasa.gov/Features/Deforestation/printall.php [NASA - Earth Observatory – Tropical Deforestation, Rebecca Lindsey]
The human footprint

http://visibleearth.nasa.gov/images/1438/earth_lights.jpg
...socio-economic dimensions and drivers of LUCC

The human footprint
...topics in sequence

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...wide area coverage & real time data required

Information Services for Decision Making and Implementation Support are particularly based on

a) the near real time registration of the surface status

b) harmonized geo-information products

c) the combination, analysis and modeling of data received from Earth Observation satellites as well as ground-based networks

Target is to

a) monitor changes [location, magnitude, reason]

b) support and test scenaria by projecting the validated trends in the present and past to delineate possible situations in the future
...office to nature in the EU

POLICY ADAPTATION & FEEDBACK

EU POLICY

FUNDING FRAMEWORKS

RESEARCH

OPERATIONALIZATION

CAPACITY BUILDING

DISSEMINATION & AWARENESS RAISING

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The European Environment Agency (EEA) is an agency of the European Union.

EEA’s task is to provide sound, independent information on the environment.

The European environment information and observation network (EIONET) aims to provide timely and quality-assured data, information and expertise for assessing the state of the environment in Europe and the pressures acting upon it.
... EU Policy consultants/ supporters

Role of the European Environmental Agency:

- Continuing to support implementation of Europe's environmental legislation through analyses and assessments of Europe's environment;

- Ensuring continuous access to high quality environmental data, information and services;

- Producing integrated environmental assessments and forward studies for Europe increasingly in the global context;

- Addressing critical environmental priorities as they arise on the policy agenda;

- Improving communications and dissemination to decision-makers and citizens via multi-media, user-friendly, multilingual information.

(from the EEA presentation at the 4th EARSeL SIG WS on LU/LC in Prague, 2011)
Global Monitoring for Environment and Security:

- An independent Earth Observation system for Europe

- The largest fleet of satellites and atmosphere/earth-based monitoring instruments in the world

- An end user-focused programme of services for environment and security

- Joined-up information for policymakers, scientists, businesses and the public

- Europe’s response to the global need for environment and climate monitoring
... EU Policy consultants/ supporters

High-level view of the GMES architecture (image credit: EC, ESA)
... strategic areas

1 Environmental themes
   1.1 Air quality
   1.2 Air pollutant emissions
   1.3 Biodiversity
   1.4 Greenhouse gas emissions
   1.5 Freshwater
   1.6 Marine

2 Cross-cutting themes
   2.1 Climate change impacts
   2.2 Vulnerability and adaptation
   2.3 Ecosystems
   2.4 Environment and health
   2.5 Maritime
   2.6 Sustainable consumption and production and waste
   2.7 Land use
   2.8 Agriculture and forestry
   2.9 Energy
   2.10 Transport

3 Integrated environmental assessment
   3.1 Integrated environmental assessment
   3.2 Regional and global assessment
   3.3 Decision support
   3.4 Economics
   3.5 Strategic futures

4 Information services and communications
   4.1 Shared Environmental Information System
   4.2 Communications

(from the EEA presentation at the 4th EARSeL SIG WS on LU/LC in Prague, 2011)
... need and use of land cover/use data

1 Environmental themes
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   4.1 Shared Environmental Information System
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(from the EEA presentation at the 4th EARSeL SIG WS on LU/LC in Prague, 2011)
Remote Sensing Working Groups in Europe

...+++++

- EARSeL
- ISPRS
- ESA
- DLR
- CNES
- EARSC
- UNESCO
- Remote Sensing Working Groups in Europe
- Belspo
- EURISY
- EUROGI
...topics in sequence

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Land cover changes – are the scientists aware? Active?

- About 14 % of all papers in major journals address CD during last decade

- Land-use & land-cover and forest are the dominant categories, followed by agriculture, urban, ocean and cryosphere

- CD methods based on „ALGEBRA“ have been and still are the most used ones. „CLASSIFICATION“ and „TRANSFORMATION“ approaches – so far – play a minor roll

- CD methods based on optical data sets are dominant. Significantly less use SAR data or a combination of both

- CD is a robust approach, very promising, especially for high resolution optical data sets.

