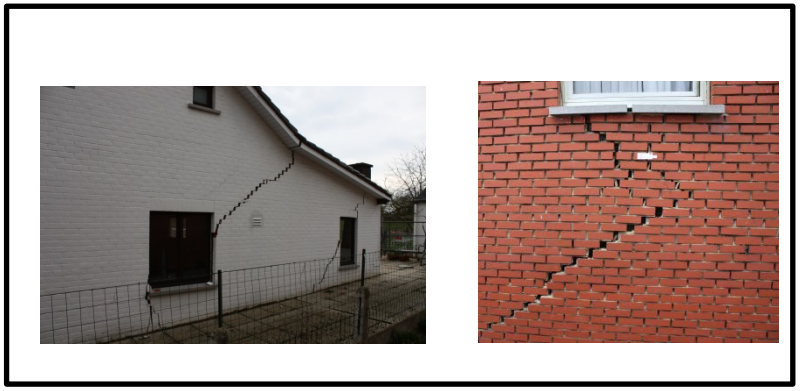
Land Motion Monitoring in Wallonia
Use of Radar data to study land movement

Nathalie Stéphenne – ISSeP
Christian Barbier - CSL

Post-mining risks: subsidence, outbreak, flooding and/or stability problems

Risk management by

- groundwater pressure and discharge monitoring to detect anomalies (2003-2015)
- Radar interferometry (2006)

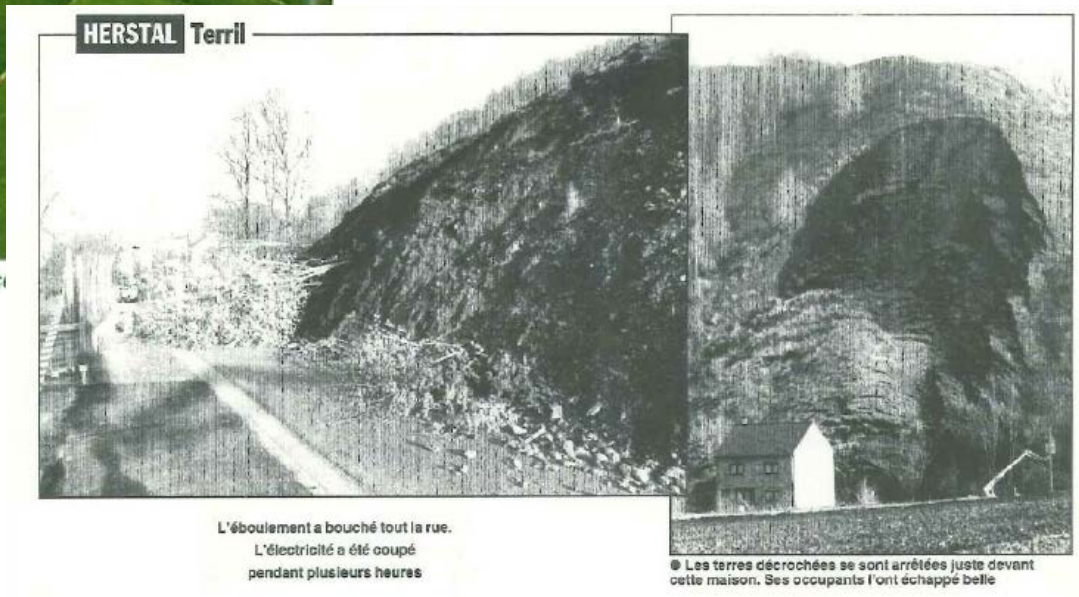


St Vaast, Mons basin (2009)

Wandre, Liège basin (Franck, 2006)

La Malogne, Cuesme,
(22/04/2015)

Vue générale de l'effondrement survenu le 22 avril 2015 (photo aérienne Polic



L'éboulement a bouché tout la rue.
L'électricité a été coupé
pendant plusieurs heures

Les terres décrochées se sont arrêtées juste devant cette maison. Ses occupants l'ont échappé belle

La Petite Bacnure,
Liège
(01/04/1999)

Bridge the gap between EO science and operational services

- CSL presentation : University lab specialised in Signal Processing
- Fundamentals on RADAR
- SAR Interferometry (InSAR) : measure of surface changes
- Potential applications
- CSL projects
- ISSeP presentation : administration specialised in Environment and facilitator of EO in other public services
- Role of ISSeP in integration of EO services

In A Nutshell

- Space Research Centre created in 1959
- Department of Liege University (Belgium)
- Centre of Excellence in Optics
- First ESA coordinated facility in 1976
- Staff of 100 persons (60% of engineers/physicists)

http://www.csl.ulg.ac.be/

CSL Organisation

3 programs interacting closely :

- **Testing**
- **Space Systems**
- **Technology Partnerships**

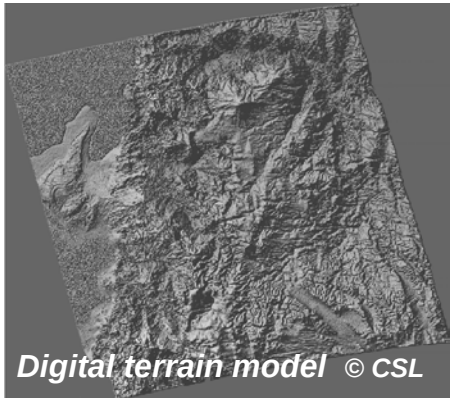
8 laboratories :

- **Signal processing**
- **Electronics**
- **Surface Engineering**
- **Lasers & NDT**
- **Optical Design & Metrology**
- **Mechanical & Thermal Engineering**
- **Test Facilities**
- **Quality**

Signal Processing Laboratory

Christian Barbier

- **Observations of the Earth** using the **SAR** (Synthetic Aperture Radar) of the ERS (Earth Resources Satellite)

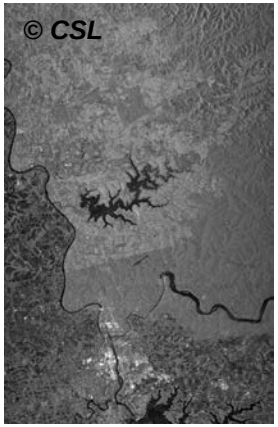


Digital terrain model © CSL

Wide range of practical applications :

- elevation model, small surface movements detection (earthquakes, landslides or glacier advancement, hazard detection system for mining industry)
- mapping and monitoring of land use (forestry and agriculture)
- biomass potential
- security & defense (maritime surveillance)
- etc.

