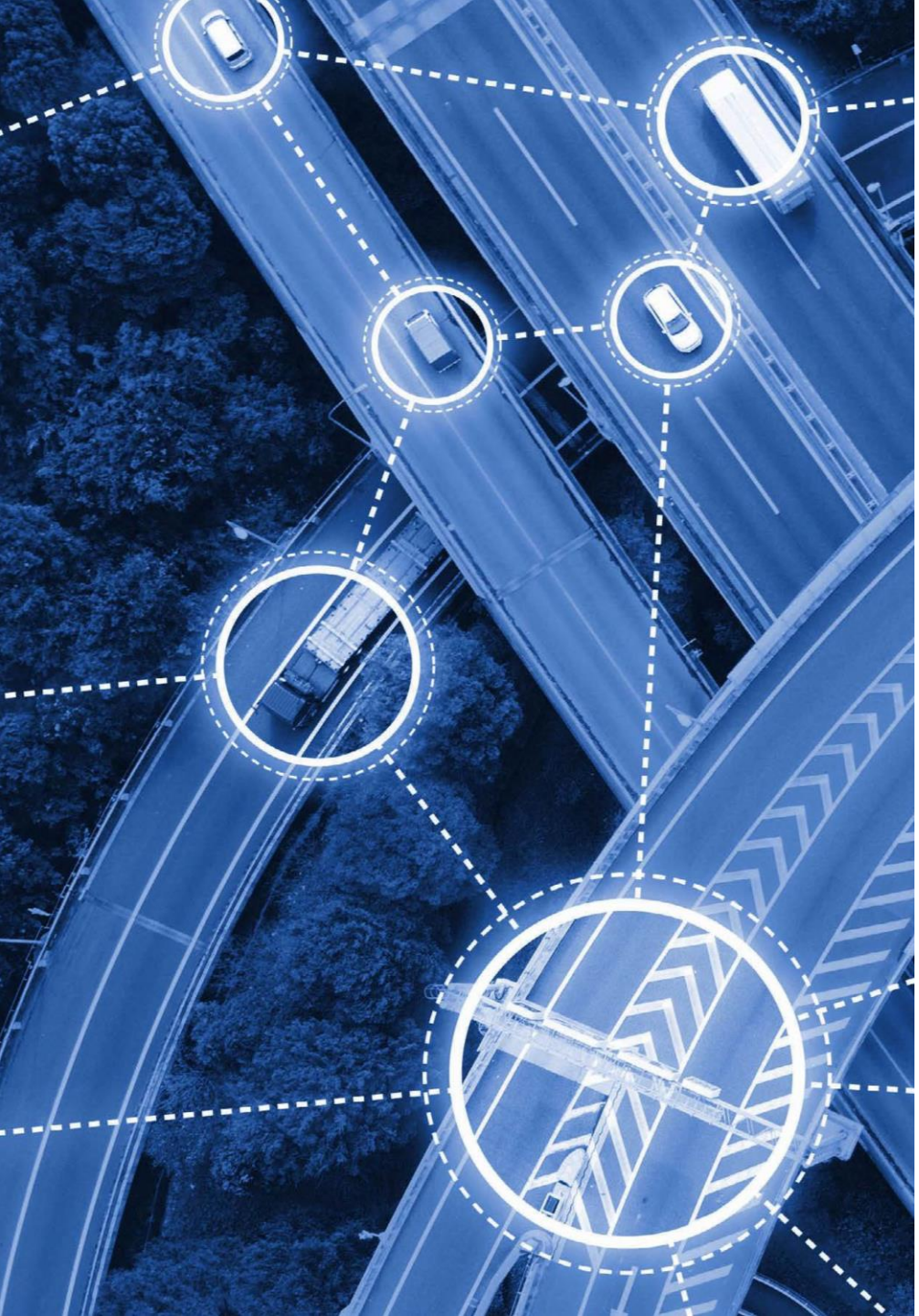


# REMOTE SENSING FOR INFRASTRUCTURE

How Geofem leverages Synthetic Aperture Radar (SAR) with ENVI SARscape to help make Infrastructure more resilient to Climate Change

**JAMES SLATER** | L3HARRIS GEOSPATIAL | CHANNEL MANAGER EMEA
**NICOLAI HOLZER** | L3HARRIS GEOSPATIAL | SALES ENGINEER EMEA
**SKEVI PERDIKOU** | GEOFEM | TECHNICAL MANAGER

June 9th, 2022

# Agenda

## Introductions

## Make Infrastructure More Resilient to Climate Change with SAR Data

Introduction to Synthetic Aperture Radar (SAR)

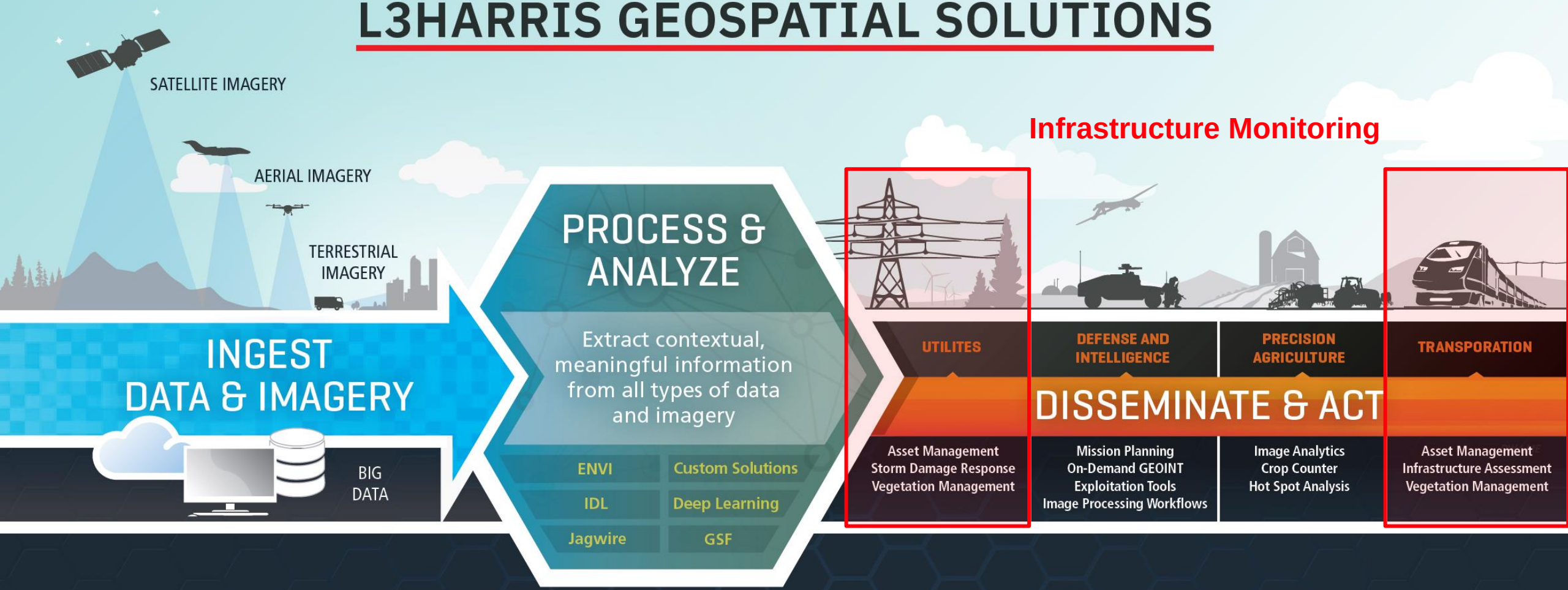
Applications using SAR for Infrastructure Monitoring

Introduction to ENVI SARscape

## Questions

L3HARRIS
FAST. FORWARD.

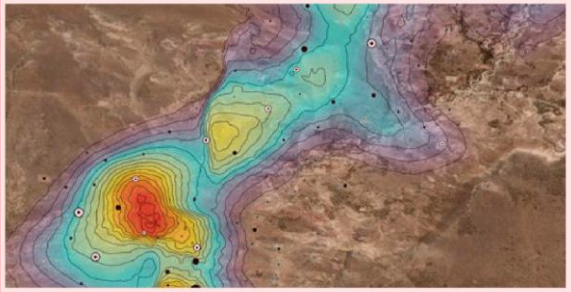
# L3HARRIS GEOSPATIAL SOLUTIONS



# Introduction to Synthetic Aperture Radar (SAR)

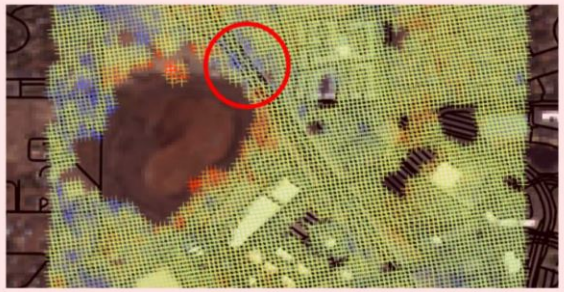
# Main Applications of Synthetic Aperture Radar (SAR) Data

## LANDSLIDES



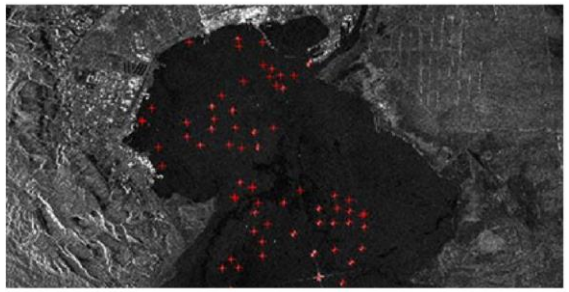
Map and measure surface movement caused by human activity or from natural causes.

## SUBSIDENCE



Monitor surface subsidence to understand the effects of tectonic and human activities.

## SHIPPING

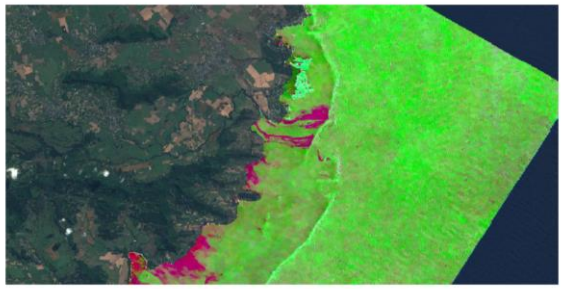


Detect and identify ships (including dark vessels and semi-submersibles) and perform maritime surveillance.

## AGRICULTURE

Measure plant health, growth and biomass even in areas with frequent rain and cloud cover.

## OIL SPILLS

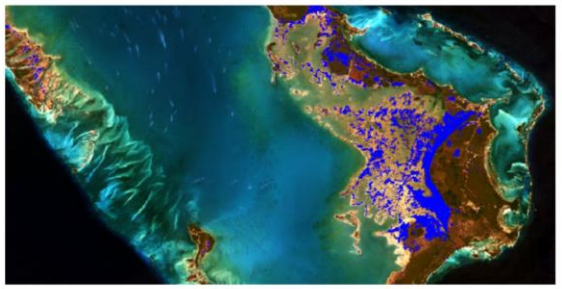


Detect and monitor oil spills and map their extent.

## DEFORESTATION

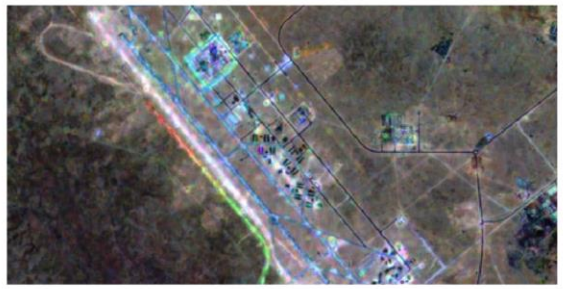
Monitor and calculate deforestation and forest degradation and analyze the impact.

## FLOODING



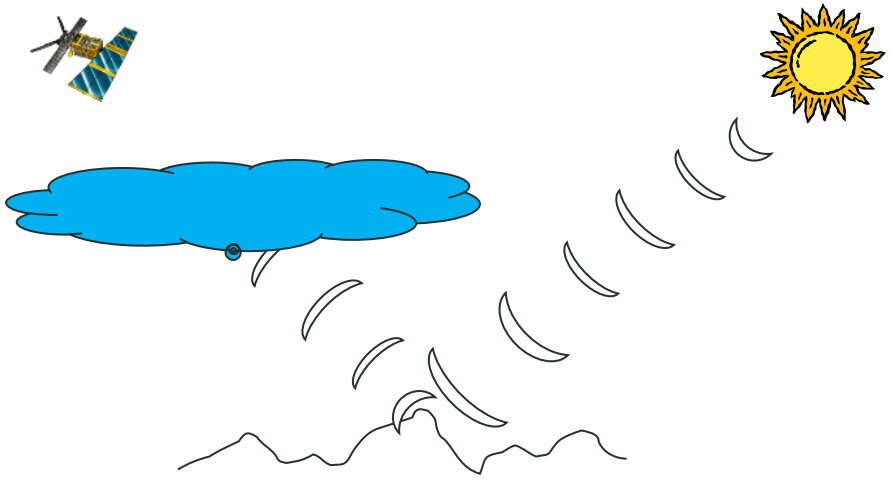
Gather timely information and calculate flood extent to respond to and mitigate effects from floods.

