



**TRE**  
**ALTAMIRA**  
A CLS Group Company

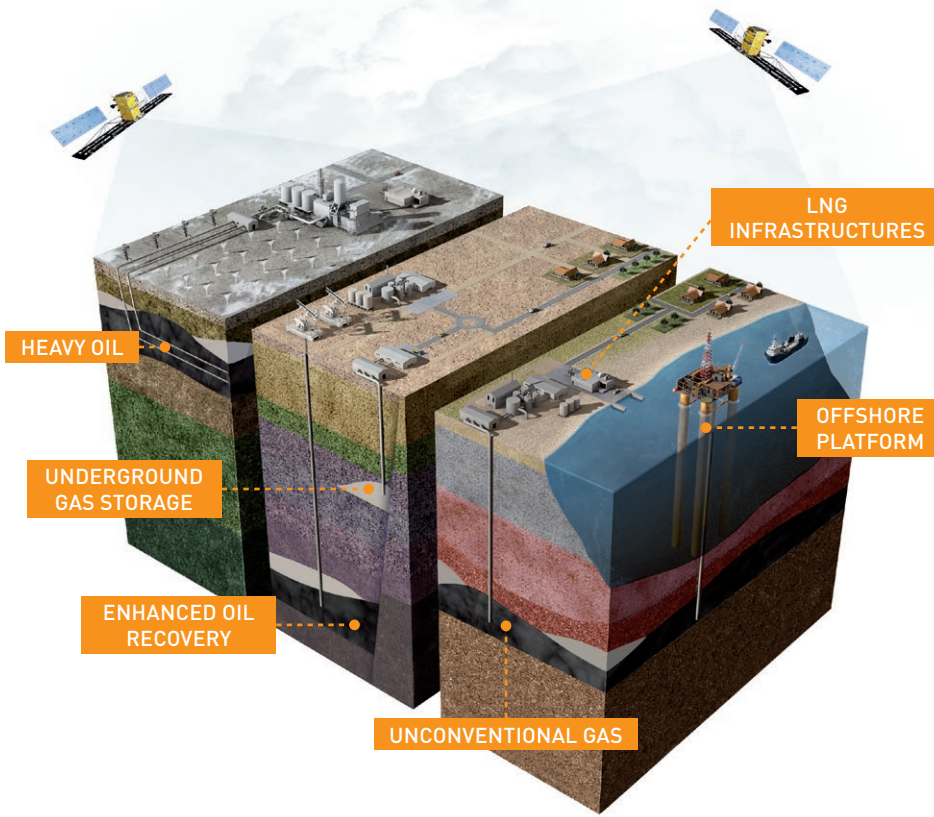
# GROUND MOTION MONITORING FOR **OIL & GAS OPERATIONS**



# Monitoring ground motion with SqueeSAR™

SqueeSAR™ is the industry standard of advanced InSAR techniques.

InSAR technology measures surface deformation up to millimetric accuracy by comparing radar images captured by satellites. SqueeSAR™, our advanced InSAR technique, allows the identification of thousands of measurement points that exist in the area of interest. Each point has an associated time-series showing how that specific location has moved over time.



## What can SqueeSAR™ do for the oil and gas industry?

### Optimize production strategies

SqueeSAR™ provides information on the location and spatial extent of surface deformation, as a response to operations in the reservoir (e.g. steam injection and water flooding). This information is a vital tool for making operational decisions on injection activities and production optimization.

### Calibrate reservoir models

The spatial patterns of surface displacement provide another layer of information in reservoir models. These patterns give an insight into where extracted fluids are drawn from and where injected fluids flow to.

### Facilitate HSE regulatory compliance

SqueeSAR™ is recognized by the main regulatory bodies as a reliable method to detect, measure and monitor surface motion in response to field operations. It helps meet HSE requirements.