- **Synthetic Aperture Radar data processing**



© CSL

Example of SAR Image Reconstruction

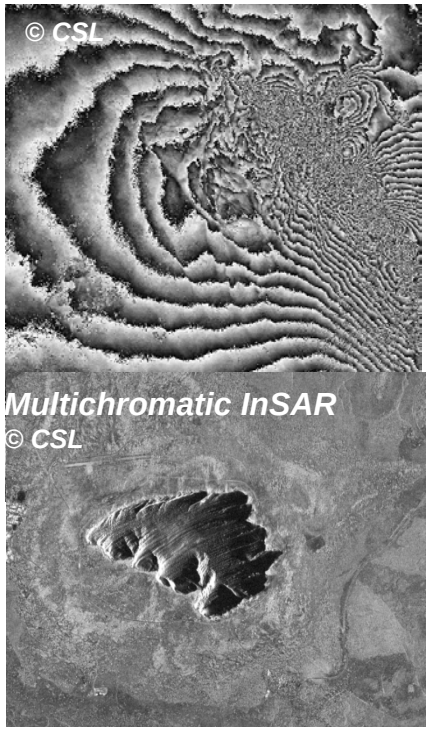
SAR Image Reconstruction

SAR Interferometry (InSAR)

SAR Polarimetry (PolSAR)

Polarimetric SAR Interferometry (PolInSAR)

Multichromatic InSAR



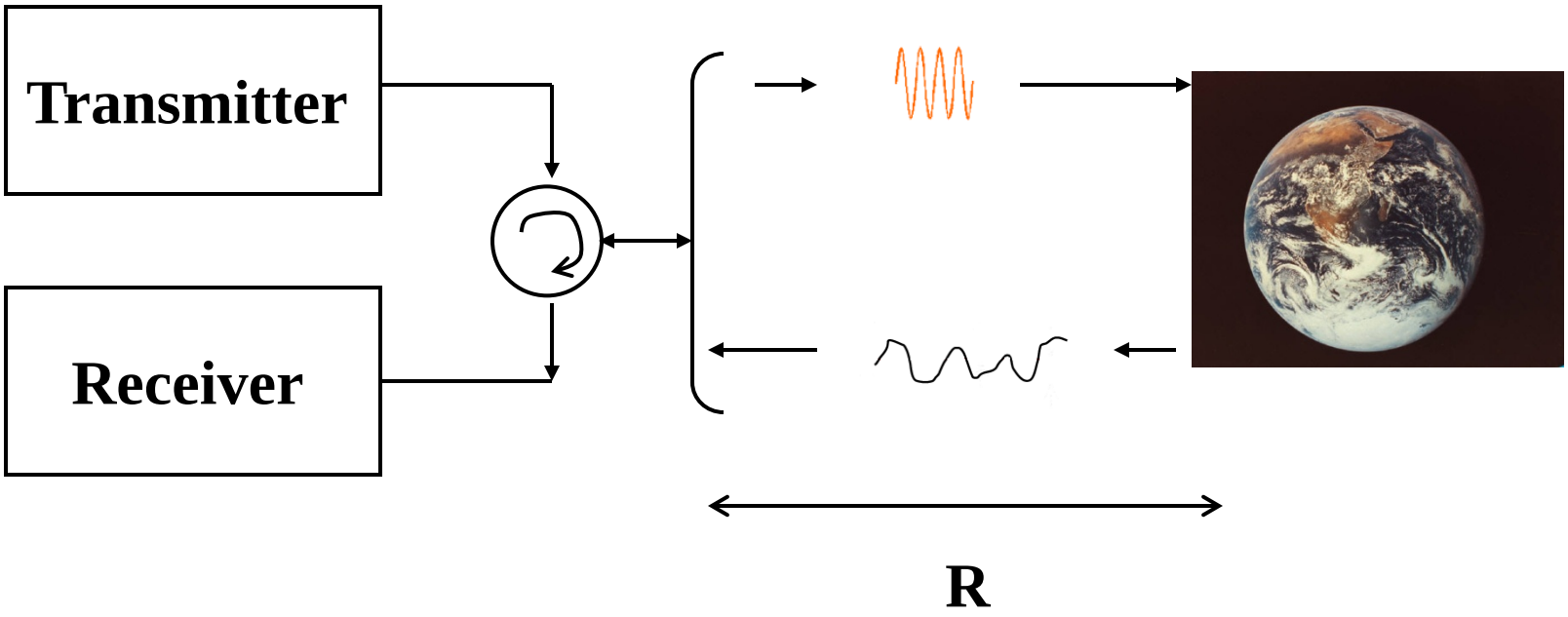
© CSL

Multichromatic InSAR

© CSL

Differential nterferometry

RADAR = RAdio Detection And Ranging



Information in :

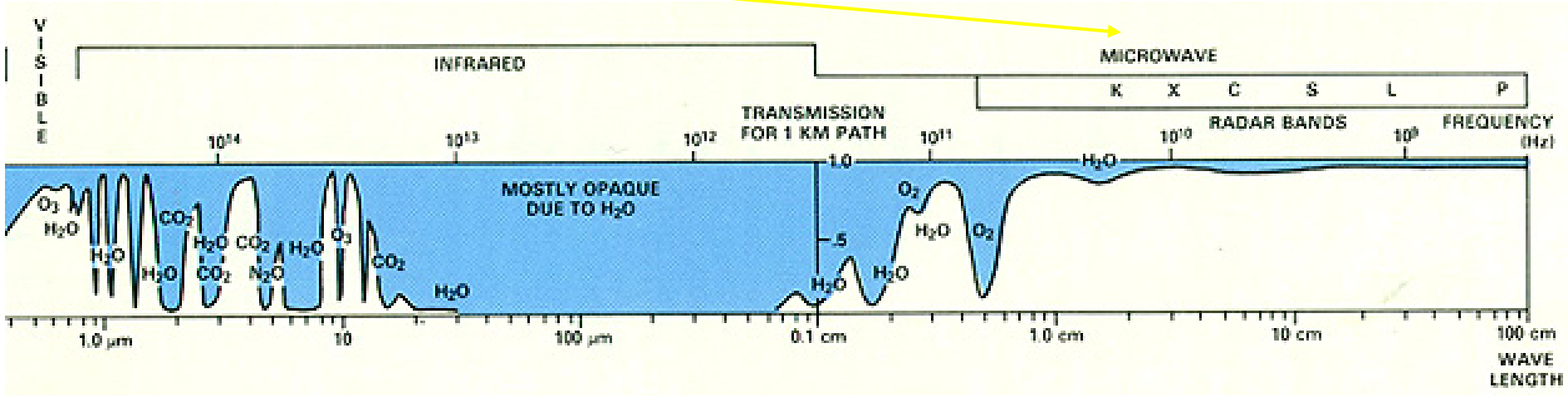
- **Distance : $R = c\Delta t/2$**
- **Signature : σ**