## ACTIVITY MONITORING

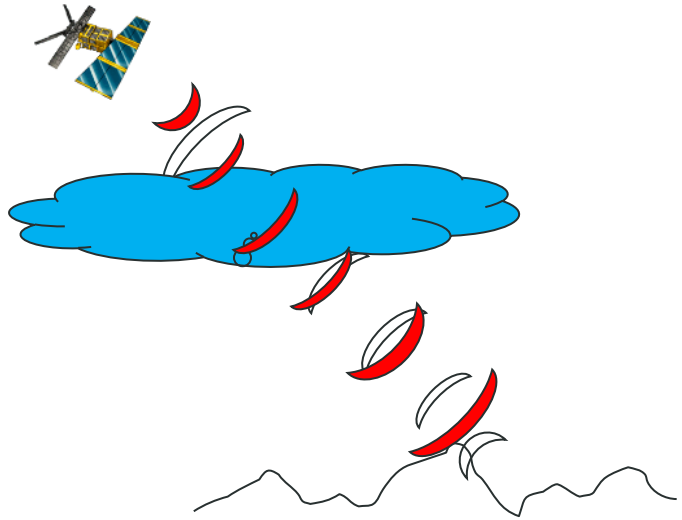


Understand activity patterns and changes to the patterns to support Activity Based Intelligence (ABI).

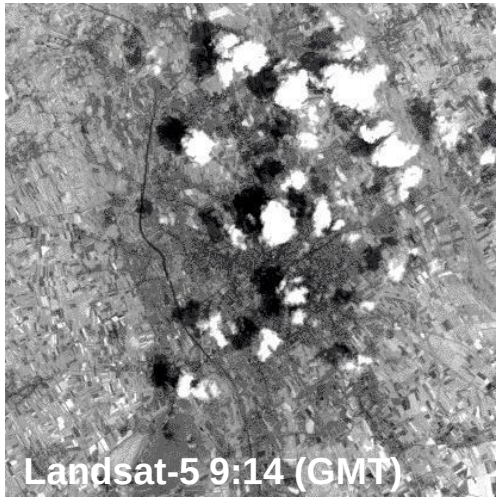
# Optical vs. Synthetic Aperture Radar (SAR)



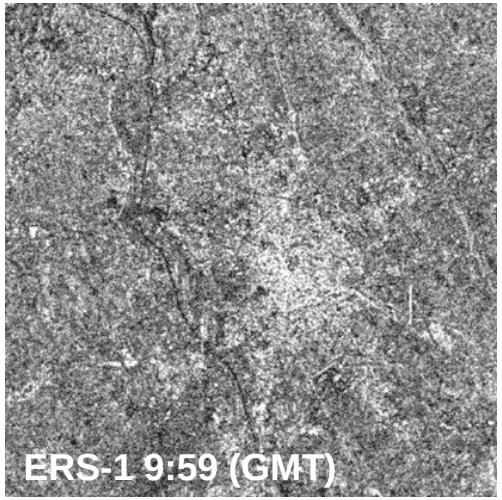
**Optical:** reflected sunlight



**SAR:** active microwave



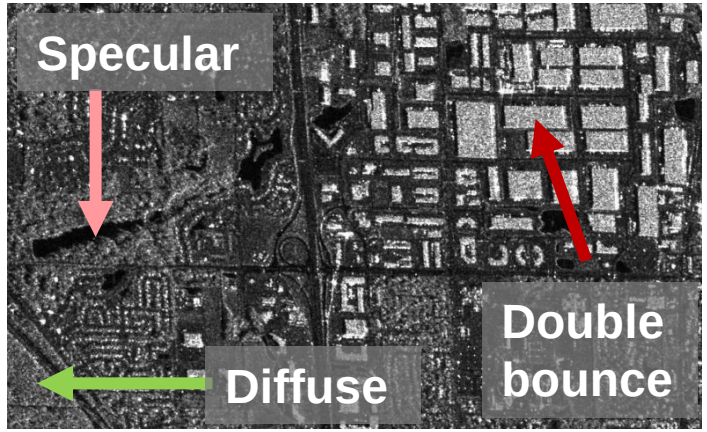

*Udine, Italy, April 07th,1993 © ESA*



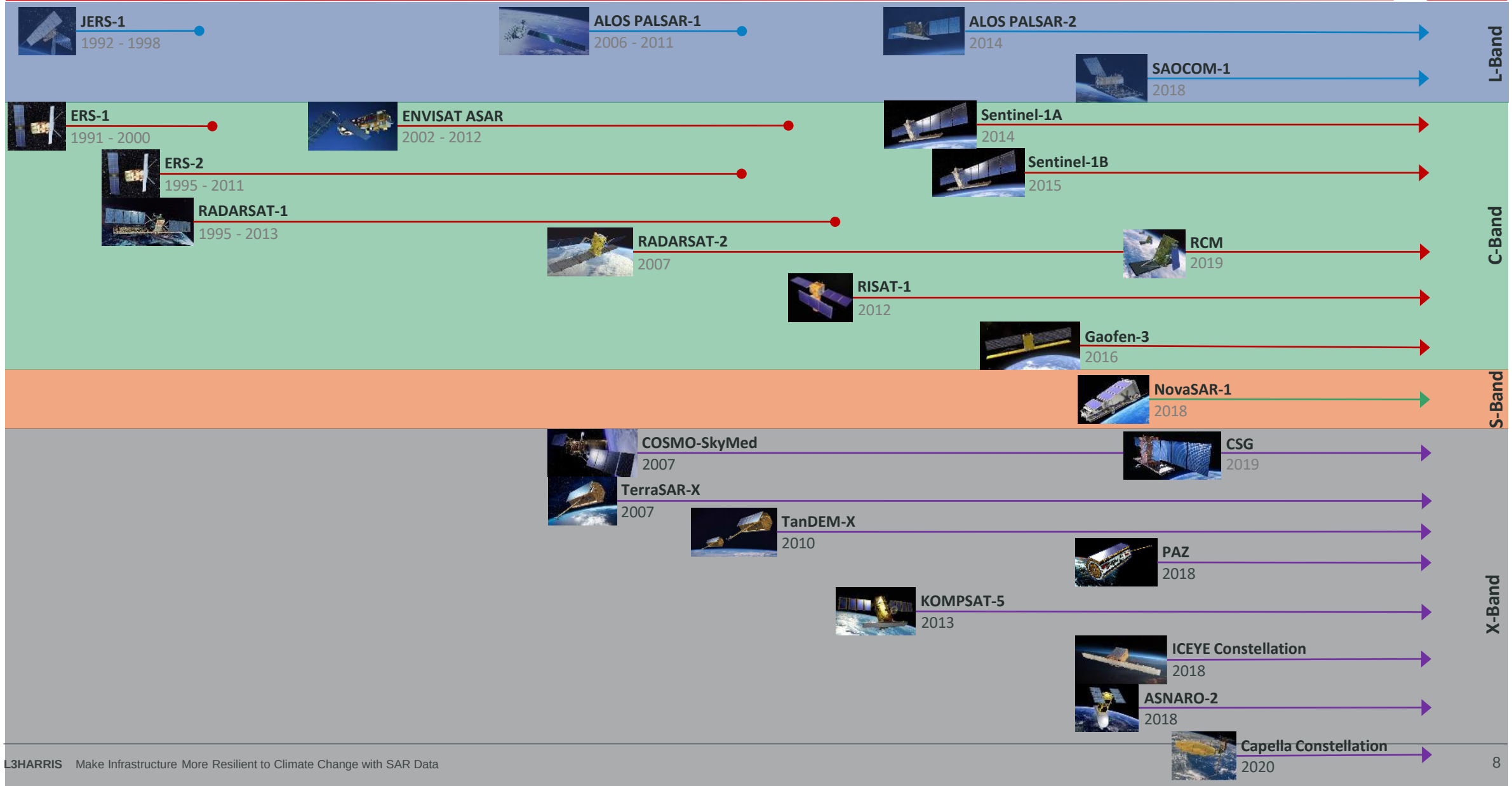
# SAR Backscatter / Evolution of Sensors

COSMO-SkyMed StripMap Mode, Halberstadt, Germany. © COSMO-SkyMed data, ASI / e-GEOS

- Radar sensor
  - Emits own radiation
  - Microwave
  - One channel
  - Day / night
  - See through clouds
- Sensitivity to surface parameters
  - Roughness
  - Geometric shape
  - Water content
  - …