## CCS AND UGS

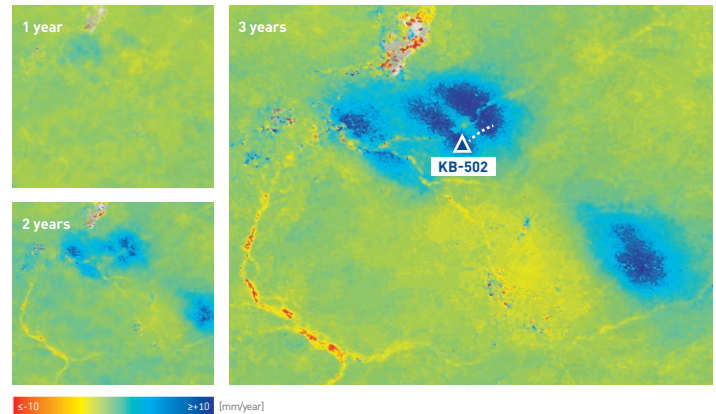
- Caprock integrity surveillance
- Reservoir model calibration
- Gas storage optimization (working gas)
- Environmental safety

### Carbon capture and storage

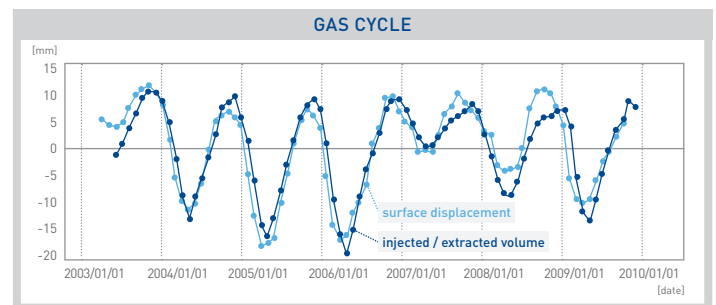
SqueeSAR™ measurements reveal uplift associated with the geological storage of carbon dioxide. Through a regular acquisition of radar images, site engineers can monitor injection activities to ensure that reservoir pressure distribution and surface uplift remain within safe operational limits. According to the spatial distribution of ground motion, it is possible to infer how CO<sub>2</sub> plume propagation is oriented.

### Underground gas storage

SqueeSAR™ also provides a detailed map of the surface response to gas storage activities. When coupled with injection and extraction rates, displacement measurements can be used as an input into geomechanical models to estimate volume and pressure changes over time, again ensuring that safe operational limits are maintained and gas storage strategies optimized.



Geological storage of CO<sub>2</sub>. The analysis of the double-lobed pattern in range change over the injection well KB-502 suggests an opening of a tensile feature.  
Satellite imagery: ENVISAT, analysis period: 07/2004 – 05/2008.



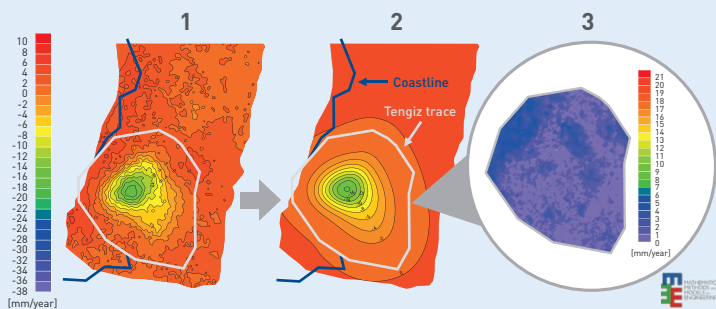
Summer injection and winter extraction of gas can produce seasonal surface displacement. Displacement time series obtained with SqueeSAR™ shows a strong correlation with the injected/extracted gas volume.  
Satellite imagery: RADARSAT, analysis period: 01/2003 – 01/2010.

# OIL AND GAS PRODUCTION

- Reservoir recovery optimization
- Reservoir model calibration
- Caprock integrity surveillance
- Risk mitigation

Rapid satellite image acquisition and fast delivery of results allow satellite monitoring to be part of operational plans. In particular, displacement maps obtained from satellite data can highlight rapid changes in movement rates over large areas correlating with the activation of fault and fracture systems. This information can be integrated into reservoir models and used to assist in optimizing recovery.

