INSAR services for GMES:

Utilisation of ERS & ENVISAT for pan-European geo-hazard land motion monitoring

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(1) ESA, ESRIN, Frascati, Italy
GMES Action: Terrafirma

The consolidated pan European service portfolio looking at Land Motion Geo-Hazard (subsidence & landslides)

**SERVICES**

H1: Basic ground motion measurements
H2: Causal interpretation of ground movement
H3: Modelled results
M1: Monitoring product
LSI: landslides inventory service
LSM: landslides monitoring service

**EXAMPLE POLICIES**

**LOCAL**
- Mining - e.g. F: Loi no. 99-245 du 30 mars 1999
- Planning law specific for each European country

**NATIONAL**
- Environment assessment - e.g. UK: Town and Country Planning Act 1990
- Public participation - e.g. Freedom of Information Act 2000
- Emergency response and civil protection

**EUROPEAN**
- Aarhus Convention
- 6th Environmental Action Programme
- Directive on Assessment of Effects of Public & Private Projects on Env.

**SUPPLIERS**
- NPA
- BGS
- TNO
- BRGM
- TRE
- SciSys
- GAMMA
- Altamira

**USERS**
- BRGM
- BGS
- ARUP
- TNO
- ENEL
- EMSC (Int)
- PGI
- EPPO
- IGME
- NKUA
- GSI
- NGU
- ICC
- IGME
- IG
- GSI
- GII
- SOLETAN
- CHE
• Two types of product: **Historical** and **Monitoring**.
• Different levels of analysis: **Geological Value Adding**
• Historical Products:
  – Integrations of ERS-1/2 SAR and ENVISAT ASAR data **already in archive**
  – 3 levels of sophistication:
    ➢ H-1: Base product - ‘raw’ PSI output
    ➢ H-2: Causal Product (initial interpretation)
    ➢ H-3: Modelled Product
• Monitoring Products: Implies specific satellite tasking, or ordering of next ‘visible’ acquisition(s).
• Landslide Inventory Product: Basin analysis.
• Landslide Monitoring Product: Specific landslide event.
STOKE H2: THE SPATIAL DATASETS ANALYSED (Credits BGS)

Digital Geology at 250k, 50k and 10k, inc:
- Bedrock and superficial deposits geology
- Distribution of borehole and shafts (1:25k)
- Surface Mineral Resources (1:25k)

OS Topographic data, 250k, 50k, 10k & 1.25k

NEXTMap elevation data (radar derived)

Derived geological data from Geosure (1:50k)
- Superficial deposits thickness and Rockhead elevation

Geohazard data from Geosure (1:50k):
- Shrink Swell, Compressibility, Dissolution, Running Sand, Slope Stability

Engineering Geology data (1:25k or larger):
- Artificial Ground, Engineering characteristics, Hydrogeology
- Undermined areas, Ground stability constraints, Fault reactivation
- Leachate and gas constraints

Geophysical Data:
- Magnetics and Gravity
PS POINTS & 1:25K GEOLOGY, NE STOKE-ON-TRENT (Credits BGS)
Example: H2 product Geological 2.5D model (Credits BRGM)
GMES TERRAFIRMA Stage 2: Deliver services to users in EU25 countries

<table>
<thead>
<tr>
<th>Historical subsidence motion measurements</th>
<th>New ground motion measurements concerning urban subsidence so as to increase overall coverage to at least 10% of the overall population of EU 25 and applicant states</th>
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</thead>
<tbody>
<tr>
<td>Subsidence motion monitoring</td>
<td>Service for at least 7.5% of the cities for which baseline historical subsidence motion measurements are planned over three years. During Year 1 provide service for at least two cities in total.</td>
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<tr>
<td>Subsidence causal analysis</td>
<td>Provide service for at least 15% of the cities for which historical subsidence motion measurements are planned over three years. Primarily focus on areas where the required geological information is available.</td>
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<td>Subsidence modelling / forecasting analysis</td>
<td>Provide service to at least two sites concerned with urban subsidence for which the dynamic analysis of subsidence phenomena is relevant (for instance post-mining activities, flood defence, etc).</td>
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</table>
GMES TERRAFIRMA Stage 2: landslide services

| Landslide inventory       | Depending on the specific requirements of the local/regional administration
|                          | Provide service for at least two separate basins/regions in Europe and affected by landslide risk
|                          | During Year 1 provide service for at least one basin/region. |
| Landslide motion monitoring | Provide service for at least 5 different sites in basins/regions affected by landslide risk. During Year 1 of Stage 2 provide service for at least two sites. |
Landslide monitoring (example from ESA DUP project SLAM, Cutigliano Italy)
User criteria concerning GMES services:

**Availability, Reliability, Affordability**

GMES Geo-hazard land motion services are available: **16 H1, 11 H2-3, 1 M1**

New GMES Geo-hazard land motion services: **17 H1, 8 H2-3, 2 M1, 2 LSI, 4 LSM**

At Q3 2005

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**Product status**

- 7 H1a products
- 1 H1b product
- 27 H1c products
- 10 H2a products
- 1 H3a product
- 1 M1 product

= **47 PRODUCTS**

At Q3 2005
Amsterdam (H1c)      Athens (H1a)           Athens (H1c)       Palermo (H1c)
Haifa (H1c)           Istanbul (H1c)        Lisbon(H1c)        Dublin (H1c)         Sofia (H1c)
Sosnowiec (H1c)      Stoke-on-Trent(H1c)    Thessaloniki(H1b)  Brussels (H1c)     St. Petersburg (H1c)
GMES TERRAFIRMA Stage 2: deliver services to users in EU25 countries
User driven criteria concerning GMES services:

- **Availability**
- **Reliability**
- **Affordability**

GMES services require supply chain redundancy

<table>
<thead>
<tr>
<th>InSAR provider</th>
<th>Current monthly processing capacity</th>
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<td>TRE</td>
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</table>

Conservative estimates of maximum number of PSI processes per month, by InSAR provider
User driven criteria concerning GMES services:

Availability, Reliability, Affordability

ACCESS to SERVICES:

- GMES services delivered via Service Level Agreements (SLA) between provider and recipient (Geological Survey, City, etc); obligations for both parties; only 2 service deliveries are financed by ESA. Approach:

  1. **Signed SLAs** with description by the GS/user (expected benefit of service, end-user, non EO data & tools available, availability of non space/non R&D funding, etc)
  2. Proper information concerning user feedback (benefit of service)
  3. Overall, aim at equally serving users at European level (25 EU countries)

Point of access: [www.terrafirma.eu.com](http://www.terrafirma.eu.com)

User organised within **User Executive Bureau**: EMSC (Chair) alongside with EGS and EFG. Represent all users interested in Land Motion Geo-hazard (national Geological Surveys, administrations and authorities concerned with landslide risk, civil protections, etc)
Timing & tasks of GMES Service Element:

- Stage 1 (2003-2005): consolidation
- Stage 2 (today-3years): scaling up

**Task 1: User Federation & Strategic Planning**
Build user awareness, acceptance & adoption of services; Gather requirements from new users
Generate user-oriented promotional materials and packages; Deliver service-related training
Support ESA-EC communication activities; Engage key users

**Task 2: Service Network Coordination**
Establish and manage a geographically distributed network of service providers; Manage Configuration Control of the Service Network; Integrate and manage common network infrastructure; Negotiate common access conditions to external data sources; Enforce network-wide quality and validation processes; Define and maintain standards for service deliver; Coordinate with other GMES Providers

**Task 3: Service Provision & Qualification**
Generate & deliver services; Verify service quality and validation; Evaluate & report on service utility

**Task 4: Service Portfolio Evolution**
Test & integrate new and improved methods; Improve validation of services; Improve compliance with user-domain standards

GMES TERA FIRMA kicked off in October 2005
Barcelona for Soletanche Bachy

Product: Barcelona
User: Soletanche Bachy

HELPING TO ASSESS EFFECTS OF TUNNELLING

Period: ERS 1 & 2 data from 1995-2000
First MONITORING Service of Terrafirma

ERS-ENVISAT integration

Every possible scene is programmed and acquired to MONITOR structural stability

Product: Barcelona
User: City of Barcelona
Issues raised by users in the course of this activity (2003-2005):