(after the University of Bonn presentation at the 4th EARSel SIG WS on LU/LC in Prague, 2011 / Prof Gunter Menz)
Detect land cover changes – using?

**Algebra:**
- results are change magnitudes for individual channels or ~ combinations; limited use for change labeling

**Transformation:**
- results contain information about changes, often difficult to interpret, postprocessing for change labeling necessary

**Classification:**
- result is a final change map, no further labeling necessary, disadvantage: supervised training of change classes is necessary

(after the University of Bonn presentation at the 4th EARSel SIG WS on LU/LC in Prague, 2011 / Prof Gunter Menz)
Image analysis approaches/ information extraction

Automatic Learning

Supervised Learning

SemiSupervised Learning

Unsupervised Learning

Active Learning

Passive Learning

Training samples definition


Most promising approaches nowadays:

- Supervised classification methods + Active learning methods: active learning is an effective method for transforming an initially unrepresentative training set in a representative and optimized training set [requires: Supervised classifier; Query function; Supervisor (user); Training set; pool of unlabeled samples]

- Semisupervised approaches: jointly exploits labeled (training) and unlabeled samples in the learning of the classifier

- Kernel methods (e.g. Support Vector Machines) that are robust to the problem of the small ratio between training samples and feature space
Land cover changes challenges

- Preprocessing issues (geometry & radiometry)

- Systematic investigations about...
  ...the influence of CD algorithm, segmentation approach and threshold selection
  ...the accuracy of the change mask,
  ...the influence of number and type of sensors
  ...the influence of features

- Towards automation?
  Selection of training areas
  Selection of threshold
  Selection of segmentation level
  Development of Automated processing chains for CD

(after the University of Bonn presentation at the 4th EARSel SIG WS on LU/LC in Prague, 2011 / Prof Gunter Menz)
Accuracy assessment

Why is the accuracy low?

Genuine difficulty in discriminating classes (definition)

Technical problems such as mis-registration, pre-processing, ++

Use of inappropriate reference targets

  spatial autocorrelation that violates the assumption of sample independence & spatial variability of spectral signatures of land-covers

Use of misleading measures of accuracy

Use of a biased approach to accuracy assessment – not all errors seen to be in the remote sensing

(Inspired by Prof Giles Foody, University of Nottingham & Prof Bruzzone, University of Trento)
Accuracy assessment

One poorly understood sources of error and uncertainty is the impact of error in ground data.

Ground data are not a gold standard reference – contain error and are not ‘truth’.

Ground data ‘quality’ is of major importance on estimating the accuracy of land cover change detection and land cover change extent.

Impacts vary with nature of errors and often with prevalence.
...topics in sequence

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Ground data provide reference data for:
- classifications
- atmospheric corrections
- modeling

especially in agriculture...

Remote sensing’s role is the normalization of the relative signal registered with the remote sensing sensor in a typical physical measurement value for the growth stage.

---

Remote sensing data
Ancillary information
Vegetation growth models
Direct models
Inversion algorithms
Geo- and bio-physical parameters

e.g.: $\sigma_o$, $\rho$
e.g.: sun illumination, rain mean air temperature
e.g.: number of leaves, LAI
e.g.: $\sigma_o$, $\rho$
e.g.: biomass, crop yield

ESA, 1998
5 Signature types are known in RS:

- **spectral:**
  - bio-geo-chemical parameter: pigment- and water status, cell structure, mineral composition, etc.

- **angular:**
  - plant architecture, canopy structure

- **textural:**
  - pattern of similar frequency inside a structure

- **polarisation**
  - not sufficiently explored, low experience

- **temporal**
  - change of signatures between two or more observations

*Information content with respect to the status of objects*

(Gerstl, 1990)
Coupling of Ground with Spaceborne data

Final identification & classification result
Airborne support for agricultural management

Air photo DAEDALUS ATM
Spatial resolution 5m
RGB presentation: NIR,R,G

Vegetation Index NDVI: four segmentation levels

Vitality & Biomass:
- High
- Average
- Low
Vicarious calibration of Airborne Data

Example methodology – steps to follow:

- Simulation of the airborne sensor’s channels
- Calculation of the indices (NDVI, IR/G, G/R)
- Regression analysis with the biomass and yield data
- Evaluation of the findings
- Fusion of the empirical functions

\[ R(\text{in situ}) = a_1 * [\text{biomas or yield}] + b_1 \]
\[ R(\text{in situ}) = a_2 * [\text{airborne image data}] + b_2 \]

for the extrapolation of the findings from the parcels to the whole plot and correction of the atmospheric interference (conversion of the reflection to a value of a physical feature of the canopy)

\[ \text{[biomas or yield estimation]} = \frac{[a_2 * \text{(airborne image data)} + b_2] - b_1}{a_1} \]
Atmospheric correction using Ground Data for WV-2

WV02 Relative Spectral Radiance Response

- No. CLASSES
- RMSE REGRESS
- RMSE ATCOR
- RMSE FLAASH

RMSE (%)

WV2 central wavelength (nm)

No. classes for validation

40 out of 70 © GR, Thessaloniki, CERTH-ITI @ 14/03/12 - ioannis Manakos, Dr. © imanakos@iti.gr © 0030 2311 257 760
Reflection models may be distinguished into

1. *empirical formulas* based on the approximation of the reflectance behaviour by mathematical functions

Red Edge Inflection Point (REIP) vegetation index at the flowering growth stage Versus seed production (wheat sort Flair) –

After Dr J. Liebler, TUM

![Graph showing the relationship between REIP value (nm) and seed production (dt/ha). The equation is given as $y = 8.5166x - 6062.7$ with $R^2 = 0.8755$.](image)
2. *semiempirical models*

Based on approximated consideration of physical processes and the use of complementary empirical parameters.

![Graph showing RMSE errors and input dataset numbers for AMBRALS and PROSAIL models.](image)
Modeling

3. **physical models**
   based on a physical theory, the radiation path and its interaction with every chemical component and physical structure of the plant and canopy elements is simulated

**Prospect Leaf Model**

**SAIL Canopy Model**

**PROSAIL Model**

Leaf inclination angle (°)
Forest Cover Monitoring over Europe

Study sites within the bio-geographical regions
...topics in sequence

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In situ

FIGOS, Zurich
In situ

EGO, JRC, Ispra
In situ

PARABOLA, NASA
In situ

MUFSPEM - Mobile Unit for Field SPEctroradiometric Measurements
In situ

MUFSPEM@MED - Mobile Unit for Field SPEctroradiometric Measurements at the Mediterranean [www.gi-eastmed.net]
In situ
Airborne – Example: DLR Germany

Falcon aircraft

Airborne Reflective Emissive Spectrometer

DO228 Aircraft – Sensors

Credit: M. Gottwald, DLR-IMF

High Altitude and Long Range research aircraft
Spaceborne platforms/ sensors

EO missions handled by ESA

1990

METEOSAT
M-1, 2, 3, 4, 5, 6, 7

2000

METEOSAT Second Generation
MSG-1, -2, -3

2004

METOP-1, -2, -3

2010

Meteo

in cooperation with EUMETSAT

Science

to better understand the Earth

Earth

Explorers

ERS-1, -2

Cryosat 2 (Polar Ice Monitoring)

GOCE (Gravity and Ocean Circulation Explorer)

SMOS (Soil moisture)

ADM/Aeolus (global wind profiles)

EarthCARE (clouds, aerosols)

SWARM (Earth's magnetic field)

Applications

Services
to initiate long term monitoring systems and services

Third-Party Missions: European access to non-ESA missions
ALOS, SPOT-4, Landsat, MODIS, SeaWifs, Scisat ...

ESA Sentinels satellites

+ National missions (Pleiades, TerraSAR, Cosmo-Skymed...)