Two specificities of radar :

Observations

✓**night and day.**

✓**all-weather.**



Every pixel tells the story

$$pixel = \underbrace{A}_{\substack{amplitude \\ SAR}} \exp(j \underbrace{\phi}_{\substack{phase \\ InSAR}}) \underbrace{\vec{p}}_{\substack{polarisation\ state \\ PolSAR}}$$

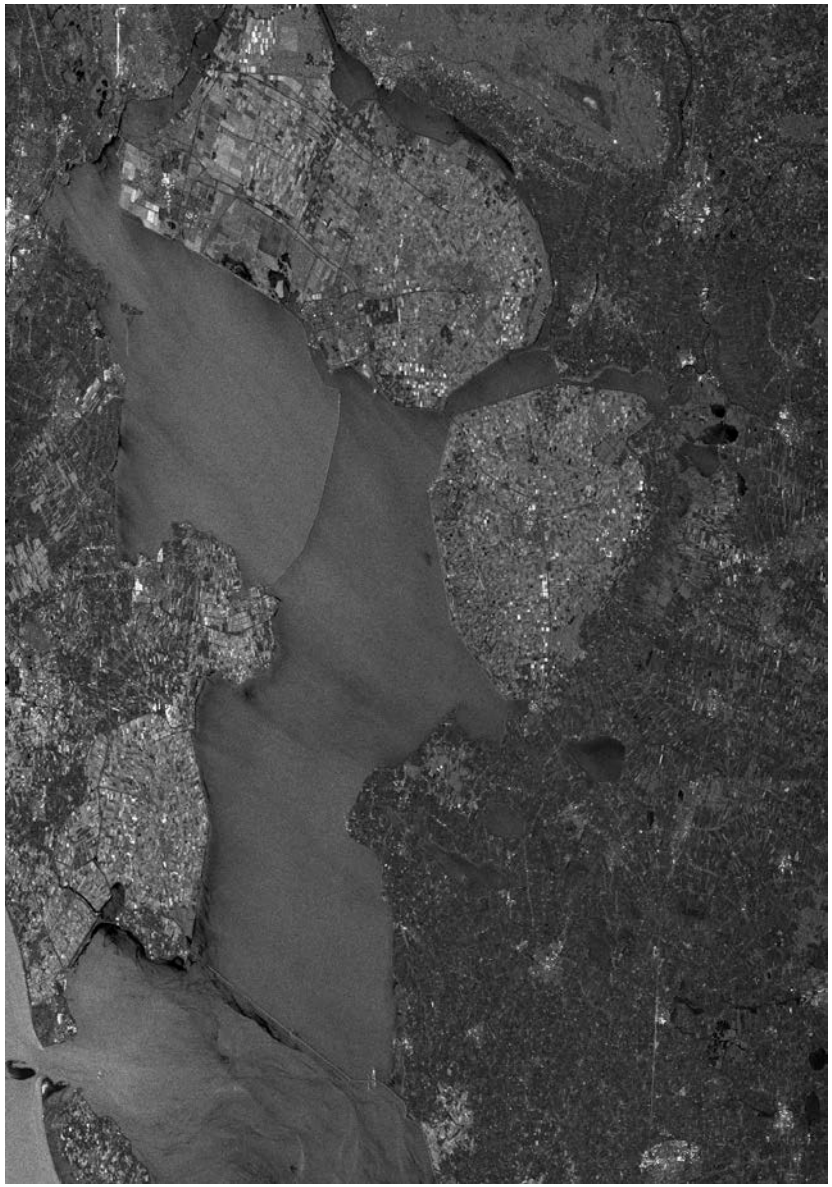
PolInSAR

« Usual » (but not so trivial) imagery

$$pixel = \underbrace{A}_{\substack{amplitude \\ SAR}} \exp(j \underbrace{\phi}_{\substack{phase \\ InSAR}}) \underbrace{\vec{p}}_{\substack{polarisation\ state \\ PolSAR}}$$

PolInSAR

Flevoland (NL)



SAR INTERFEROMETRY (InSAR)

SAR Interferometry (2-Pass version)

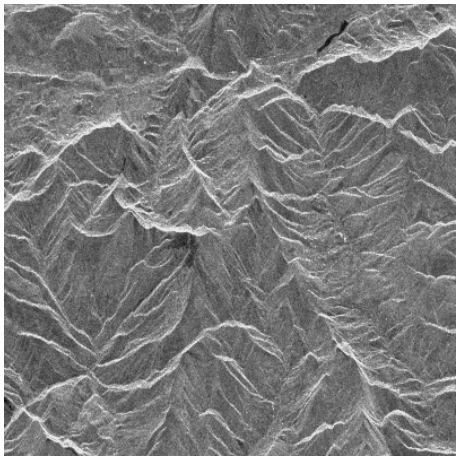
$$pixel = \underbrace{A}_{\substack{amplitude \\ SAR}} \exp(j \underbrace{\phi}_{\substack{phase \\ InSAR}}) \underbrace{\vec{p}}_{\substack{polarisation\ state \\ PolSAR}} \quad \Big\} \; PolInSAR$$

