InSAR monitoring to Support the Oil and Gas Industry

Alain Arnaud
Altamira Information, Barcelona, Spain.
(e-mail: alain.arnaud@altamira-information.com)

Guan Oon
Altamira Information, Melbourne, Australia.
(e-mail: guan.oon@altamira-information.com)

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Introduction to InSAR technology

Applications for the Oil & Gas sector

Why measuring motion with InSAR

InSAR measurements in CSG fields in Australia

Conclusions
ALTAMIRA INFORMATION & CLS Group
Providing integrated services for industry, environment and security.
Introduction to InSAR technology
Measuring ground motion with radar satellites

Radar satellites

In terferometric = Superimposition of waves to detect differences
Interferometric
Synthetic aperture SAR = High resolution radar system
Synthetic Aperture Radar

1st satellite pass
1st measurement
Reference distance between sensor and ground measured with millimetric precision

2nd satellite pass
2nd measurement
Detecting a change of distance between sensor and ground indicates movement

Results

Ground motion measurements map

Cm / year
+ 1 cm
+ 0.5 cm
+ 0 cm
– 0.5 cm
– 1 cm

Time series for each point

For a specific measurement point

Ground movement is measured with radar satellites, comparing the satellite distance from the Earth surface at different moments in time.
Natural Points

Existing Points over Earth surface
Roofs, metallic structures, man-made objects that reflect very well the radar signal.
Arid terrains, rocks or areas with scarce vegetation can provide large density of points.

Artificial Corner Reflectors

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Aluminum Trihedrals
Used in areas where there are not enough natural points: areas with dense vegetation, snow, ongoing constructions…

Possibility to conduct historical studies or monitoring

Allow for densification of measurements

surface changes during the monitoring could require the installation of artificial reflectors in order to guarantee measurement points.
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Overview of main applications in the Oil & Gas sector

- **Reservoir monitoring**
  - Safety of reservoir and infrastructure: Prevent reservoir compaction
  - Extraction efficiency: Ground motion measurements can deliver information about gas distribution and pressure in the reservoir

- **CH4 / CO2 storage**
  - Quality and safety control of natural gas and CO₂ storage sites with uplift and subsidence monitoring
  - Monitoring stability for storage sites with seasonal pressure changes

- **Pipeline monitoring**
  - Detection of pipeline leakages
  - Prevention of potential leakage risks by measuring ground motion on pipeline tracks

- **Monitoring of LNG terminals**
  - Safety of storage sites
  - Ground motion monitoring for LNG terminals, in coastal areas

- **Mapping**
  - 3D and structural mapping, especially in remote areas
  - Digital Elevation Models can be updated efficiently with new data

- **Platform monitoring**
  - Monitoring of offshore platform settlement (sea-bottom-anchored platforms) to support decisions on platform replacement timing.
Gas Storage: CH₄ and CO₂

InSAR surface monitoring for reservoir characterization

**Pre injection phase**
- **Historical analysis** of the selected site to get ground motion information of the surface and detect vulnerable areas.
- **SAR Structural Image & DEM** to enhance textural surface information to provide structural maps.

**Injection and future monitoring**
- **HR Ground deformation monitoring** when injection starts with monthly or even weekly updates.
- **Installation of Corner Reflectors** where measurement points are not guaranteed (*optional*).
- **Combination** of ground motion monitoring results with other monitoring technologies: micro-seismic, ground-level gas measurements, temperature, pressure.
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Why measuring ground motion with InSAR

“It’s a matter of Safety”
Why measuring ground motion with InSAR

"It's a matter of Safety"

COSMO-SkyMed results – 3 m resolution

Mean Displacement rate (mm/year)
1. Steam injection to dissolve heavy oil

2. Surface uplift as a consequence of steam chamber formation

3. Ground motion measurements using radar satellites

4. Measurement results: Uplift

5. Measurement results: Subsidence
Measuring ground motion for Safety
Oil sands in Canada: Installation of corner reflectors

Monitoring:
Monthly and bi-weekly update with a new images every 1-3 days.
Flexibility to increase monitoring to weekly rhythm.