Satellite monitoring also increases safety by showing the evolution of displacement around injection and production wells. It helps meet regulatory and lease boundary compliance.

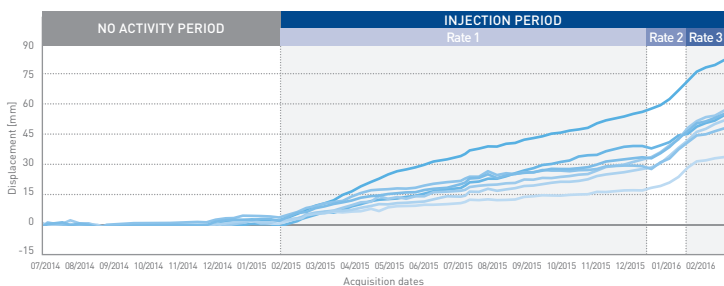
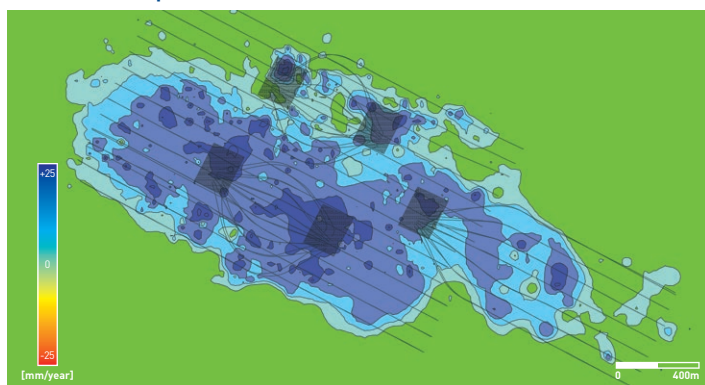


- Calibration of a reservoir model with SqueeSAR™
- 1 : SqueeSAR™ results
  - 2 : Subsidence rate computed by the model after EGO calibration
  - 3 : Difference between SqueeSAR™ and computed subsidence rates

## Heavy oil

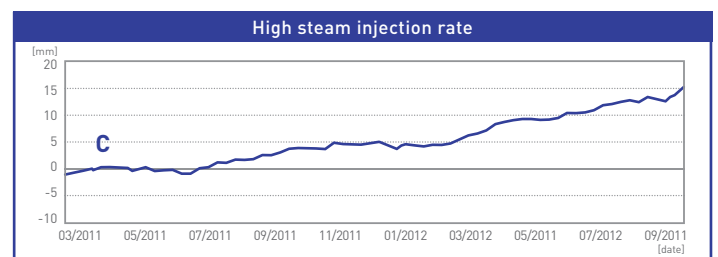
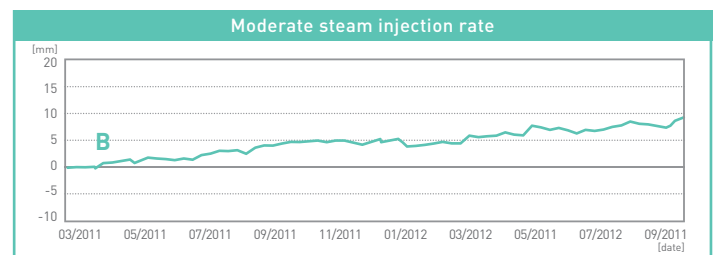
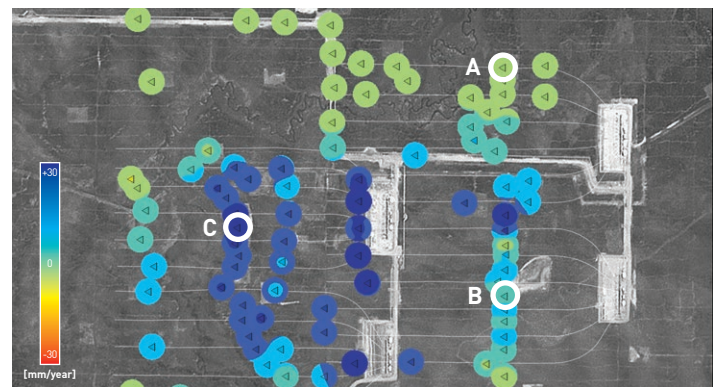
For heavy oil operations (e.g. Steam Assisted Gravity Drainage, SAGD, Cyclic Steam Stimulation and other high-pressure techniques), satellite information on the location and spatial extent of surface displacement is used by operators to analyse steam chamber expansion and caprock integrity, hence contributing to operational decisions on injection activities and production optimization.