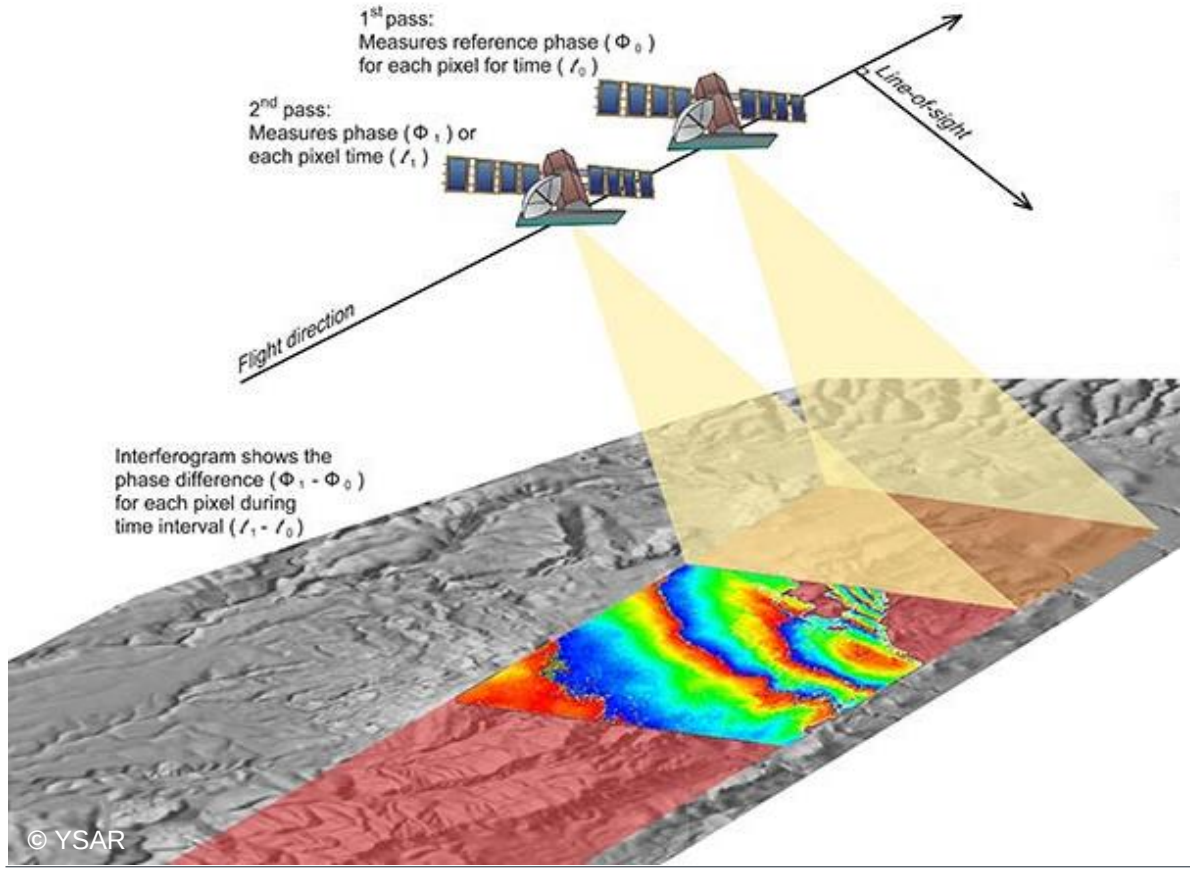


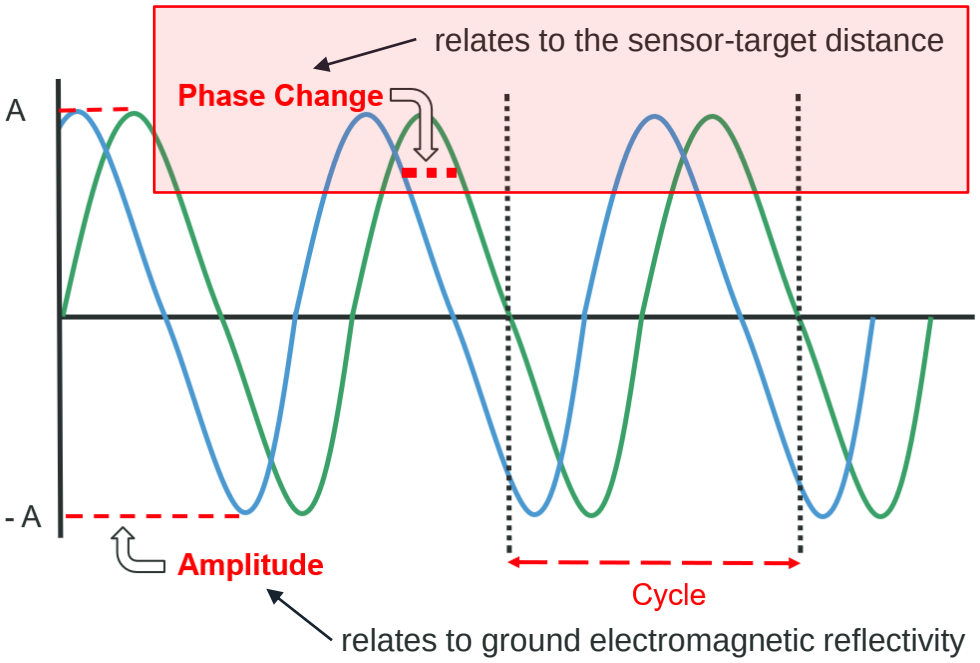
# Commercial SAR Spaceborne Sensors



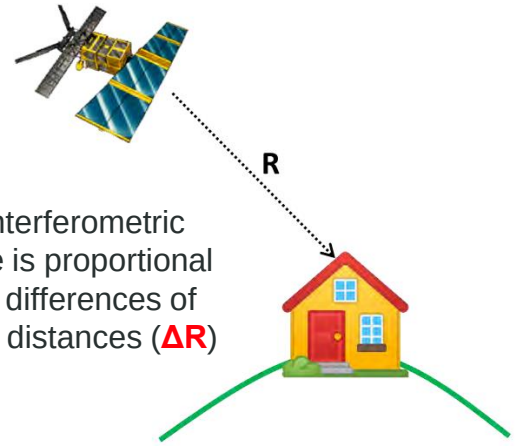
# SAR Interferometry

- A SAR image is a set of pixels characterized by both amplitude and phase values
- Through SAR interferometry, it is possible to reconstruct Topography (**InSAR**) or Land Movement (**DInSAR**)

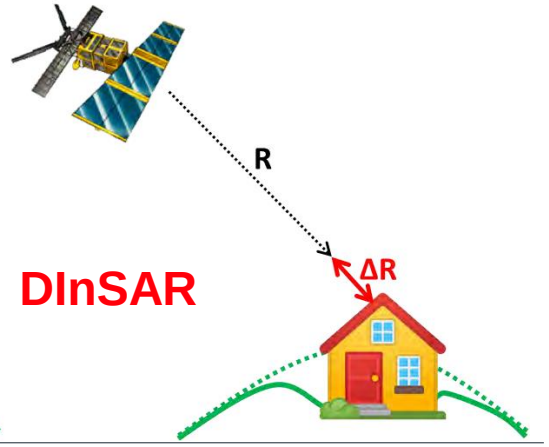


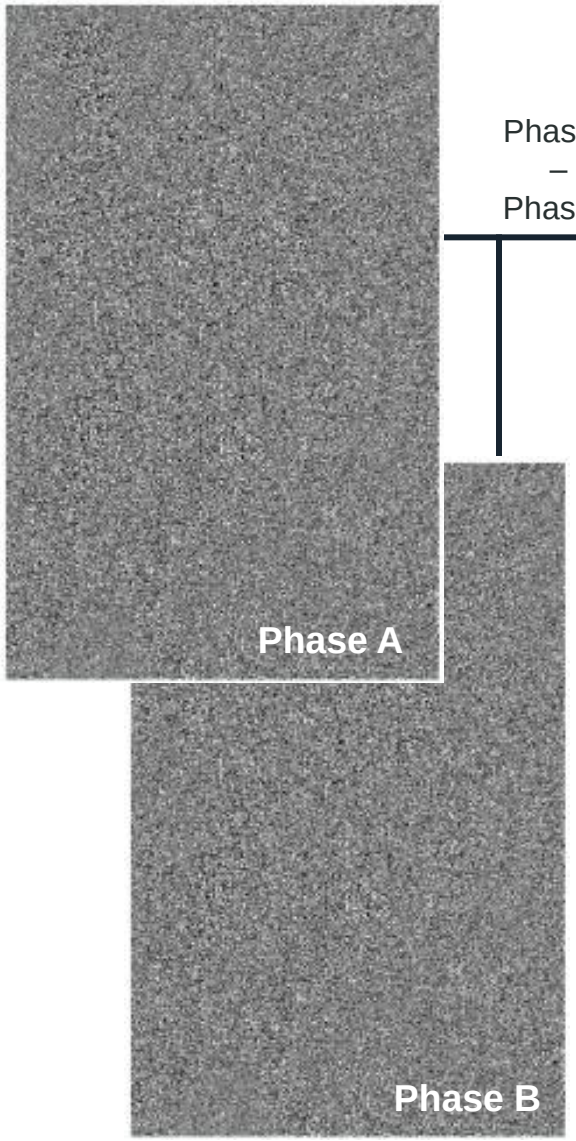

The interferometric phase is proportional to the differences of range distances (**ΔR**)



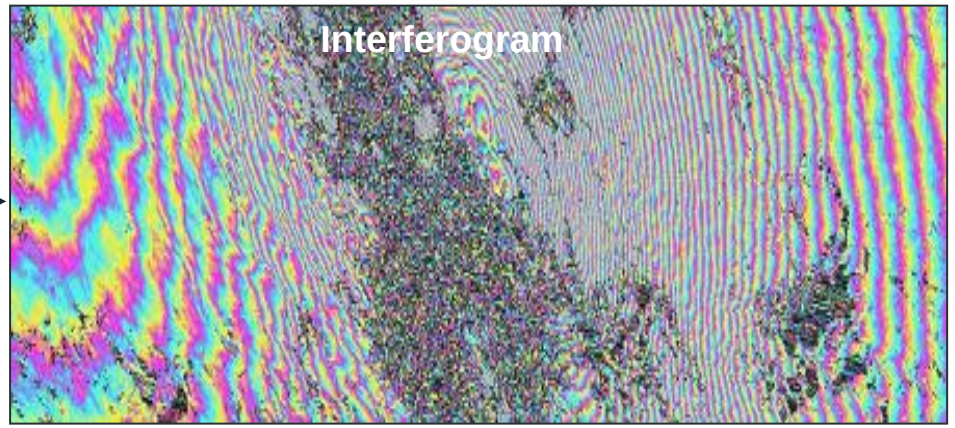

**DInSAR**



# SAR Interferometry

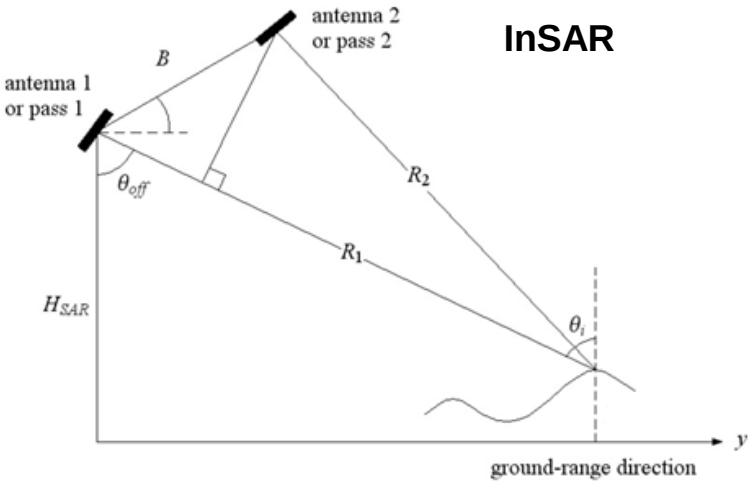



Phase A
–
Phase B




**SAR Interferometry**

**InSAR**




$$\phi_{Int} = \phi_{Topography} + \phi_{Movement} + \phi_{Noise} + \phi_{Atmosphere}$$

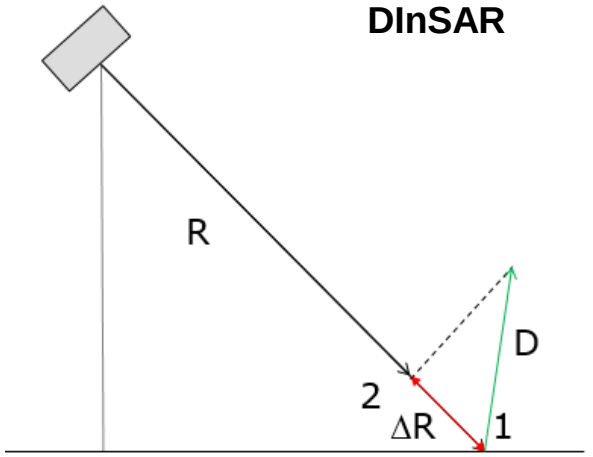
$$\phi_{Int} = \phi_{Topography} + \phi_{Noise}$$

**DEM Generation**

$$\phi_{Int} = \phi_{Movement} + \phi_{Noise}$$

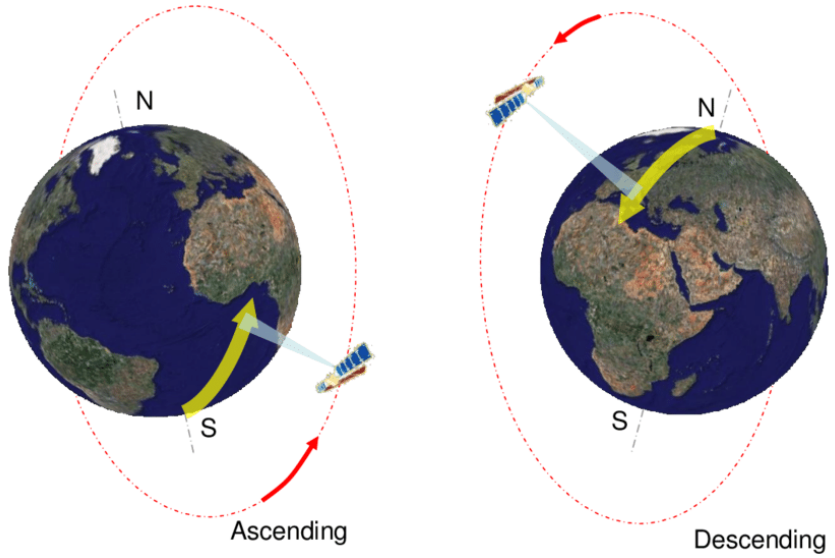
**Displacement Generation**

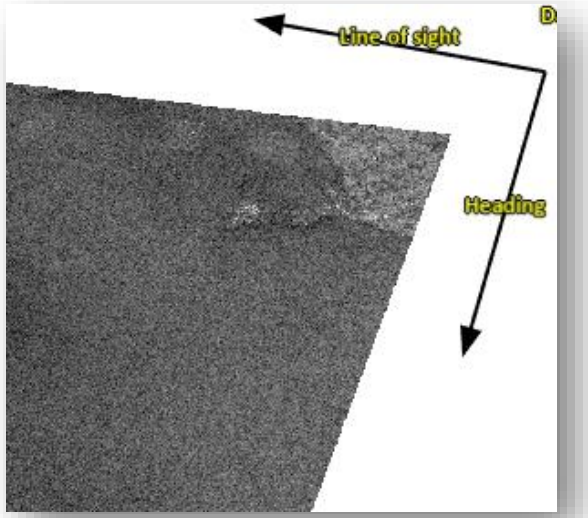
**DInSAR**



# Deformation Projections

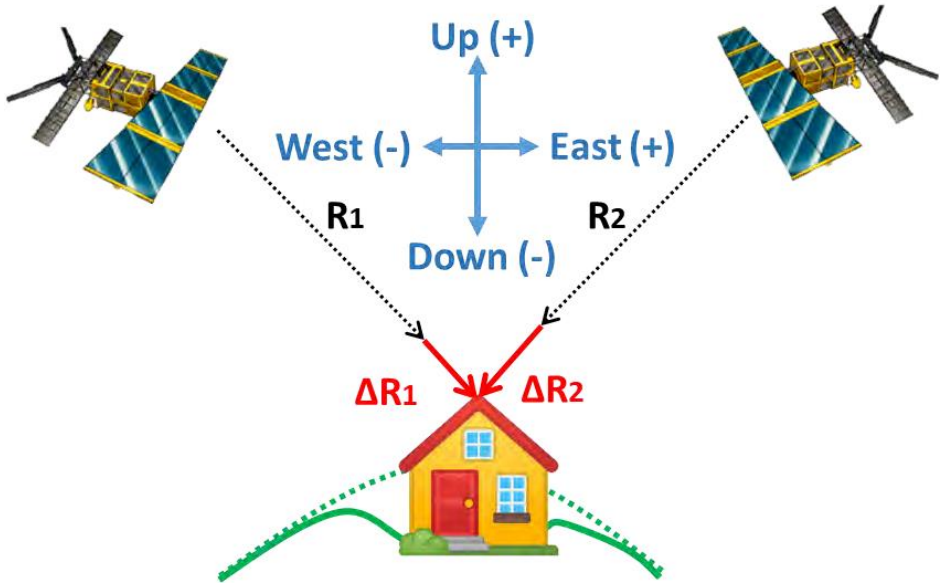
- Due to the SAR side looking geometry, displacement is measured along the Line of Sight (LOS)
- To reconstruct horizontal and vertical displacements, ascending and descending data over the same area is required