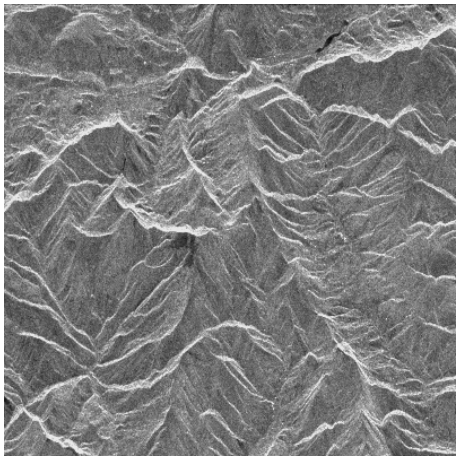
Full-resolution SAR images are complex-valued :

☑ amplitude → classical SAR imagery
☑ phase → optical path (geometrical + atmospheric effects) + backscattering

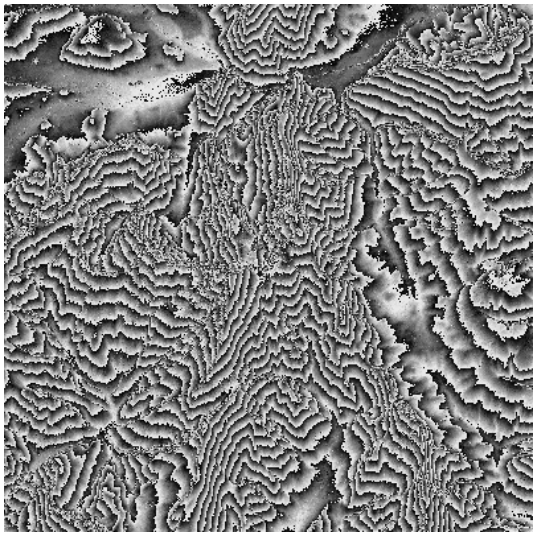
If the scene has not changed between the two acquisitions and if the two images remain correlated, the phase *difference* is purely topographical.

⇒ Possibility to generate *Digital Terrain Models* (DTMs).