## SAGD field operations



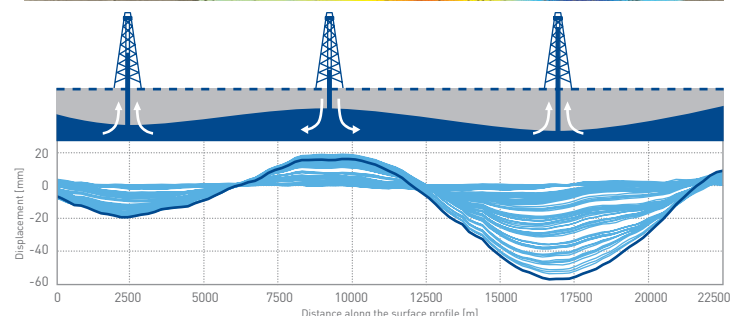
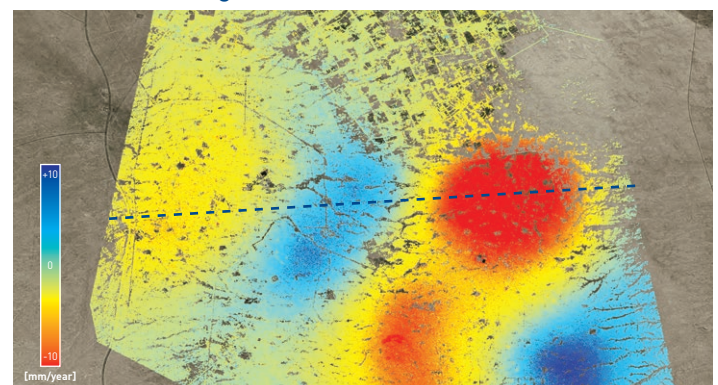
Satellite monitoring provides information on surface displacement that can be linked to caprock integrity and steam chamber propagation in SAGD fields. Displacement time series obtained with SqueeSAR™ shows a correlation with steam injection operations. Satellite imagery: RADARSAT-2, analysis period: 07/2014 – 03/2016.

## Artificial reflectors over a production field



Heavy oil: Artificial Reflectors (AR) over a production field. All-season measurements are guaranteed with AR. AR are installed to measure surface displacement over areas where the ground is not naturally reflective all year round, such as areas covered by snow in winter months or areas that are densely vegetated. Satellite imagery: COSMO-SkyMed, analysis period: 03/2011 – 09/2011.

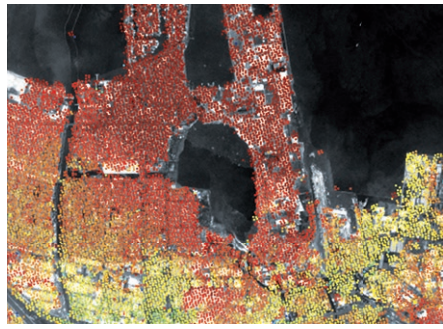
## Waterflood management



Waterflood operations are significantly improved by accurately determining the temporal evolution of displacement around injection and extraction wells. Satellite imagery: TerraSAR-X, analysis period: 03/2009 - 03/2013. Background image: Bing maps.