**Ascending Orbit**
*South → North*

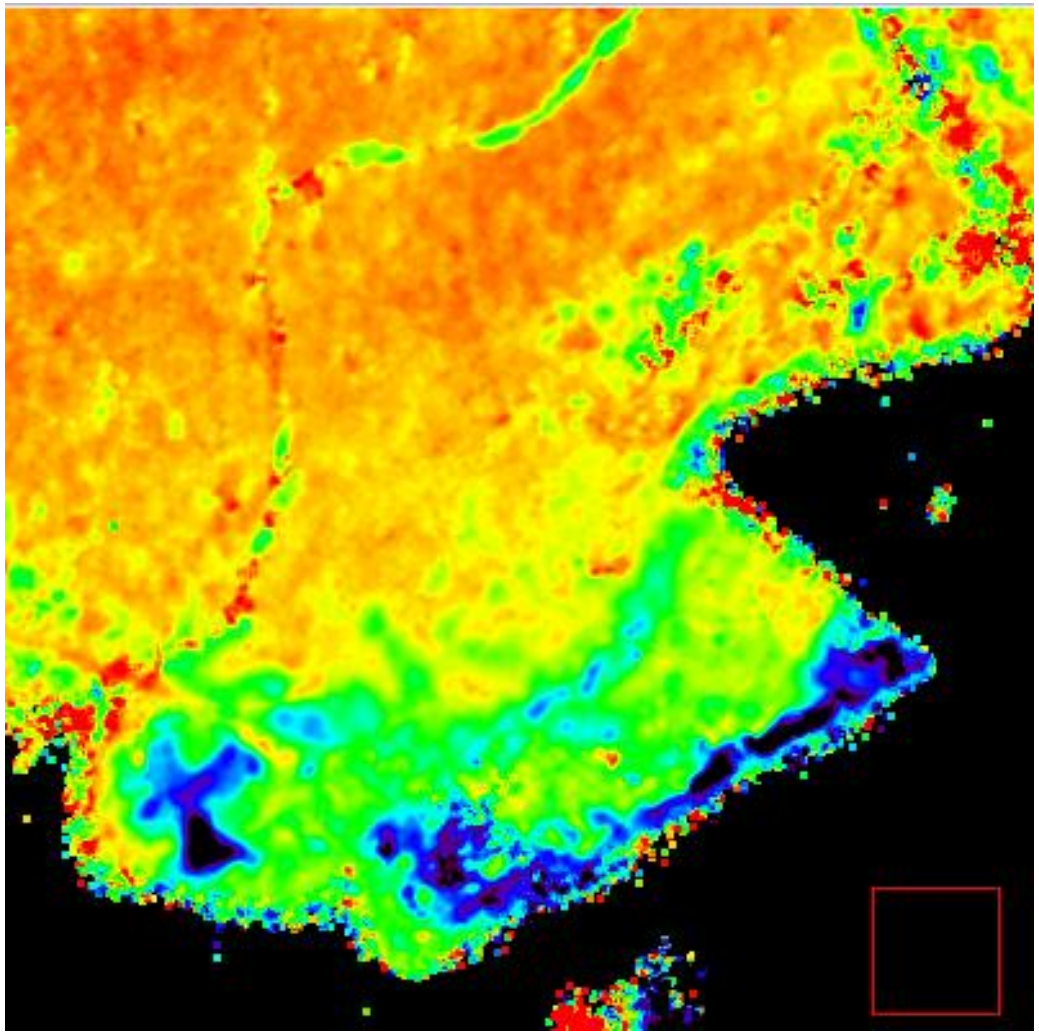
**LOS**
East looking



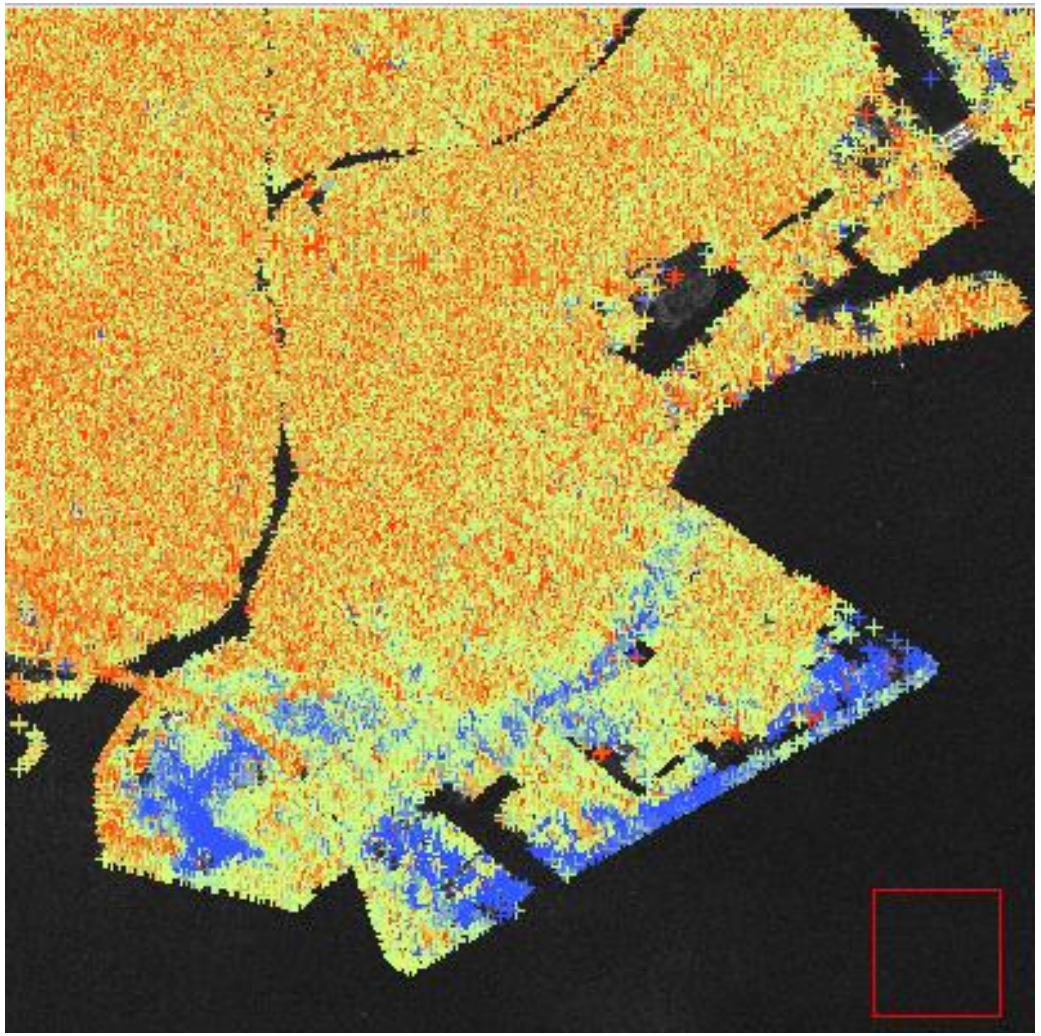

**LOS**
West looking

**Descending Orbit**
*North → South*

# SARscape Interferometric Stacking Types



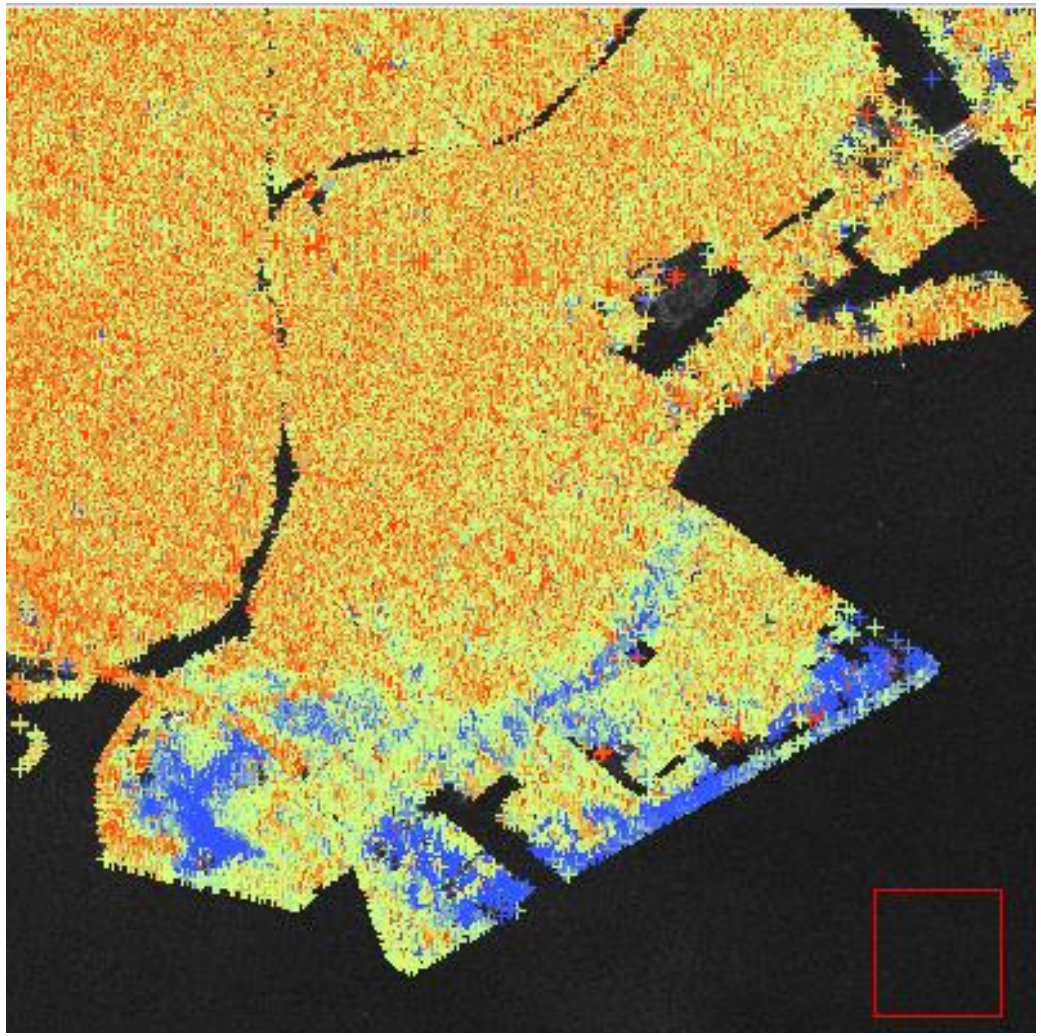
Small BAseline Subsets (SBAS)



Persistent Scatterers (PS)