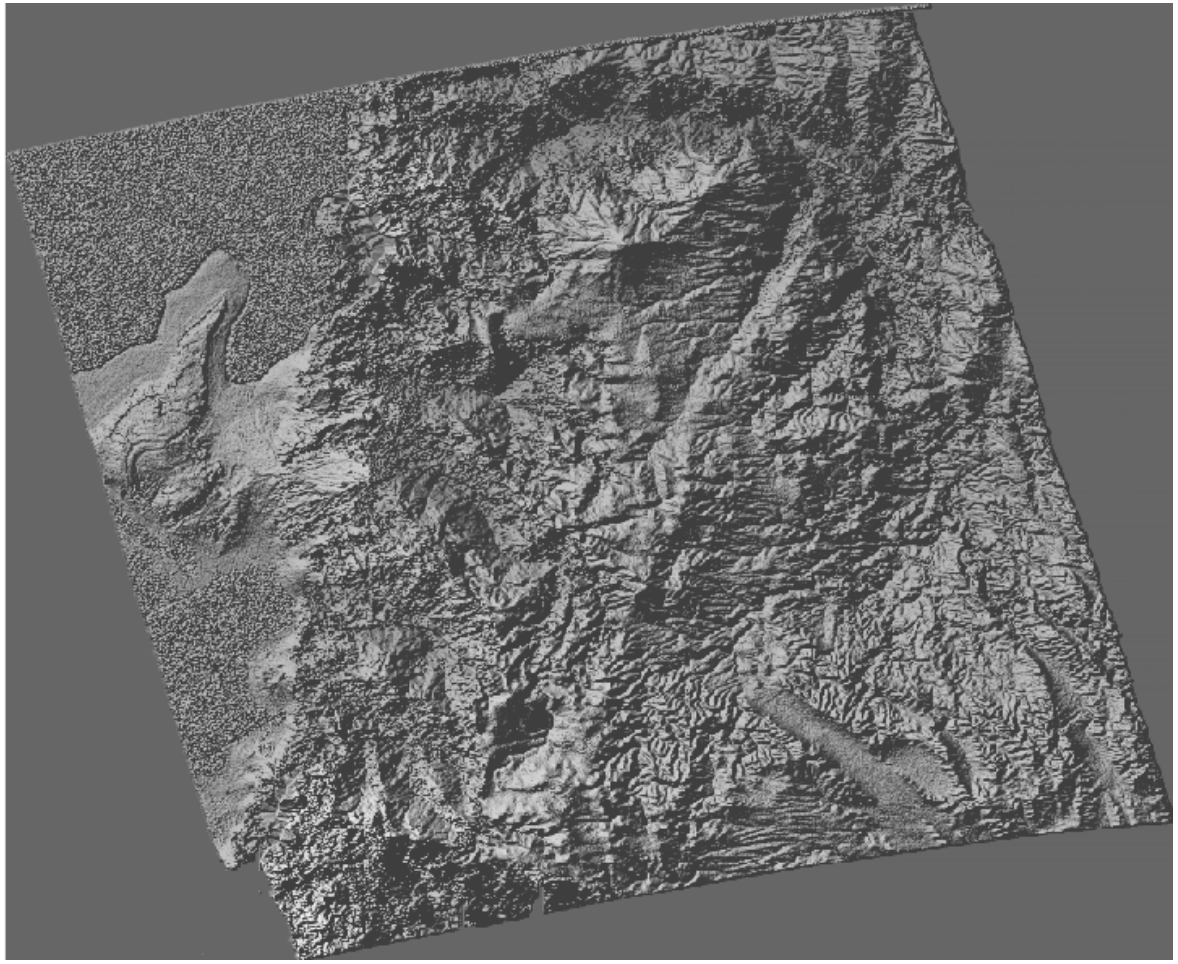


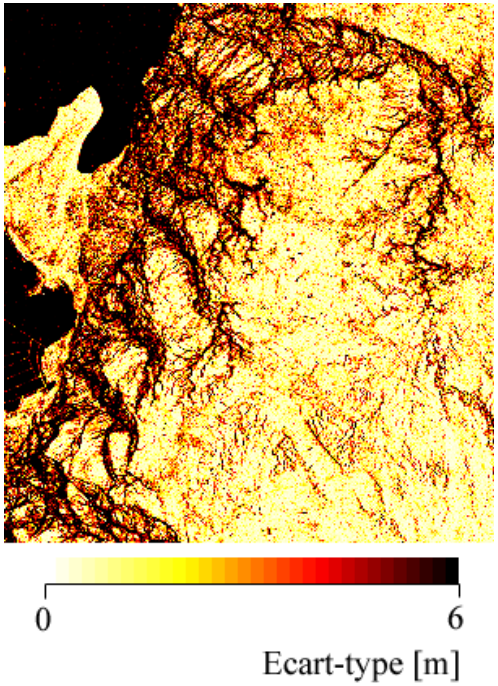
Pass 1 **Pass2**



Interference pattern

Sample example

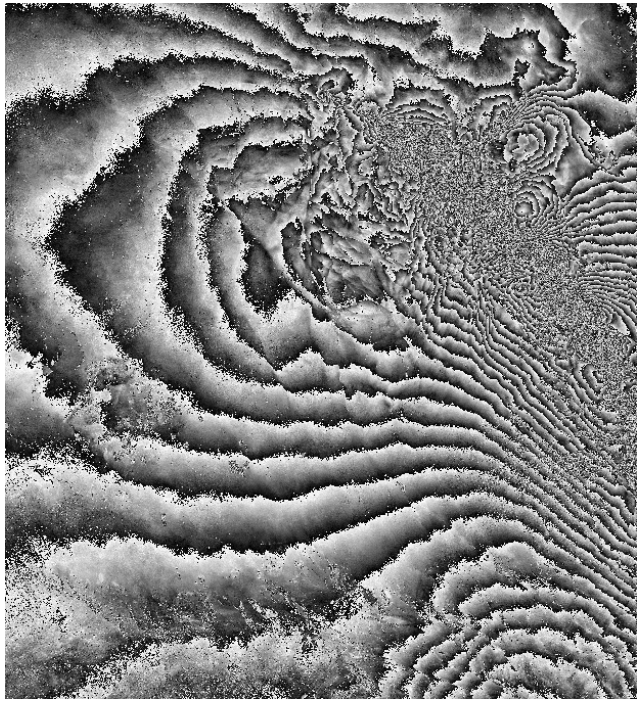




A relief map of the Jordan coast, obtained by applying the interferometric technique to one ERS-1 image and one ERS-2 image. The Dead Sea can be seen on the left-hand part. This map covers an area of 50 km x 50 km (SSTC Contract No T3/12/012 "Neotectonic Study in Hill and Mountain Countries : an Interferometry Application").

SAR Differential Interferometry

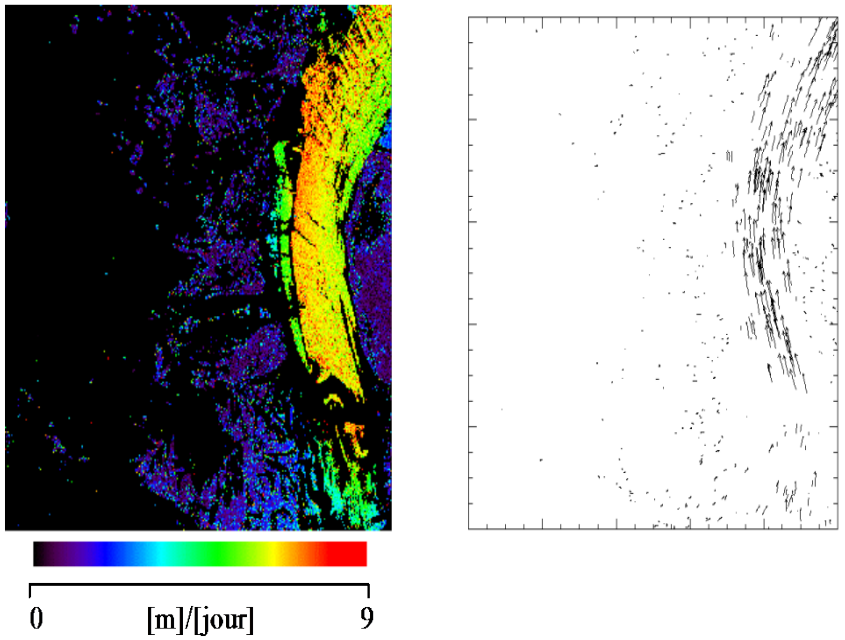
Possibility to measure *surface changes* by removing the topographical component.



A spectacular result of radar interferometry : the interference pattern reflects the terrain displacements due to the Landers (California) earthquake in June 1992. Displacements of only 28 mm can be detected despite of the altitude (800 km) from which the images were acquired. The fracture fault can be seen on the right, where the fringe density is the highest. This interferogram covers an area of 50 km x 50 km (SSTC Contract No T3/12/012 "Neotectonic Study in Hill and Mountain Countries : an Interferometry Application").