European users

GR, Thessaloniki, CERTH-ITI @ 14/03/12 - ioannis Manakos, Dr. imanakos@iti.gr 0030 2311 257 760
Spaceborne platforms/ sensors

GMES Space Component
Progressive built-up 2008-2016

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<tr>
<th>Year</th>
<th>SAR</th>
<th>Optical HR</th>
<th>Optical VHR</th>
<th>MR land ocean</th>
<th>Atmospheric</th>
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<tr>
<td>2013</td>
<td>ERS-2</td>
<td>ALOS Landsat Proba</td>
<td>ALOS</td>
<td>Envisat</td>
<td>ERS-2</td>
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<tr>
<td>2009</td>
<td>Radarsat</td>
<td>IRS-P6/P5</td>
<td>Ikonos</td>
<td>Terra/Aqua</td>
<td>Envisat</td>
</tr>
<tr>
<td>2010</td>
<td>Cosmowire</td>
<td>Rapideye</td>
<td>QuickBird</td>
<td>SeaWiFS</td>
<td>GOSAT</td>
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<tr>
<td>2011</td>
<td>Tandem-X</td>
<td>DMC Diurnal</td>
<td>Pléiades</td>
<td>Jason</td>
<td>Scisat</td>
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<tr>
<td>2013</td>
<td>PAZ</td>
<td>SPOT 6/7</td>
<td>PRISMA</td>
<td>SPOT VGT</td>
<td>MSG</td>
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<tr>
<td>2014</td>
<td>Sentinel-1</td>
<td>Sentinel-2</td>
<td>Sentinel-3</td>
<td>PROBA-V</td>
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<tr>
<td>2016</td>
<td>Sentinel-1</td>
<td>Sentinel-2</td>
<td>Sentinel-3</td>
<td>Sentinel-5</td>
<td>Sentinel-5</td>
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</tbody>
</table>
# Spaceborne platforms/ sensors

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<thead>
<tr>
<th>Sentinel 1 – SAR imaging</th>
<th>All weather, day/night applications, interferometry</th>
<th>x 2 satellites, 693 km, Dawn dusk orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentinel 2 – Multi-spectral imaging</td>
<td>Land applications: urban, forest, agriculture,.. Continuity of Landsat, SPOT</td>
<td>x 2 satellites, 786 km, LTDN 10:30 am</td>
</tr>
<tr>
<td>Sentinel 3 – Ocean and global land monitoring</td>
<td>Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry</td>
<td>x 2 satellites, 814 km, LTDN 10:00 am</td>
</tr>
<tr>
<td>Sentinel 4 – Geostationary atmospheric</td>
<td>Atmospheric composition monitoring, trans-boundary pollution</td>
<td></td>
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<tr>
<td>Sentinel 5 – Low-orbit atmospheric</td>
<td>Atmospheric composition monitoring (S5 Precursor launch in 2014)</td>
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<th>possible launch dates</th>
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<tr>
<td>Sentinel 1: 2013 / 2015</td>
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<tr>
<td>Sentinel 2: 2013 / 2016</td>
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<tr>
<td>Sentinel 3: 2013 / 2017</td>
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<tr>
<td>Sentinel 4: 2019</td>
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<tr>
<td>Sentinel 5: 2020+</td>
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</tbody>
</table>
**Spaceborne platforms/ sensors**

**TerraSAR-X**

**MISSION:**
provision provide value-added SAR (Synthetic Aperture Radar) data in the X-band, for research and development purposes as well as scientific and commercial applications

**TanDEM-X**

**MISSION:**
Create global DEM in 3 years
12 m resolution, <2 m vertical accuracy
1.5 petabytes expected
1,000,000,000,000,000 B (at 8bits/B)

Credit: DLR and M. Gottwald, DLR-IMF
Spaceborne platforms/ sensors

TanDEM-X DEM of Bolivia

http://www.terrasar.de/image-gallery
### Spaceborne platforms/ sensors

#### EnMap mission (launch: 2015)

**Spectral coverage**
- 420 nm - 2450 nm
- VNIR (420-1000 nm)
- SWIR I (900-1390 nm)
- SWIR II (1480-1760 nm)
- SWIR III (1950-2450 nm)

**NEΔR (Noise Equivalent Delta Radiance)**
\[\text{mW/cm}^2 \text{ sr } \mu\text{m}\]
- VNIR: 0.005
- SWIR I: 0.003
- SWIR II: 0.003
- SWIR III: 0.001

**Spectral sampling**
- VNIR: 5-10 nm (6.5 nm average)
- SWIR: 10 nm (average)

**Spectral stability (VNIR-SWIR)**
- 0.5 nm

**Radiometric stability**
- ± 2.5 % between calibrations

**GSD (Ground Sampling Distance)**
- 30 m x 30 m nadir

**Frame readout rate**
- 230 MHz (4.3 ms integration time)

**MTF (Modulation Transfer Function)**
- > 25% at 16.6 cycles/km (Nyquist) for all wavelengths across track
- > 16% at 16.6 cycles/km (Nyquist) for all wavelengths along track