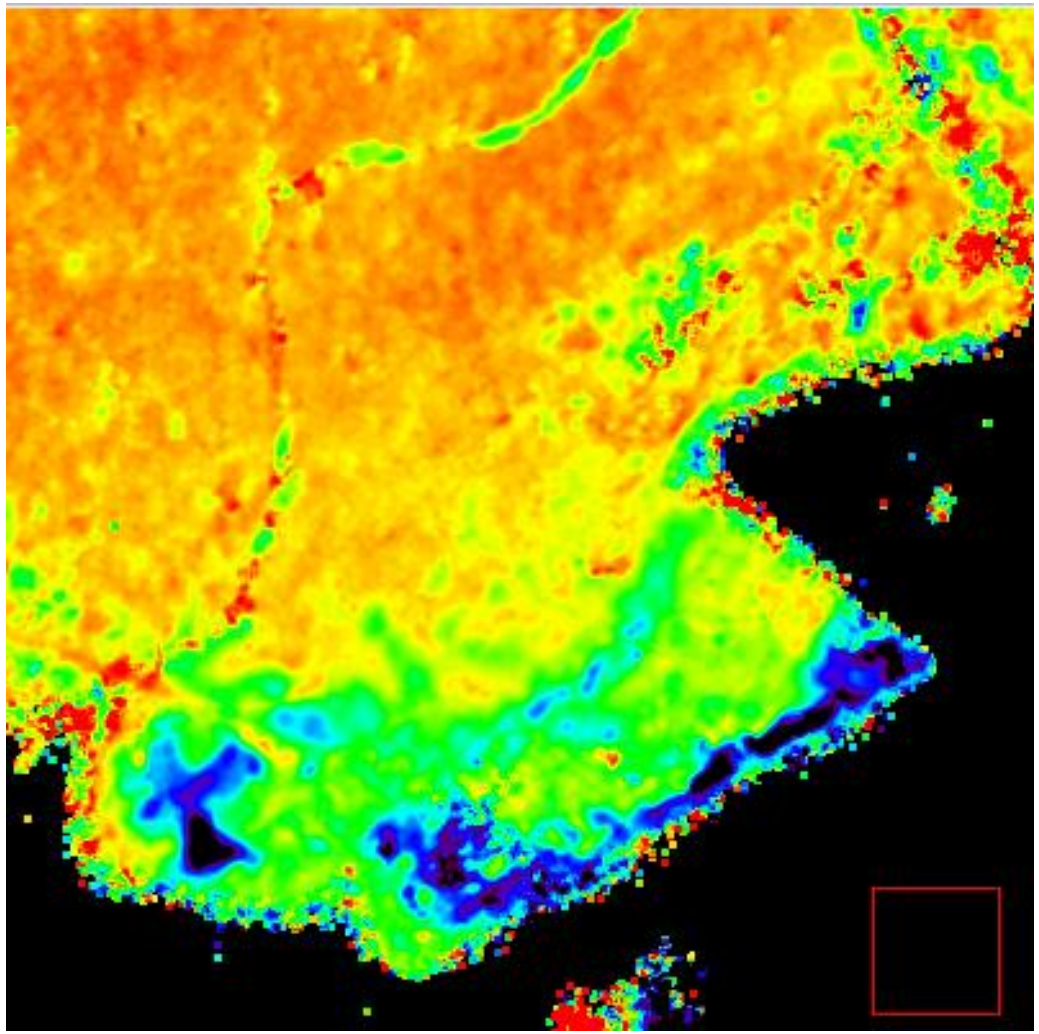
# Persistent Scatterers (PS)

- Point targets (Persistent Scatterers)
- Linear behavior
- For objects with consistent signals, such as urban regions and rock type features
- Independent, uncorrelated motions of single, non-connected positions / pixels
- Can have large differences between adjacent pixels
- Will ignore areas with lack of coherence instead of trying to interpret them
- Expects continuous time series
- Time interval between two acquisitions is limited by the displacement rate
- Can be run completely automatically



# Small BAseline Subsets (SBAS)

- Natural targets (Distributed Scatterers)
- Non-linear behavior
- For urban and non-urban areas, such as open fields and not very geometrically characterized objects
- Spatially correlated displacements with smooth changes over time
- Can be used for areas with lower coherency
- Capable of handling time series with temporal holes
- Time interval between two acquisitions is limited by temporal decorrelation
- Can be run completely automatically (since SARscape 5.6.2), but quality control of generated interferograms still needed



# Applications using SAR for Infrastructure Monitoring

# Assessing infrastructure resilience by satellite

Dr Skevi Perdikou
Technical Manager

GEOFEM

# Contents

- ***Case studies where 5+ years of data can be obtained retrospectively to determine asset trends***

- ***AI for infrastructure susceptibility to geohazards***
  - Climate change
  - Reduction of carbon footprint

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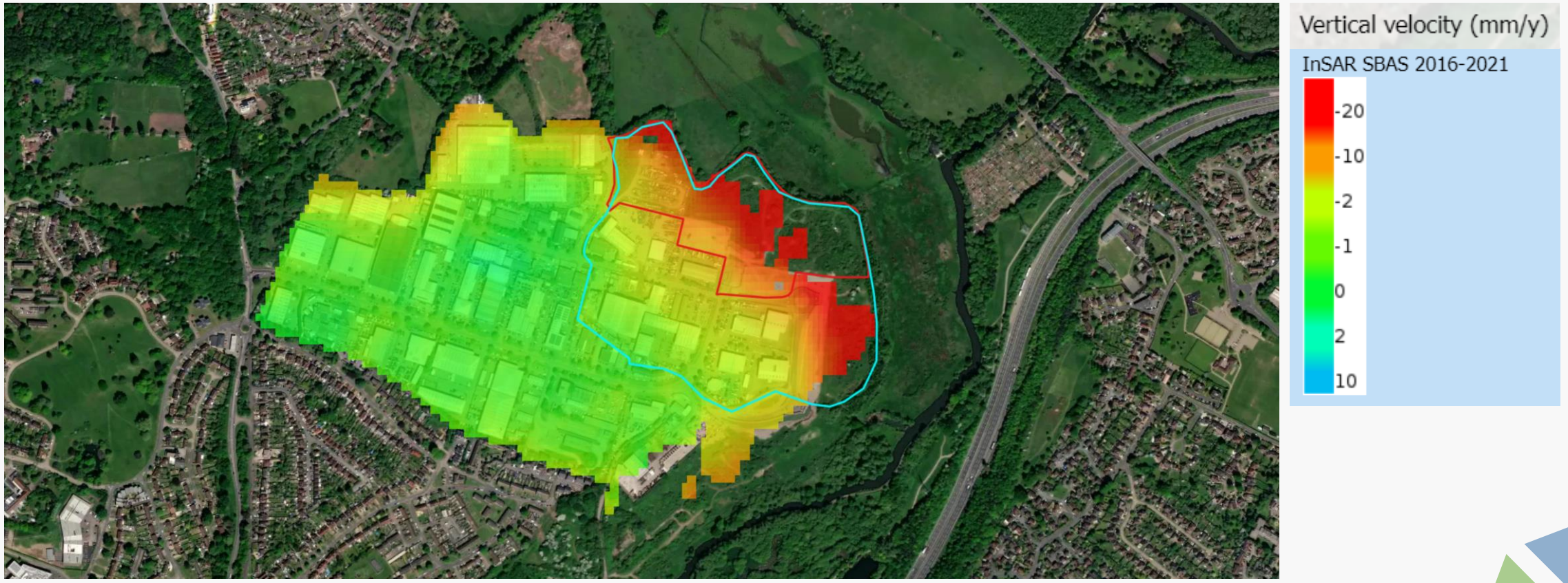
# SAR data

- Global coverage.
- Retrospective analysis since 1992, but regular data *since 2015* (free data – Sentinel-1).
- Historical commercial data might exist for major cities.

www.eyegis.net

# Case studies - Landfill

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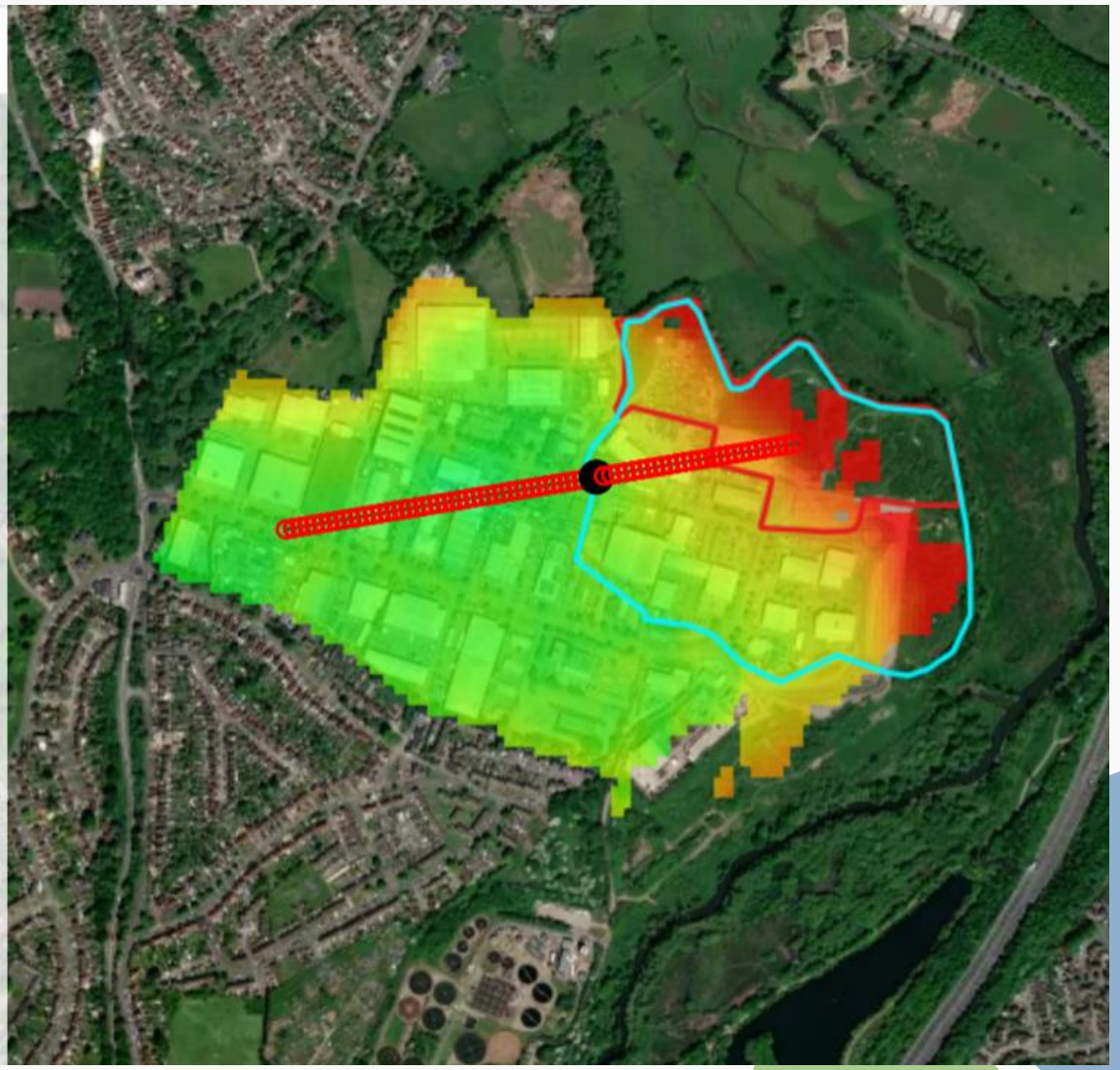
# Case studies - Landfill