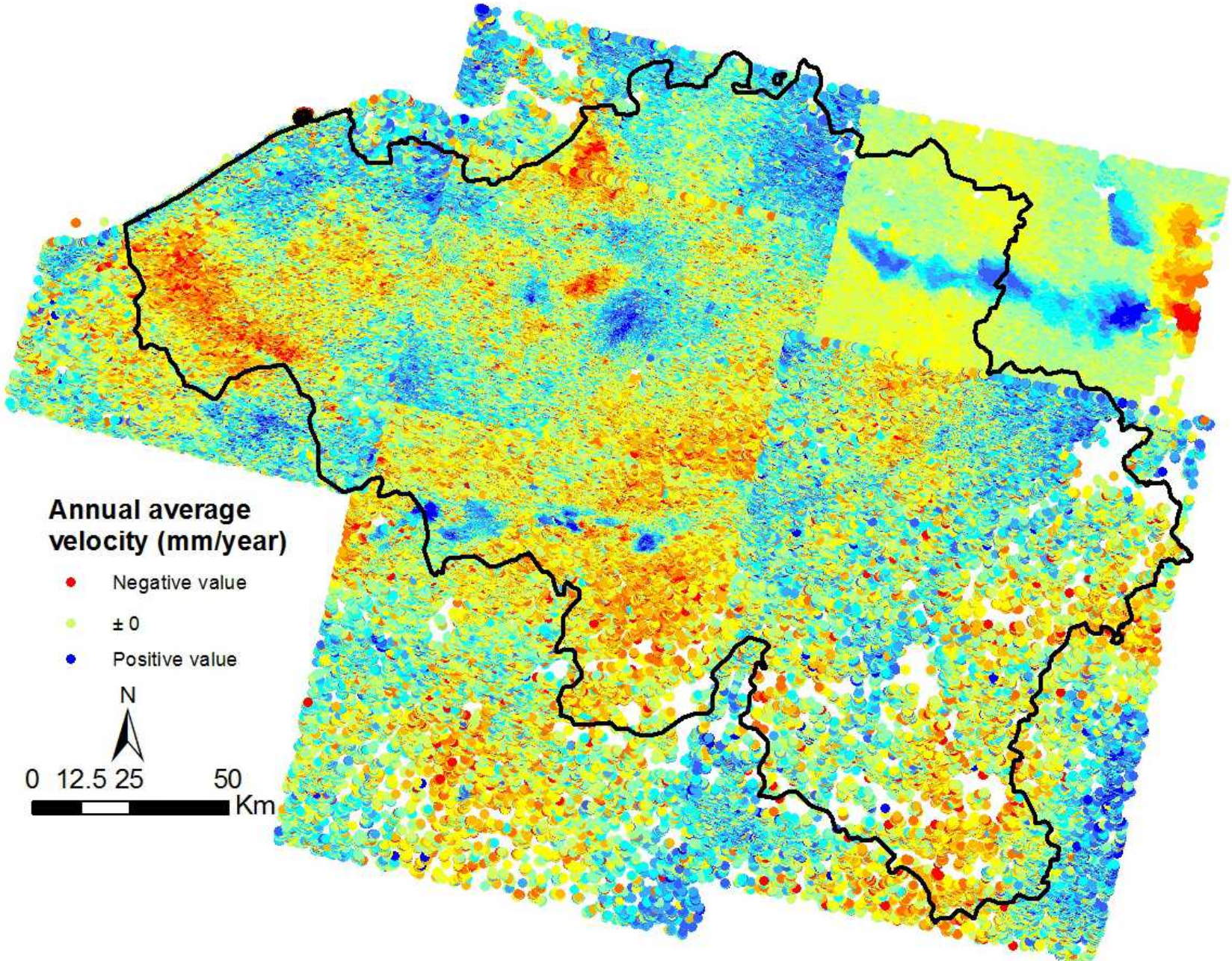
Potential application fields :

- ❑Earthquakes monitoring
- ❑Volcanoes
- ❑Terrain subsidence
- ❑Glaciers
- ❑Crop monitoring
- ❑….. Change monitoring



Coherence tracking measurements of the Shirase glacier, a fast flowing ice stream in Antarctica. The amplitude of the measured displacements are shown on the left. A vectorial representation is given on the right.

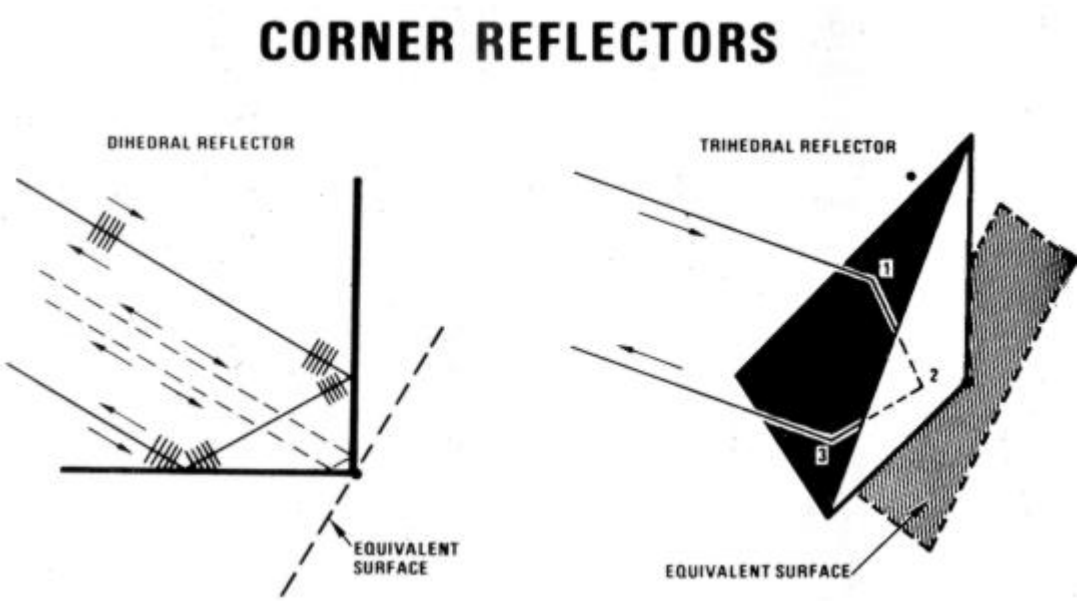
Soil motion in Belgium (2003-2010)



Main Issue : existence of stability islands

- Measuring ground displacements by differential SAR interferometry requires phase stability « islands » generally referred to as Persistent Scatterers

<u>Solution 1</u> : Corner Reflectors deployed on-ground



<u>Solution 2</u> : artifical or natural PS identified and monitored over an extended (>25) time series of images

Related CSL projects

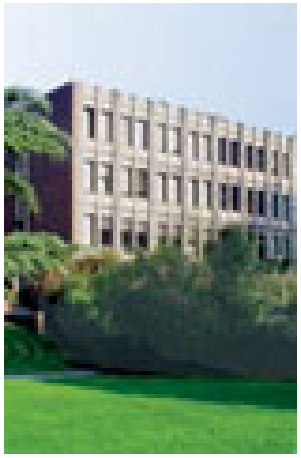
Project	Client/Partners	Key features
Demonstration and Evaluation of SAR Interferometry Based on ERS-1 Images	Belgian Science Policy Office (Belspo)	First InSAR processor in Belgium
Neo-Tectonic Study in Hill and Mountian Countries : an Interferometry Application	Belspo/ ULg Laboratoire de Géomorphologie et de Géologie du Quaternaire - Prof. A. Ozer)	ERS-2 Pilot Project
Surface Velocities and Ice Dynamics Inferred from ERS-1 and ERS-2 SAR Differential Interferometry	Belspo/ Vrije Universiteit Brussel - Prof. F. Pattyn)	ERS-1/2 Tandem pilot project (as Co.I.)
Quality Assessment of InSAR Topographic Mapping	ESA (DUP)	InSAR DEM's of Belgium and of the Beijing area
Development of InSAR Processor	ESA and SPACEBEL (GSTP)	CSL was sub-contractor of SPACEBEL Informatique for the development of a scalable computer architecture hosting a complete SAR/InSAR/DInSAR processing chain
Development of a SAOCOM SAR Processor	Belspo and CONAE	Project aiming at developping a Stripmap SAR/TopSAR processor and post-processing tools (incl. InSAR/DInSAR, PolSAR and PolInSAR) for the Argentinian SAOCOM satellite, under a bilateral agreement between Belgium and Argentina.
Wide-Band Multi-Chromatic InSAR	ESA and Bari University	Sub-contract to University of Bari (I)
VI-X	Belspo/Belgian Museum of Central Africa	InSAR monitoring of Nyiragongo volcano
MUZUBI	Belspo/Belgian Museum of Central Africa	InSAR monitoring of volcanoes, extended use of Sentinel-1 data
GEPATAR	Belspo/RBINS/RMA/et al...	Use of Persistent scatterer technique to monitor building displacements on risky areas in Belgium (incl. Wallonia)