## Over 15 years measuring ground motion using satellite data

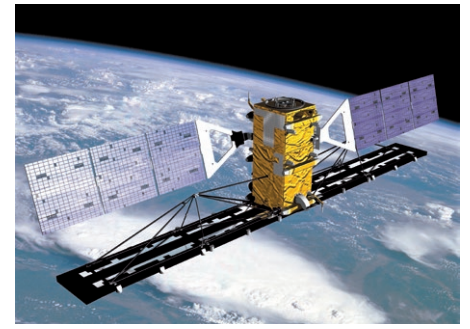
**TRE ALTAMIRA** is the largest InSAR group worldwide. With over 15 years' experience, it is globally recognized as the world leader in millimetre-precision displacement measurements from satellite radar data, which are used in a variety of sectors including oil & gas, mining, civil engineering and environmental monitoring.



### High measurement point density

SqueeSAR™ provides the highest density of measurement points for all types of terrain. Clients benefit from receiving the densest and most accurate information over their area of interest.

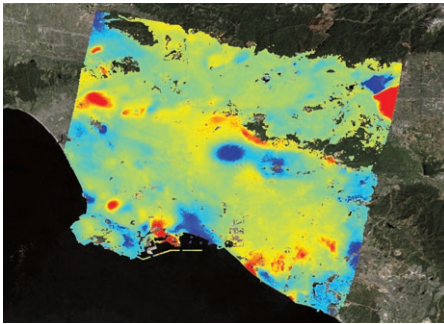
In areas where snow or major surface disturbances limit the reflectivity of the ground, Artificial Reflectors are installed to ensure precise measurement points.



### Works with all radar satellites

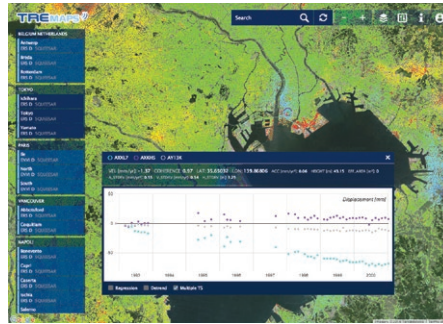
SqueeSAR™ works with all radar satellites. Based on project conditions, TRE ALTAMIRA can select the best satellite data-stack in terms of resolution, coverage, reliability and cost.

Historical ground motion studies can go as far back as 1992 thanks to archives of radar images acquired by different satellite missions.



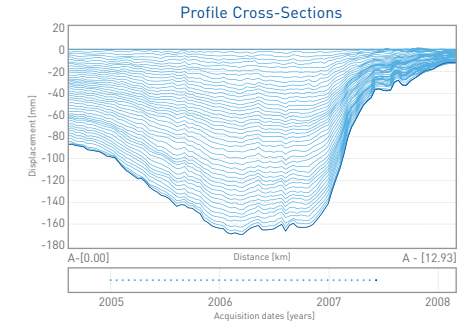
### Coverage from very large areas to single structures

From 1 to 10,000 km<sup>2</sup>, SqueeSAR™ is unrivalled in its ability to obtain measurements of surface deformation over large or small areas of the Earth's surface. SqueeSAR™ can accurately measure the displacement of single structures thanks to the availability of high resolution satellite imagery.

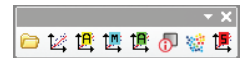


### SqueeSAR™ results presented in Web platforms

Clients can take advantage of TREmaps™, WebGIS and 3D VIEWER to rapidly visualize millions of measurement points on an easy-to-use web interface. Navigation is intuitive and by clicking on any measurement point, ground motion development over time is presented in a graphic format.



### Tools



TRE ALTAMIRA offers their clients additional tools for managing SqueeSAR™ results. The cross-section tool uses point data measurements to trace how the ground surface profile changes over time. The toolbar allows clients to improve visualization of SqueeSAR™ results in an ArcGIS environment.

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