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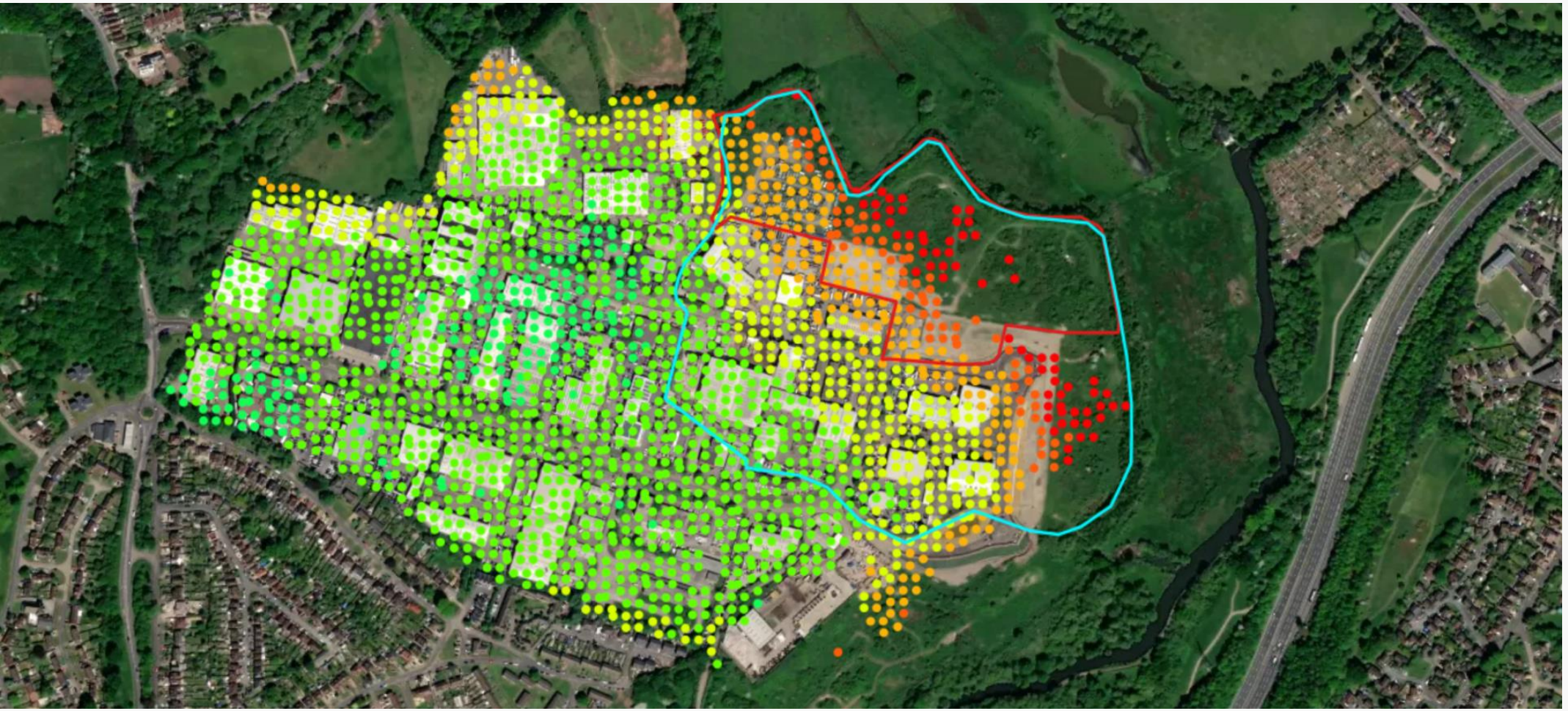
# Case studies - Landfill

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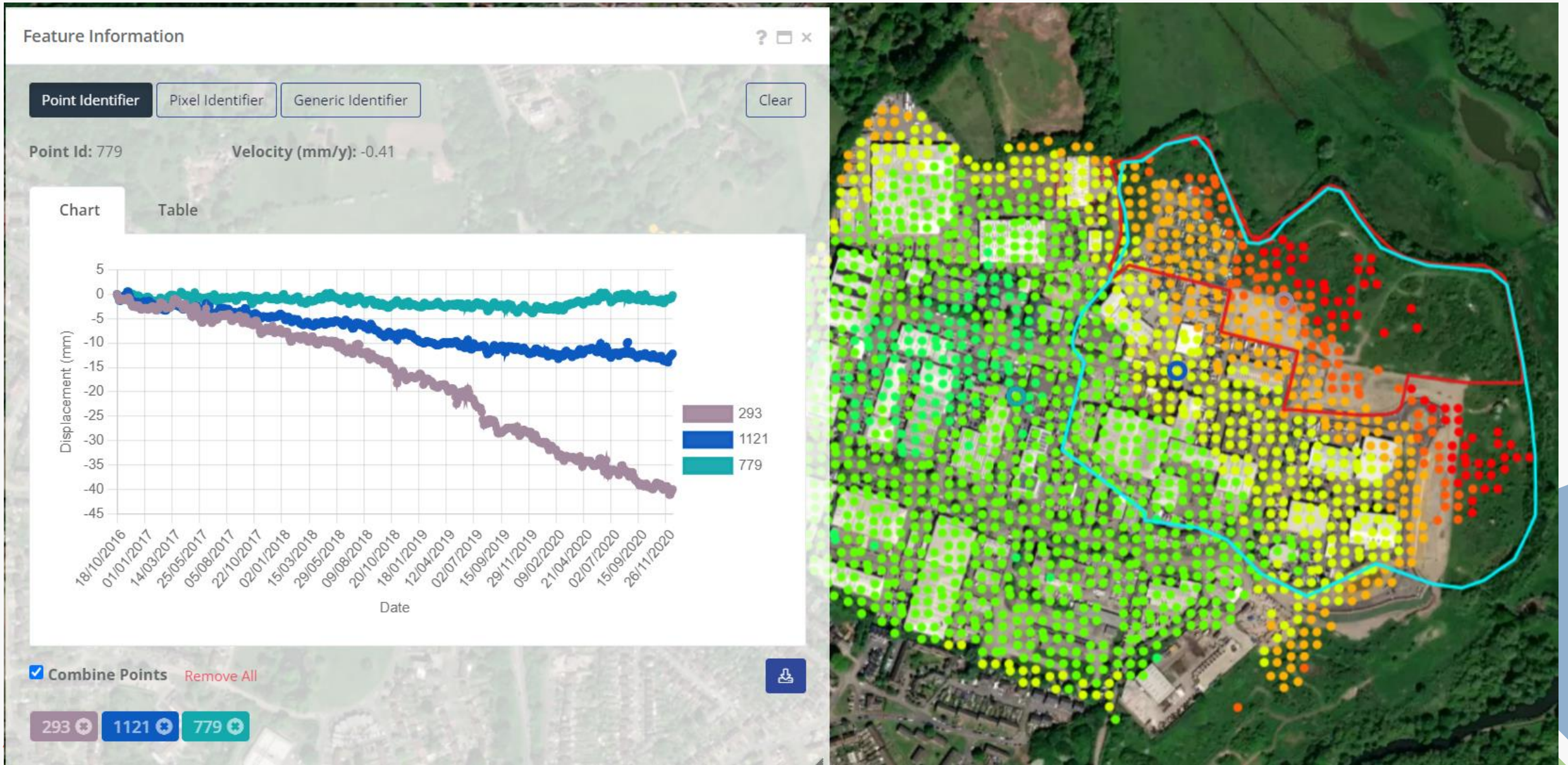
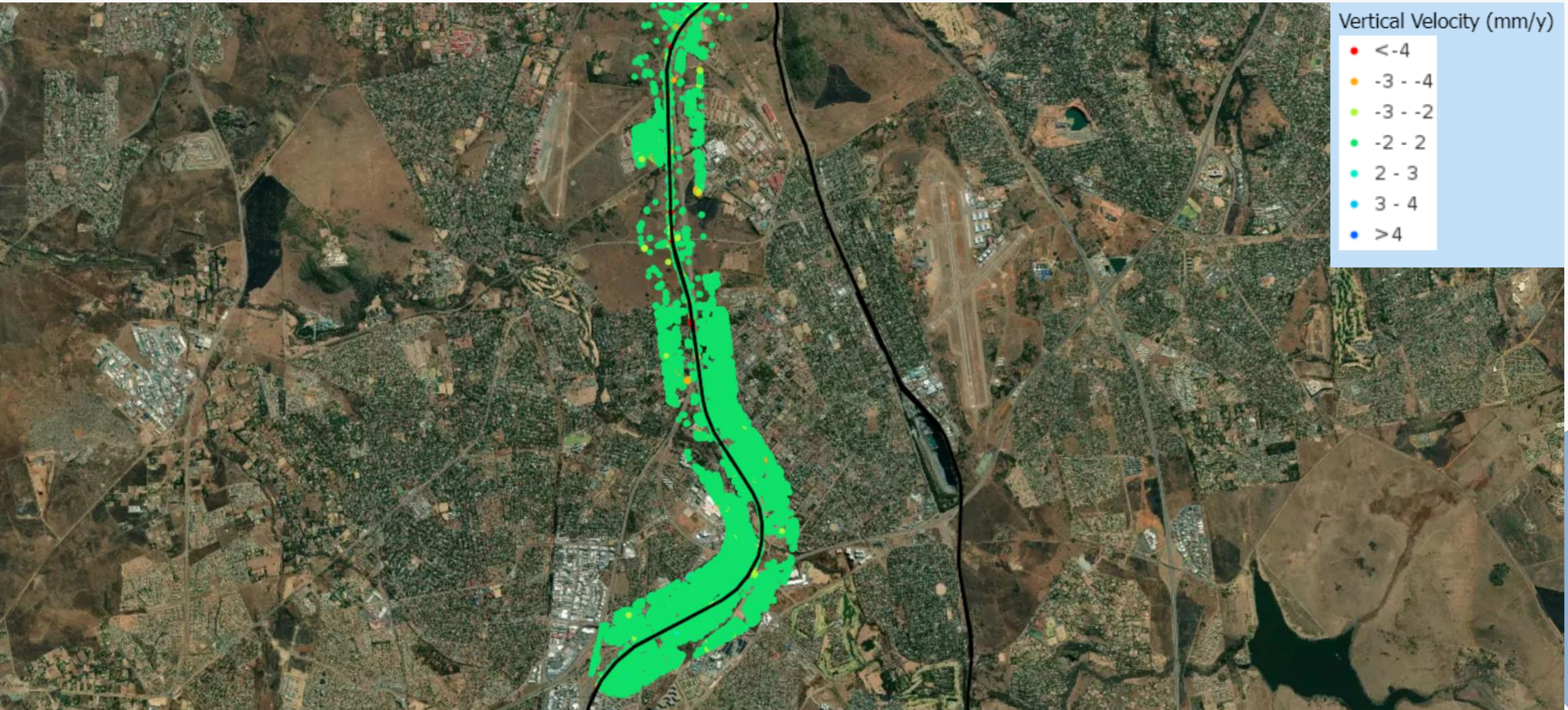
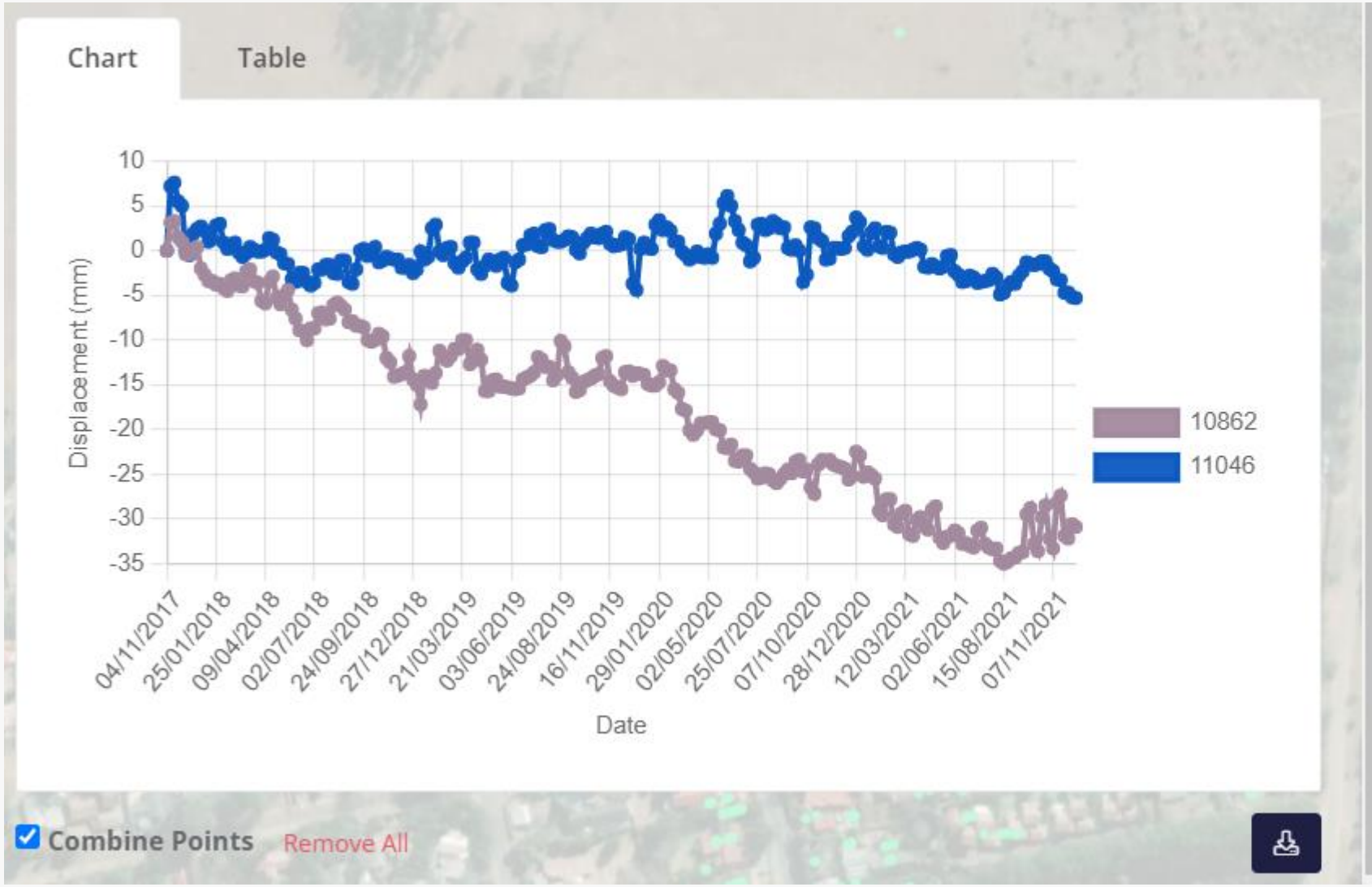
# Case studies - Landfill