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Millimetric ground motion measurements are illustrated in isolines...
A very high density of measurement points with a very high precision allows the identification of gradients of ground motion over critical infrastructures.
Why measuring ground motion with InSAR

“It’ a matter of Safety”

To fulfill the requirements from the regulator
Why measuring ground motion with InSAR

To fulfill the regulator requirements

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Ground motion monitoring to fulfil regulator requirements
Oil sands in Canada: Natural Targets and CRs in X-band

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“It’ a matter of Safety”

To fulfil the regulator requirements

For reservoir monitoring purposes
Ground motion measurement for reservoir monitoring

Oil sands in Canada: Ground motion caused by team injection

Steam injection at highlighted well

Uplift appearing in well center

Low injection
Increase in injection
Decrease
Continuous high level of injection
CO₂ storage at 1900m depth.


Areas of **uplift** (5mm/year) have been detected surrounding the injection wells. (Blue areas on the images).

Areas of **subsidence** (2.5 mm/year) in the extraction area have been detected affecting gas field facilities.
Applications for the Oil and Gas industry

CO₂ injection monitoring (Northern Africa): Modelling

- Cumulative surface displacement along the line of sight vector from December 2003 to the 16th January 2010: InSAR data (left) and best prediction from the forward model (right) → differences are within the expected errors.

Surface deformation measurement obtained via InSAR is increasingly used in the context of reservoir monitoring to improve models the surface uplift induced by fluid injection.
Reservoir pressure changes (from the initial state) in January 2010: history-matched ECLIPSE simulation (left) and results of the inversion of InSAR data.

Model assumes flat ground surface, homogeneous mechanical properties at large scale.

Not perfect match although the location of the pressure spikes associated with the injector are captured (some discrepancies with the maximum values).

The other drops associated with production are not as visible.

The inversion presented here is thus most probably polluted by the modeling error associated with the hypothesis of a homogeneous half-space.
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Historical study over very large basin 2007 - 2011

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InSAR measurements in CSG fields in Australia
Analysis of ground deformation patterns in active CSG fields

Accumulated water extraction (barrels)
- 40463 - 165321
- 165321 - 304169
- 304169 - 673153
- 673153 - 1102576
- 1102576 - 1888951

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Analysis of deformation patterns in active CSG fields

InSAR ground motion measurements at 200m of radius

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info@altamira-information.com
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Analysis of ground deformation patterns in active CSG fields

InSAR against well extractions

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InSAR measurements in CSG fields in Australia
Time Series correlation analysis between both measurements

- **Good correlation** of the accumulated water extraction profile with some InSAR TSs (best TS correlation index of 0.99)
- It seems there are **two different deformation mechanism** over this area (probably linked with different land cover or geological conditions?)

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Analysis of ground deformation patterns correlated with floodplain maps

Floodplain map of Taroom and surroundings 2010/2011

Floodplain map mask

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Analysis of ground deformation patterns correlated with floodplain maps

Floodplain map mask

InSAR Time Series showing common patterns

InSAR measurements in CSG fields in Australia
Analysis of ground deformation patterns correlated with floodplain maps

Measured ground motion between 01/2008 and 02/2010

Floodplain map mask

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Analysis of ground deformation patterns correlated with floodplain maps

Measured ground motion between 02/2010 and 01/2011

Floodplain map mask

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Analysis of ground deformation patterns correlated with floodplain maps

Measured ground motion between 02/2010 and 01/2011

Floodplain map mask

Optical image of 2010 showing flooded and non-flooded areas

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To make InSAR data valuable……

……. You need to give value to the data
Toulouse (France)
8-10, Rue Hermès
F - 31 520 Ramonville Sainte-Agne, France
T.: +33 5 61 39 47 19

Barcelona (Spain)
C/ Côrsega, 381-387
E - 08037 Barcelona, Spain
T.: +34 93 183 57 50

Calgary (Canada)
Bankers Hall, West Tower, 10th floor,
888 – 3rd Street SW
Calgary – AB T2P 5C5, Canada
T.: +403 444 6861

Melbourne (Australia)
Suite 207, 122 Toorak Road. PO Box 42
South Yarra, Victoria 3141, Australia
T: +61 418 368 917

www.altamira-information.com

Alain Arnaud, CEO – alain.arnaud@altamira-information.com
Guan Oon, Local representative – guan.oon@altamira-information.comGuan Oon
Mobile +61 418 368 917 - PO Box 42, South Yarra, Victoria 3141