**Swath width**
- 30 km

**FOR (Field of Regard)**
- ± 390 km

**Smile and smile effects**
- ≤ 0.2 pixel

**Band-to-band registration (VNIR/SWIR detectors)**
- ≤ 0.2 pixel (co-registration)

**Local equator crossing time**
- 11:00 hours

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Schematic view of the delay observation technique of the HSI instrument (image credit: OHB, Kayser Threde)

---
...topics in sequence

1. Considerations
2. Policy making in Europe
3. Remote Sensing challenges
4. Remote Sensing in practice
5. Remote Sensing platforms/ sensors
6. **Examples - Projects**
7. Trends and Outlook
GMES on-going projects

- [www.gmes-geoland.info](http://www.gmes-geoland.info) (preoperational GMES Land Monitoring Service)
- [www.gmes-atmosphere.eu](http://www.gmes-atmosphere.eu) (preoperational GMES Atmosphere Monitoring Service)
- [www.emergencyresponse.eu](http://www.emergencyresponse.eu) (preoperational GMES Emergency Response Service)
- [www.gmes-gmosaic.eu](http://www.gmes-gmosaic.eu) (preoperational GMES Security Service)
...on-going projects

- Land Cover and Land Use Monitoring
- Biophysical Parameters
- Seasonal Change Detection
- Spatial Planning
- AgriEnvironmental Services
- Water Services
- Forest Services
- Land Carbon Monitoring
- Global Crop Monitoring
- Natural Resource Monitoring in Africa
- geoland

Remote Sensing in Europe: Status analysis and trends focusing on Environment and Agriculture
...on-going projects

Green: Stocked
Red: Non stocked areas

Remote Sensing in Europe: Status analysis and trends focusing on Environment and Agriculture
...recent supportive projects

Science Education through Earth Observation for High Schools (and GMES Users)

- World of Images
- Introduction to Remote Sensing
- Conservation of Natural and Cultural Heritages
- Coral Reefs
- Land Use and Land Use Change
- Remote Sensing and Geo-information Technologies in Agriculture
- Natural Resources Management
- Ocean Colour in the Coastal Zone
- Understanding Spectra from the Earth
- Remote Sensing Using Lasers
- Ocean Currents
- Marine Pollution
- Time Series Analysis
- Modelling of Environmental Processes
- 3D Models Based upon Stereoscopic Satellite Data
- Classification Algorithms and Methods
- Satellite Navigation with GPS
...topics in sequence

1. Considerations
2. Policy making in Europe
3. Remote Sensing challenges
4. Remote Sensing in practice
5. Remote Sensing platforms/ sensors
6. Examples - Projects
7. Trends and Outlook
...outlook

Credit: Markus Erhard Hans Dufourmont, EEA, Warsaw, Geoland2 Forum, 14-15.09.2011
Lectures at CERTH-ITI for the Winter of 2012 - Remote Sensing in Europe: Status analysis and trends focusing on Environment and Agriculture

...outlook

**Perspectives and Planning**

**EC / EEA**

**Workplan GIO Land Services**

<table>
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<tr>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tr>
<td>JFMAMJASOND</td>
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<td><strong>Member States Grants</strong></td>
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<td><strong>Web Service and Dissemination</strong></td>
<td><strong>Harmonization EU – national data</strong></td>
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<td><strong>Extract from GMES Initial Operations (GIO) timetable</strong></td>
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GMES funding – Transition phase to Operation

The GMES Programme shall build on research activities’ (Art. 2 of the proposal for a GMES Regulation)

Where we are today ...


R&D
Preparatory actions
Initial Operations
EU Operational programme

European Commission
Enterprise and Industry
...outlook & suggestions

Services are being implemented through GIO 2011-2013 (High Resolution layers)

Launch of satellites delayed, due to budget issues

EU policy is being realigned towards a new strategy regarding GMES funding

Keywords:

Research    Budget    Harmonization    Engagement
Documentation Quality Usability Members states
Thank you for your attention

At your disposal

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