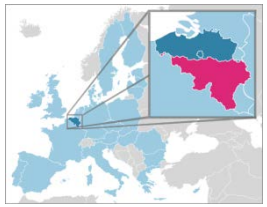
ISSeP

http://www.issep.be/

SOIL Risks Water AIR

- **Scientific** Institute for **Public** Services (Institut scientifique de service public - ISSeP)
- **Research** Institute in **Environment**
  - Environment in Copernicus
  - Research still needed in EO
- OIP– quite **independent** from SPW
  - **Public objectives** as main core since 20 years
  - **Interface** between public and private actors
- Walloon Reference **Laboratory**
  - **Protocols** of measures and field data collection
  - **Datasets for in-situ validation** (air)





Discover ISSeP

Environmental metrology

Risks assessment

Research and technological development

SOIL / WASTE

Main activities : AGW, Soil Decree (2008)

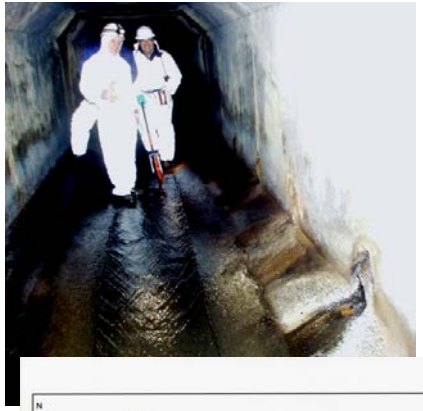
- Waste deposits sites control (CET)
- Sediment characterization
- Inventory and analysis of asbestos
- Good practice guides, Rehabilitation plans

AIR

Main activities : (Air/Climate Plan)

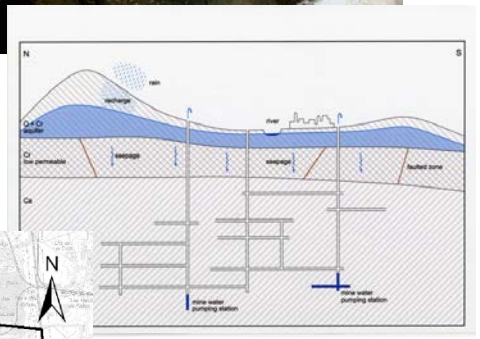
- Control of atmospheric emissions from industries
- Continuous monitoring of dioxin emissions
- Ambient air quality survey (40 years measures)
- Investigation of fine particulate matter (PM10)

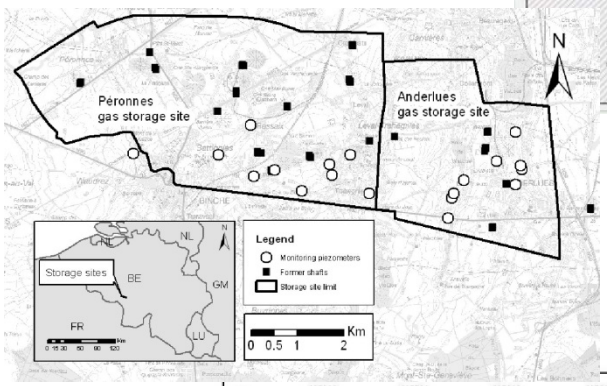
RISKS

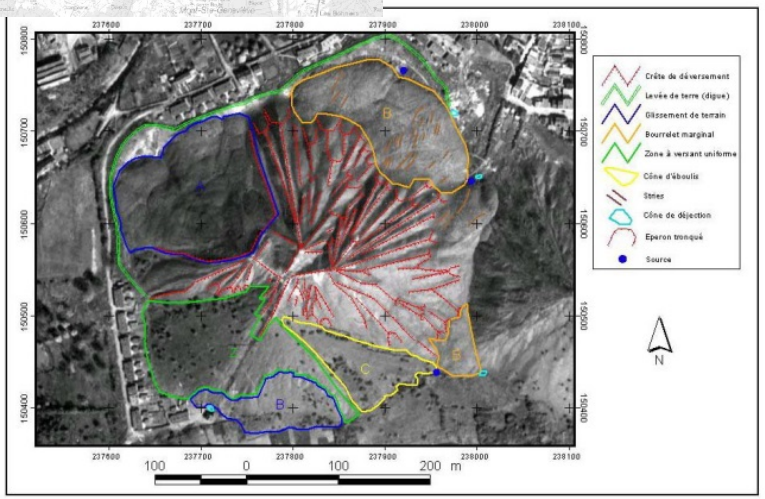


Chronic risks:

- Risks associated with polluted soils
- Risks in closed mining waste facilities
- Post exploitation monitoring and management of gas storages
- groundwater pressure and dischargemonitoring to detect anomalies (2003-2015)
- Electromagnetic field effects
- Pollution impacts on humans and environment







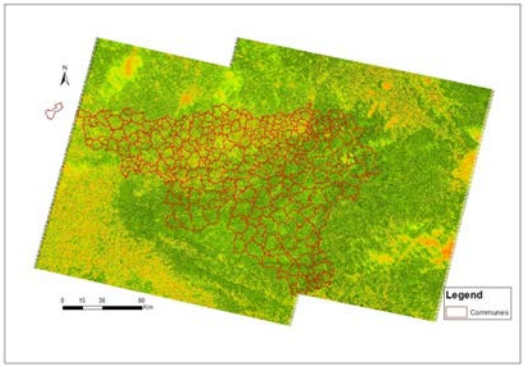
Use of EO information for Walloon adaptation of EU mining directive