- **INSAR measurements: quality assurance & validation issues**
Limitations of PSI measurement techniques:

- Single line-of-sight issues - horizontal vs vertical motions: not 3D vectors
- Phase ambiguities and the limitations of InSAR in high displacement-rate environments
- Linear and non-linear motion detections - implications for the user

Scatterer character:

- The significance and quantification of the coherence threshold which determines the 'quality' of scatterers included. (eg using linear model)
- Characterisation of scatterers, e.g. ground or building, implication of multi-path reflections.
INSAR measurements validation

PSI Processing:

• VACs process from RAW or SLC. Different SAR processors can yield different results. This could affect PSI output.

• The processing chains in general yield different results, depending on such factors as the nature of the fitting algorithm employed (e.g. linear, polynomial), nature of the statistical analysis made to produce the atmospheric phase screens. What is the precision variance between TF processing chains?

• Integrated ERS/Envisat processing: done?

• Difference/trade-offs with RSAT, ERS or ENVISAT results?
INSAR measurements validation

Accuracy of PSI measurements:

• The positional accuracy of the PSI point (or InSAR pixel) in both absolute and relative terms, and its relation to scale.

• The accuracy of the derived height in both absolute and relative terms.

• The accuracy of the motion measurement in both absolute and relative terms - comparison with other displacement data (GPS, levelling).

• The significance of the 'reference point' and its relationship to the relative accuracy of other scatterers (e.g. the accuracy decreases with distance from the reference).

• Overall budget of errors.
Validation: Responses today:

1) **Within GSE TERRAFIRMA:** QA of services to users
   Validation of Level 1 products’ **geological relevance**
   - Practical/qualitative validation against each site’s geology by integration of InSAR with in-situ geoscience data
   - **F:** BRGM and CETE; **I:** APAT and CESI; **NL:** TNO and RWE; **UK:** BGS and Arup
   Production of **hazard related products** for end-users
   - Level 2 – initial interpretation of causes of motion
   - Level 3 – geophysical modelling/risk assessment
   **Deliverable:** Terrafirma **Product Validation Manual**

2) **Scientific response:** ESA originated PSIC4 study
   - PSI Accuracy Validation
   - PSI Results Inter-comparison

3) **Scientific response:** brought by you within FRINGE’05 this week!
• Day 3, Wednesday 30 November 2005:

12:50-13:10 **PSIC4 validation activities** Daniel Raucoules (BRGM)

• Posters (examples):

**PSIC4: the IREA contribution based on the exploitation of the SBAS approach**
Eugenio Sansosti (IREA-CNR)

**DLR's results of the PSIC4 study**
Nico Adam (DLR)

**Interferometric Point Target Analysis over the PSIC4 test site**
Tazio Strozzi (Gamma Remote Sensing AG)
Continuity of data for user services

Planned EO missions suitable for INSAR services:

- Sentinel 1: C Band, continuity of data for user services in particular for GMES services – incl. land motion geo-hazard
- RADARSAT-2 (C Band)
- TERRASAR-X (X Band)
- COSMO-SKYMED (X Band)
- ALOS PALSAR (L Band)
- others
Day 5, Friday 2 December 2005
Session 10: Future missions

• 9:00-9:20
  TanDEM-X: A Satellite Formation for High Resolution SAR Interferometry
  by Gerhard Krieger (DLR)

• 9:20-9:40
  Interferometric capabilities of ALOS PALSAR and its utilization
  by Ryoichi Furuta (JAXA)

• 9:40-10:00
  RADARSAT-2: Mission Overview and Applications
  by Bernhard Rabus (MDA)

• 10:00-10:20
  SAR Interferometry Capabilities of Canada's planned SAR Satellite Constellation
  by Dirk Geudtner (CSA)

• 10:20-10:40
  Mission and System Characteristics of the European Radar Observatory (Sentinel-1)
  by Evert Attema (ESA)