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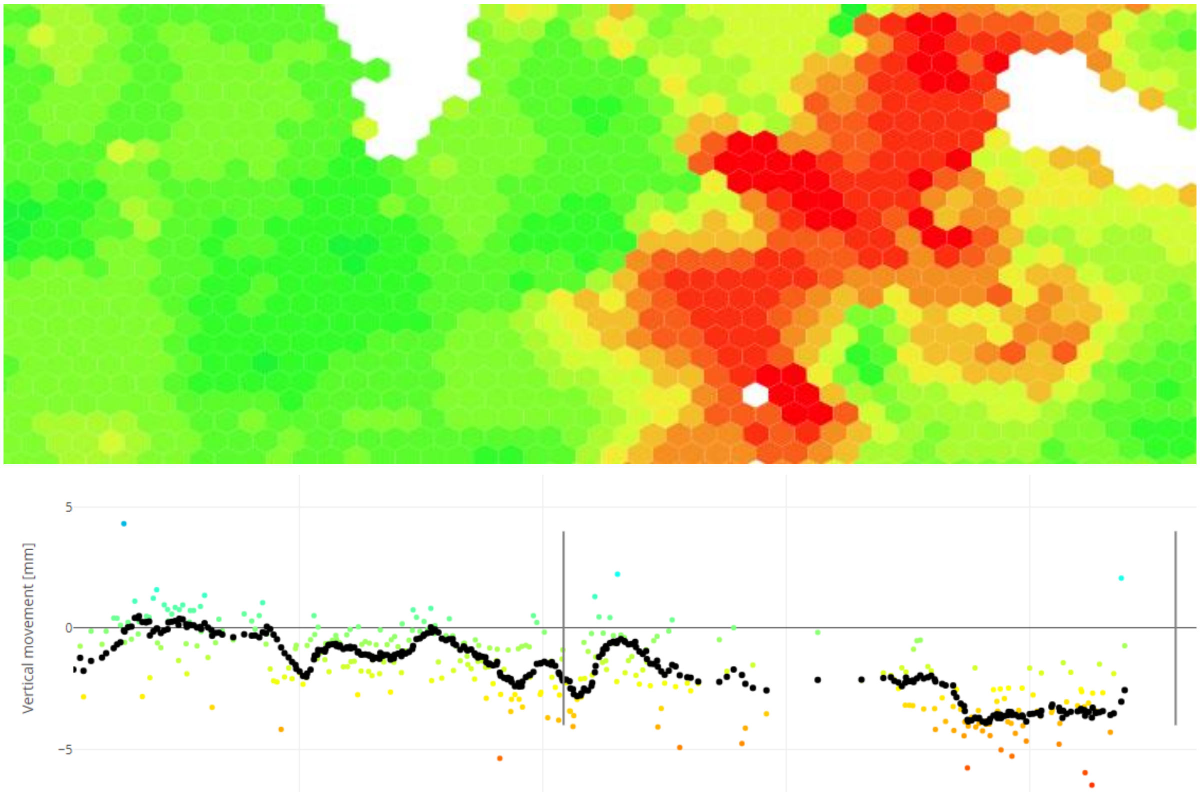
SURFACE SUBSIDENCE



Top: surface subsidence map, bottom: subsidence profile

PRODUCT DESCRIPTION

Category

☒☐Topographic information	☒ Surface deformation
☐ Impact assessment	☐ Precision ortho-images
☒ Change detection / continuous monitoring	☐ Terrain information
☐ Land cover / use	☐ Water quantity & quality
☐ Near surface geology	

Uses

Monitoring the surface movements before, during and after underground operations.

Challenges addressed

Development and Operations – Ground Stability/Geotechnical

Closure and Aftercare – Affected Stakeholders

Geo-information needs

DO-19: Underground operations – surface subsidence

CA-5: Demonstration of no impact on national heritage locations

Description

This product provides information on the surface subsidence during underground operations, based on the satellite-based InSAR (Interferometric Synthetic Aperture Radar) technique. It provides mm-precise measurements over large areas on a weekly-monthly basis and can serve as scanning tool for the complete area above the mine and the direct environment. Depending on the satellite, up to 100,000 measurements per km^2 can be obtained.

Typical mining applications of this product are monitoring the subsidence of the ground on top of an underground mine, the effects of certain backfilling or ground support approaches and the effects of the mining operation on the environment and the surrounding infrastructure. The advantages are that large areas can be monitored on a regular basis, in a fully automated manner and without human intervention, providing a spatially dense view of the effects of underground operations. Furthermore, by using satellites, a uniform data format and quality can be obtained over all mines in the portfolio.

InSAR is based on radar images, as acquired by various radar satellites. The products from these satellites differ in terms of number of measurements per km^2, measurement frequency, price (free vs. paid imagery) and availability. In most locations worldwide there is imagery available dating back to 2015 and for some locations even back to 1992. Therefore, it is easy to obtain a baseline of the deformations around the mining area and thereby context of what is or has been happening. By using multiple satellites, vertical as well as horizontal (in the east-west direction) movements can be tracked.

Triggers can be implemented to warn the mine operator if the subsidence is reaching pre-defined thresholds set by the regulator or when the above ground infrastructure is at risk. This allows for intervening before a potential accident happens and a more precise planning of backfilling/ground support strategies.