- Request from EU to assess **serious risks** to human or environment related to past mining activities

  *"Member States shall ensure that an inventory of closed waste facilities, including abandoned waste facilities, […] which cause **serious negative environmental impacts or have the potential of becoming in the medium or short term a serious threat to human health or the environment** is drawn up and periodically updated" (2006/21/EC)*

- EU Technical Adaptation Committee (**TAC**) of Directive : Pre-selection protocol to evaluate the risks considering Source, Pathway and Receptor with available data

- Walloon responsible ask for support to ISSeP in applying EU legislation to the Walloon context
- Geographical Information Systems (GIS) combines risks factors in a common infrastructure
- Data assumed to be available in MS at 1km pixel but recent (2years) : data not available in Wallonia
  - 2landsats
  - NDVI > classif
  - Percentage of open soils

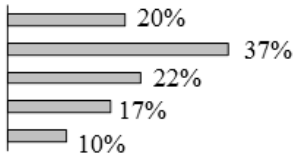


Role of ISSeP in the integration of EO services in the administrative working flow

- For administration:
  - Expert in **in-situ measurements** in Wallonia **since 20 years** : environmental data (land, air, water, soil, waste, sediments, underground, …) and mining history
  - Specialist in **field campaign organization** : from acquisition networks in fix and mobile structures to databases management, including laboratory
  - Development of Walloon **methodologies** (risks, i.e. mining waste) and guides of good practice (soil management) for the administration
  - **Cartographer** since 20 years and integrating new **web services** for better communication with administration since 4 years
- **Decision making needs has to be translated in EO technology : need for translator between EO specialists and decision makers**
  - Scientific and technological surveillance : research monitoring and link to international partners
  - Partner with research centers and private companies : Wallonie-Espace
  - Study and survey of administration needs in land-use/land-cover information (Stephenne et al 2004)

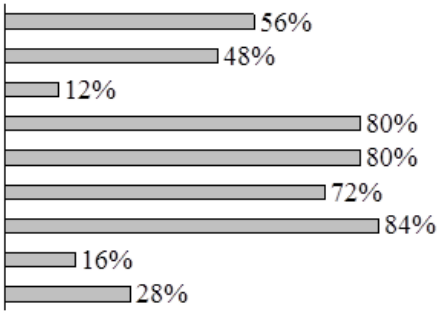
Stephenne N., Wolff E., De Genst W., Canters F., 2004, Interactivity with the urban information users in land-use/land-cover information extraction from VHR data, SPIE 10th International Symposium on Remote Sensing, Conference n° 5239 – Remote Sensing for Environmental Monitoring, GIS Applications and Geology III, Barcelona, Spain, 8-12 September 2003, Edited by Ehlers, Manfred; Kaufmann, Hermann J.; Michel, Ulrich. Proceedings of the SPIE, Volume 5239, pp. 262-273.

lack of budget (time and personnal)	8
lack of knowledge and informations	15
inadequacies of data	9
non interest for applications	7
other	4



Total = 25 observations

aerial photos	14
ortho-photos	12
remote sensing images	3
topographical maps or data	20
thematic maps or data	20
administrative boundaries	18
cadastral maps	21
digital elevation model	4
other	7

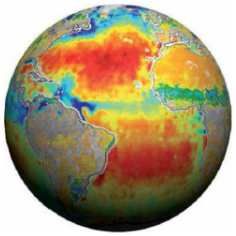


How to improve the regional / local decision making workflow with Copernicus data ?

- Identify potential users in regional and local administration
- Create places and time for exchange : platform and working groups
- Facilitate the translation of needs in services
- Initiate the administrative process by law : EOprogram – Plan Satellitaire
- Illustrate existing tools/services : demonstration of other experiences (Midi-Pyrennées, BavAIRia)
- Find research budgets to develop prototypes of these new services to be compared to the existing working flow (Ideal : public procurement H2020) > need for partners ? What about a collaboration with BavAIRia

Call Earth Observation – Topics 2016

TOPIC	TITRE	TYPE
EO-1-2016	Downstream applications	IA
EO-2-2016	Downstream services for public authorities	PCP
E0-3-2016	Evolution of Copernicus services	RIA



Current actions

- List of reinforced ISSeP contacts with potential users of EO data:
  - Geomatic professional (General secretariat) : part of the strategic committee
  - DGO1 : geotechnical survey (B Hubert, L Funcken) and roads (BRR)
  - DGO2: rivers and sediments (N Strivay, G-TEC)
  - DGO3: specialist in Environment (M Wenin, P Engels, J Beaujean)
  - DGO4: Spatial planning and natural risks (P-M Warnier, F Van Dijck)
  - DGO5: Health – risks and crisis management (Pascal Delvaux)
  - IWEPS: spatial statistics (I Reginster, J Charlier)
- “Awareness” workshop organisation : 23/10 in Wallonia (60participants)
- Working group to be organised twice a year with this panel
- Specific meetings on topics such as land motion monitoring : 29/10
- Survey on these specific topics : built-up / land movement
- Transfer of other experience : feedback of Munich workshop to administration

Research topics:
make better use of Sentinel data

Services	Description
Vegetation changes	Clear-cuts in **NATURA 2000**
Quantitative monitoring of vegetal regrowth	Localisation of un-forested areas and volumes for wood industries
Monitoring of mining pits	Land motion monitoring/ **land slide in mining pits**
Regional subsidence	Motion measurement during **geothermical drilling**, shale gas extraction, groundwater monitoring
Bridges and roads monitoring	Land movement, risk monitoring
Flood or forest calamities	Localisation, identification of damages, costs estimation
GNSS stations	positioning
Built-up	Changes, prediction, spatial planning and statistics
Agricultural monitoring	Crops identification, yield and production prediction

Remote sensing:
From science to operational services

- Since 70's, Europe evolve to the most comprehensive EO programme which currently is in transition from implementation to operation
- Need for more interaction with regional and local autorities :
  - New downstream projects calls in H2020
  - Efforts of NEREUS network and ESA project funding this workshop (thanks for the organisation of this meeting)