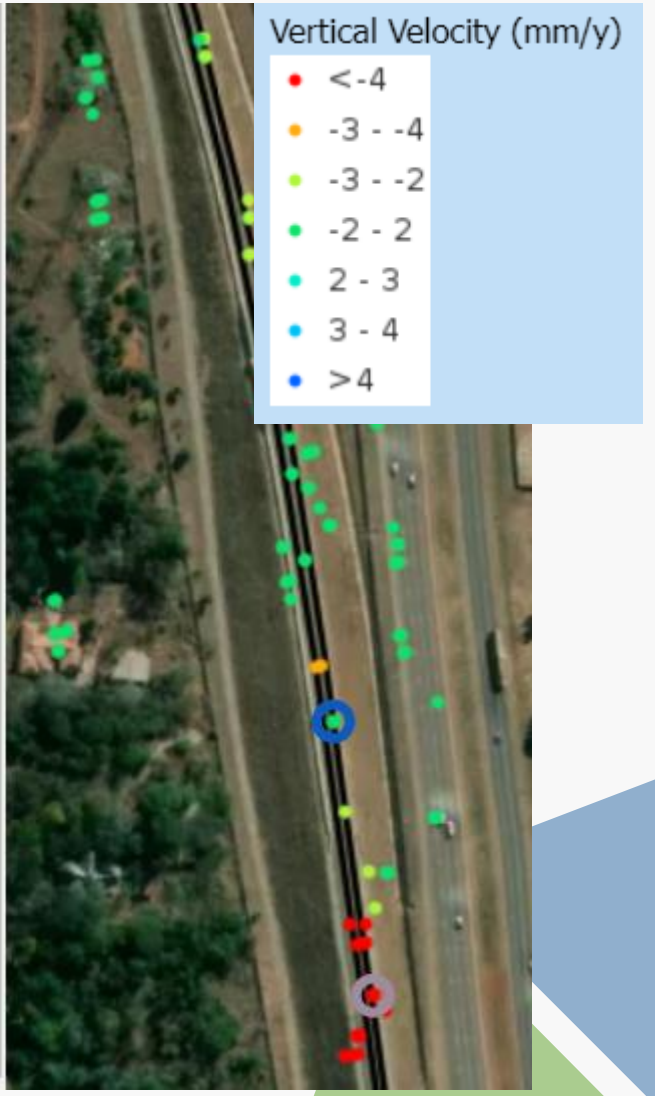


# Case studies - Railway



# Case studies - Railway

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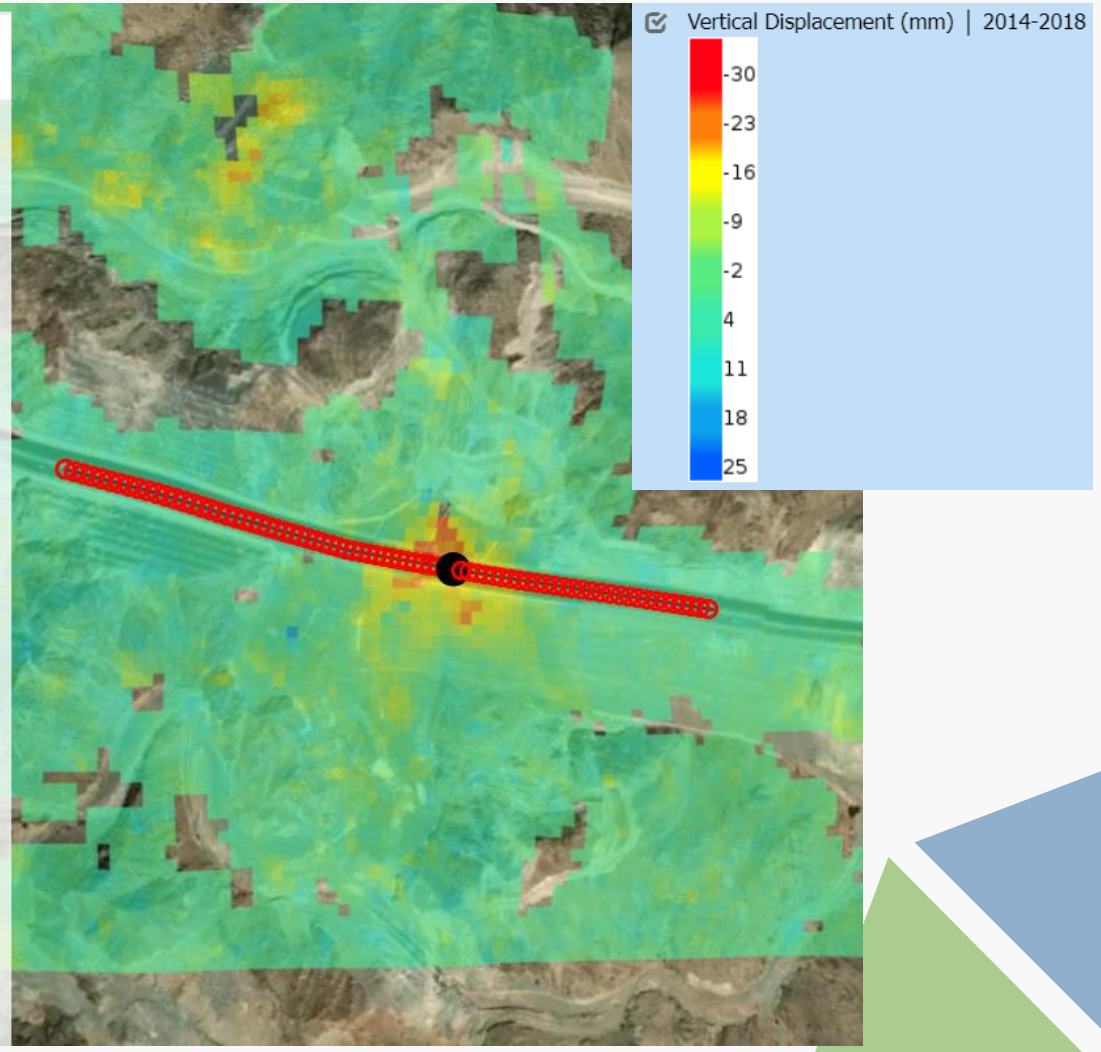
# Case studies - Highway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# FAQs

*Have these techniques been validated?*

- The ESA-funded Terrafirma project in 2009 validated SAR data from rural and urban sites in The Netherlands.
- Standard deviations of differences between time-series InSAR and ground truth of only 1.0 to 1.8mm/year