Known restrictions / limitations

The highest measurement frequency that current satellites can obtain is once per couple of days, which could be too low for certain applications. If the deformations leading up to a failure can occur in the timespan of minutes/hours rather than days, other systems for intervention are required, such as GPS or ground-based radars.

The satellite's ability to accurately measure surface subsidence is dependent on the reflectivity characteristics of the surface. For some specific locations/cases (e.g., vegetated areas, forests, flooded areas), the satellite might not be able to obtain the requested measurements.

Lifecycle stage and demand

Exploration	Environmental Assessment &	Design, Construction	Mine Closure &

	Permitting	& Operations	Aftercare
■	■■	■■■■■	■■■■

Exploration:

- Investigating fault movement for exploration purposes

Environmental Assessment & Permitting:

- Establishing a baseline measurement of movements already occurring in the area before the mine was built and taken into operation; assessment of regulator rules.

Design, Construction & Operations:

- Design: Establishing a baseline measurement of movements already occurring in the area where the mine will be built. Potential to adjust the design the strategy based on that information.
- Construction & Operations: Monitoring the surface subsidence and the effect of underground operations.

Mine Closure & Aftercare:

- Monitoring the surface subsidence after mine closure.

Geographic coverage

Global coverage

EARSC Thematic Domain

Domain	Built Environment
Sub-domain	Urban Areas
Product description	Monitor Urban Surroundings

PRODUCT SPECIFICATIONS

Input data sources

Sampling of available products:

Satellite	***Sentinel-1***	***TerraSAR-X***	***RadarSat-2***	***COSMO-SkyMed***
Status	In operation	In operation	In operation	In operation
Operator	ESA	Airbus Defence & Space	MDA	e-Geos
Data availability	Public	Commercial, on demand	Commercial, on demand	Commercial, on demand

Resolution (m)	20x4	3x3 or 1x1	25x7 or 5x5 or 3x3	3x3 or 1x1
Coverage	Global	Global	Global	Global
Frequency (days)	6-12	11	24	4-16
Launch year	2014	2007	2007	2007
Website	link	link	link	link

Minimum Mapping Unit (MMU)

The satellite can detect very small features (~decimeters), provided that objects and/or surfaces of interest reflect well enough. Generally, solid, stable, angular objects are the best reflectors.

Accuracy / constraints

Thematic accuracy:

The technique works best on solid, stable, angular objects like infrastructure, buildings, solid rock, etc. Water cannot be measured, and vegetated surfaces are more difficult to measure.

Spatial accuracy:

Dependent on the satellite resolution. The measurement can be located on sub-pixel level, typically in the order of 1-5 meters.

Measurement accuracy:

The deformation/movement of the infrastructure can be determined with a precision of around 1 mm/yr.

Accuracy assessment approach & quality control measures

The quality is assessed by automated, thoroughly tested, quality control algorithms, delivering validated results. The quality of the product and the approach taken are described in an automatically generated report, ensuring high quality and reproducibility.

Frequency / timeliness

Observation frequency:

Depending on the satellite, varying from once per 4 to 24 days.

Timeliness of delivery:

Depending on the satellite provider, the service provider and the type of application (within 1-5 working days).

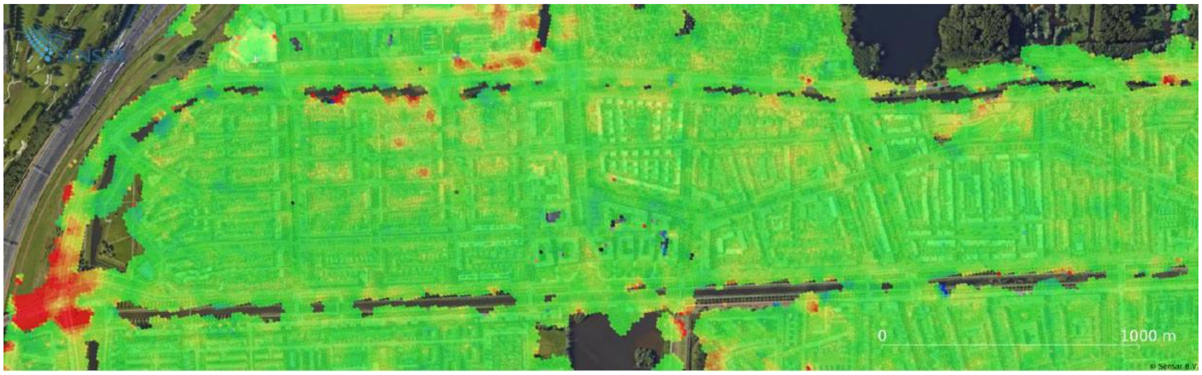
Availability

- Global coverage with free imagery, lower resolution, including archive since 2015 and in some locations since 1992.
- Global coverage on demand with paid imagery, higher resolution. Archive imagery available in some locations.

Delivery / output format

- Data via API (Application Programming Interface), as GIS file format (geopackage, shapefile, .kml, .csv, etc.) or in a webviewer.
- Triggers via API or email.
- Automated reporting in pdf.

Use case



Delft region – The Netherlands *(Source: Sensar)*

Monitoring surface subsidence to estimate future stress on underground drinking water pipelines. Differential ground subsidence can cause stress on underground infrastructure, leading to potential future leakages. By monitoring this with InSAR, the maintenance planning can be adjusted accordingly, in order to prevent damages and to save costs.