GMES

TERRAFIRMA

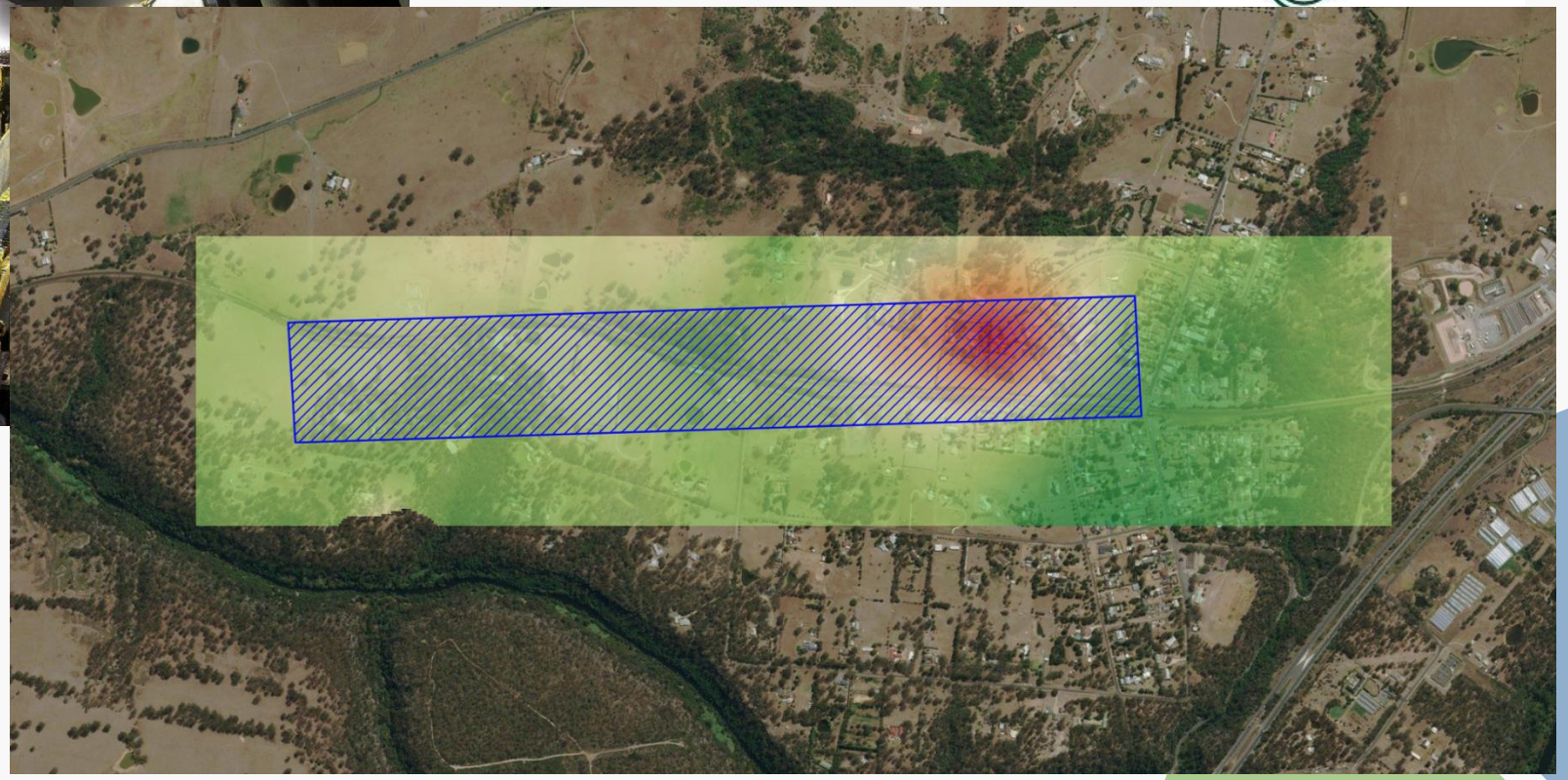
ESRIN/Contract no. 19366/05/I-EC

GMES TERRAFIRMA

GEOFEM

# FAQs

*Have these techniques been validated?*



Longwall mining, NSW

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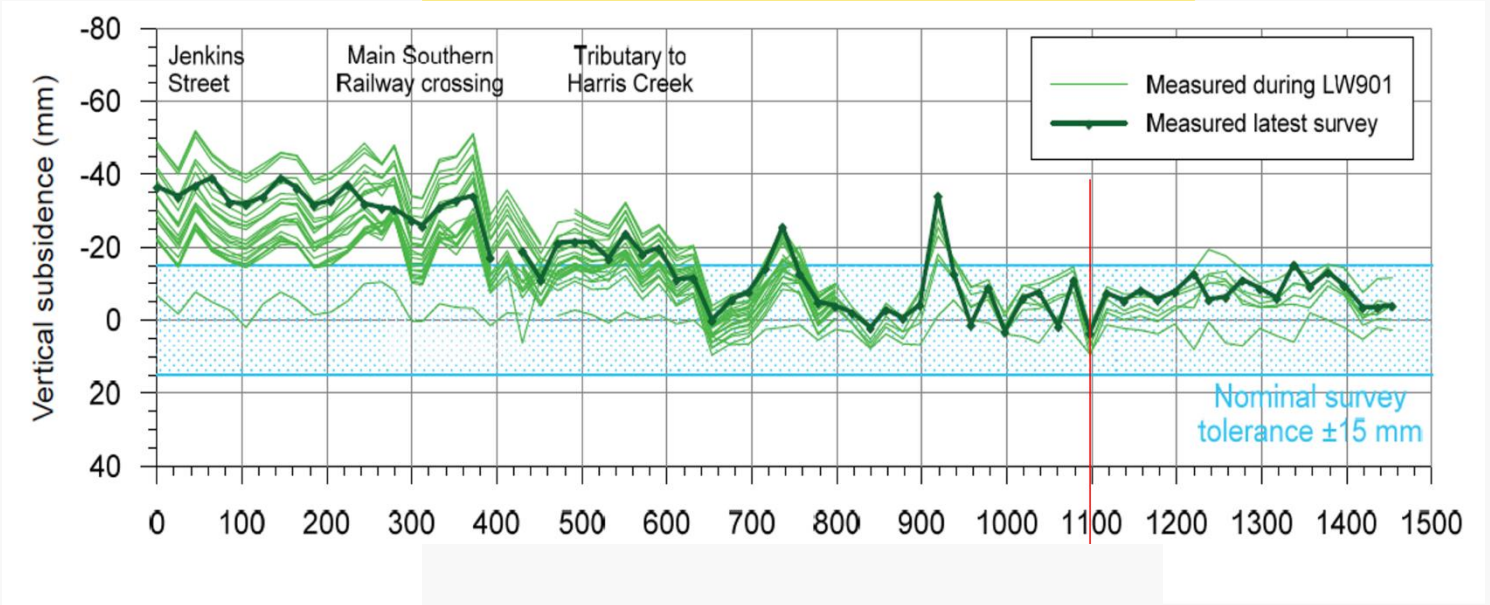
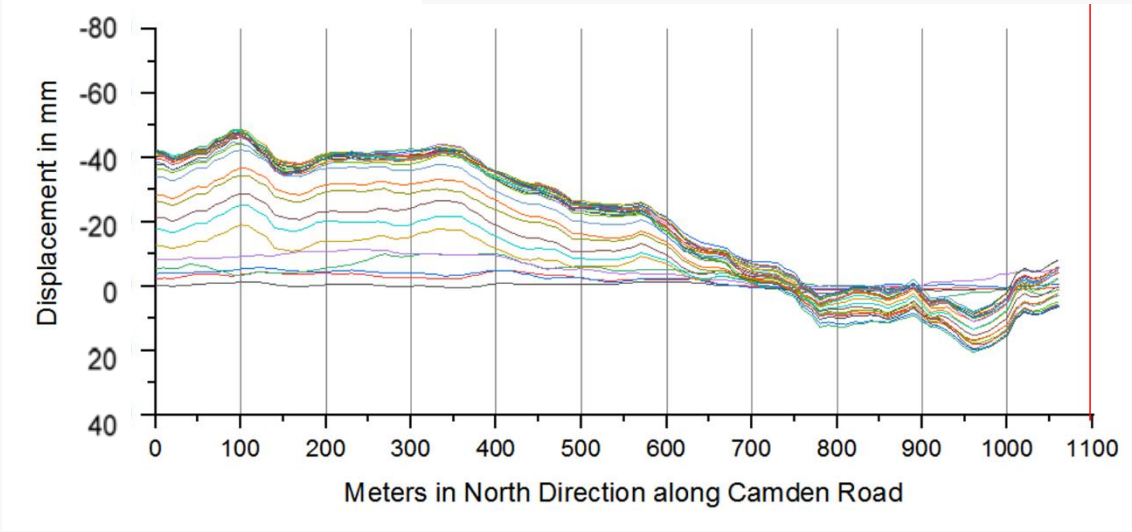
# FAQs

*Have these techniques been validated?*




Weekly in-situ survey data along Camden Road




InSAR data along Camden Road over the same period

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# FAQs

*Can you guarantee data at a certain location?*

- No. It's possible only to estimate measurement point density.
- Geolocation uncertainty means you are never certain about specific point being measured.
- Unless…

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# Corner reflector

- Metallic trihedral corner reflector
- Guaranteed displacement data if:
  - pointing in right direction
  - large enough (typically ~1m wide)
  - unobstructed view of satellite

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# Infrastructure susceptibility to geohazards

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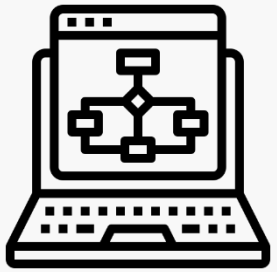
# Satellite data with engineering insight

Satellite data

- Displacement data
- Soil moisture data
- Topographical data

Asset susceptibility scores

| | |
|---|---|
| Landslides | ★ ★ ★ |
| Swelling clays | ★ ★ |
| Sinkholes | ★ ★ ★ ★ |



Artificial intelligence

Engineering know-how

Other data

- Geological maps
- Asset damage data
- Ground truth data

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# Susceptibility to geohazards:

# Landslides

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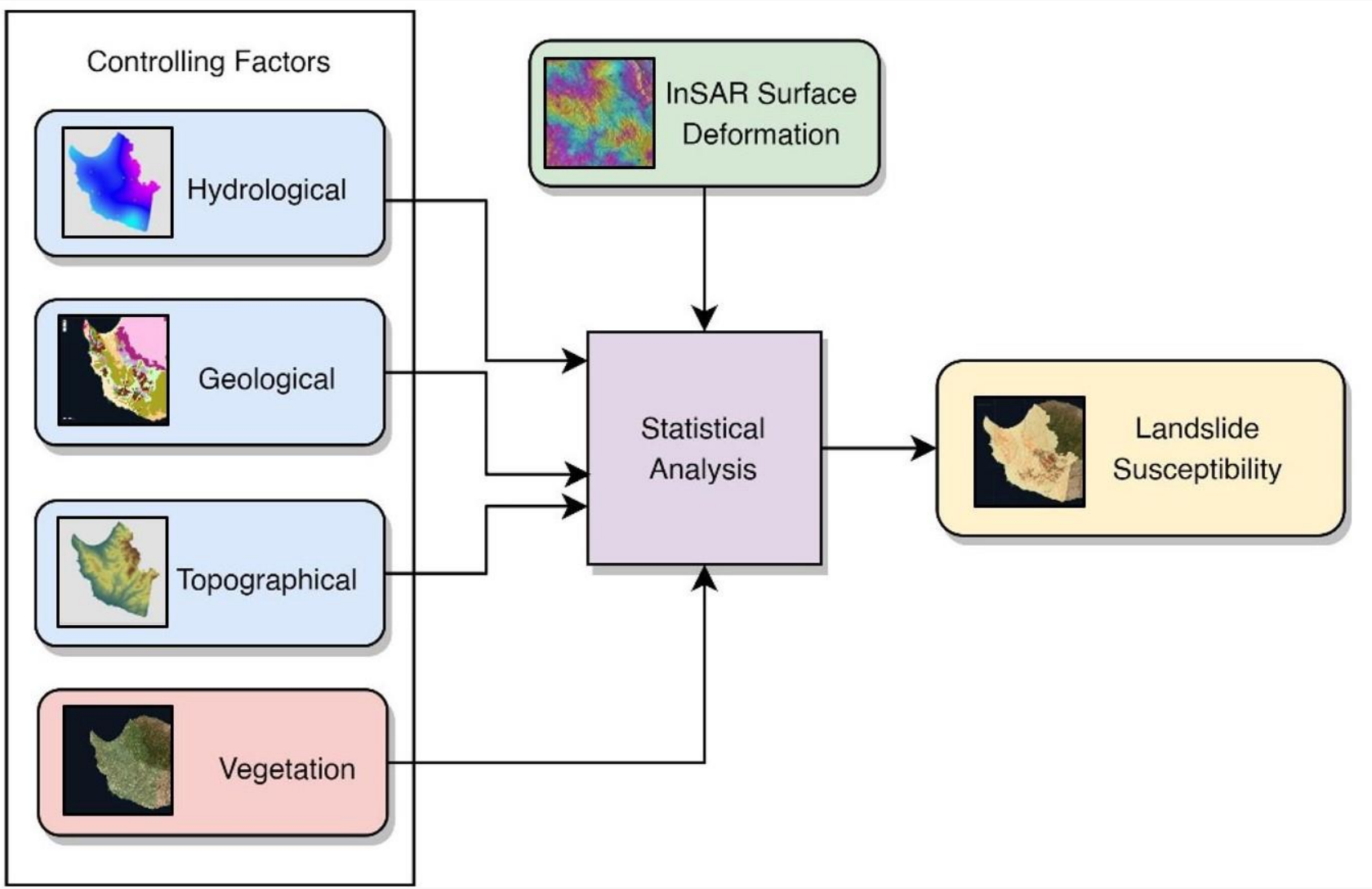
# Susceptibility to landslides

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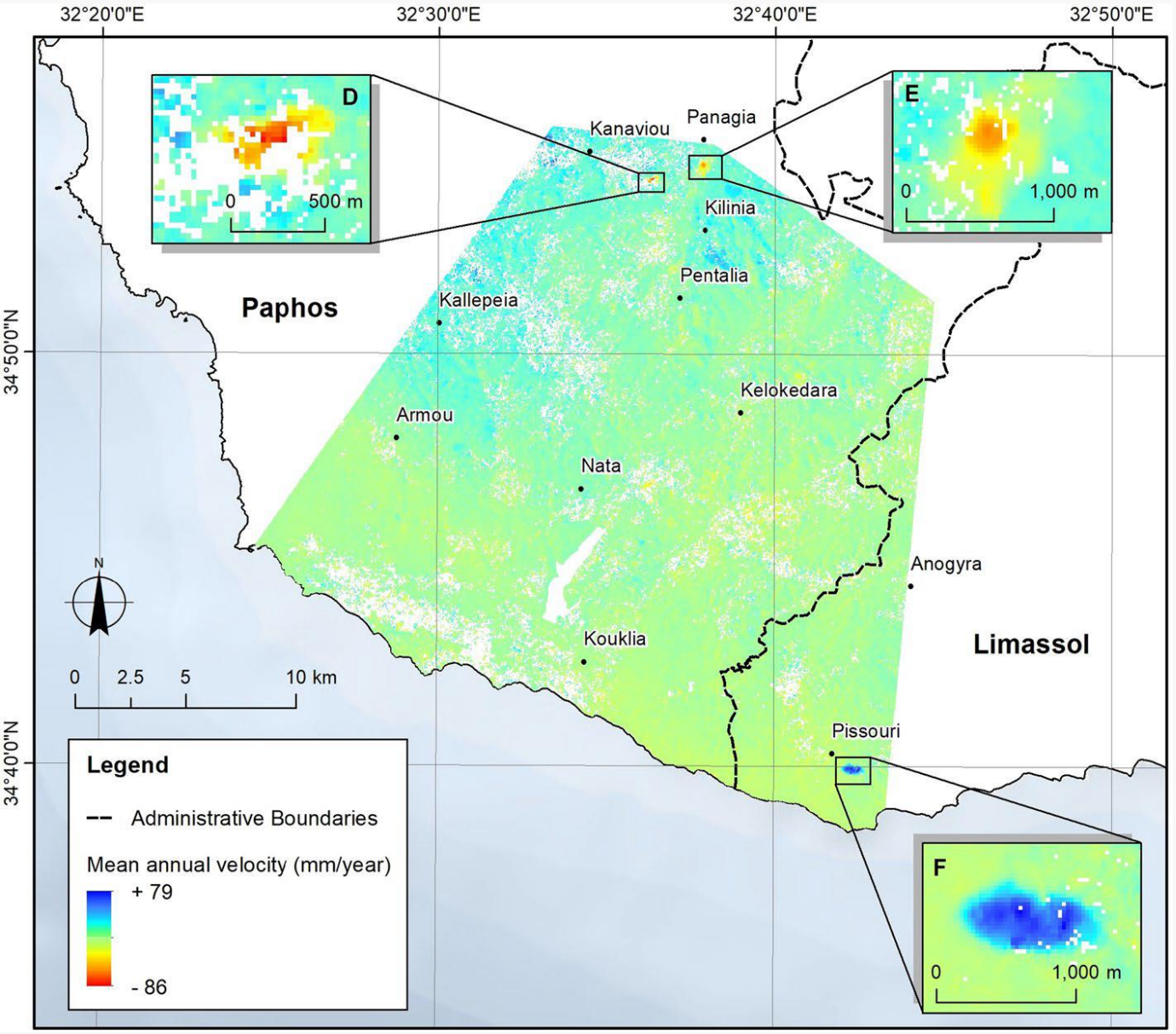
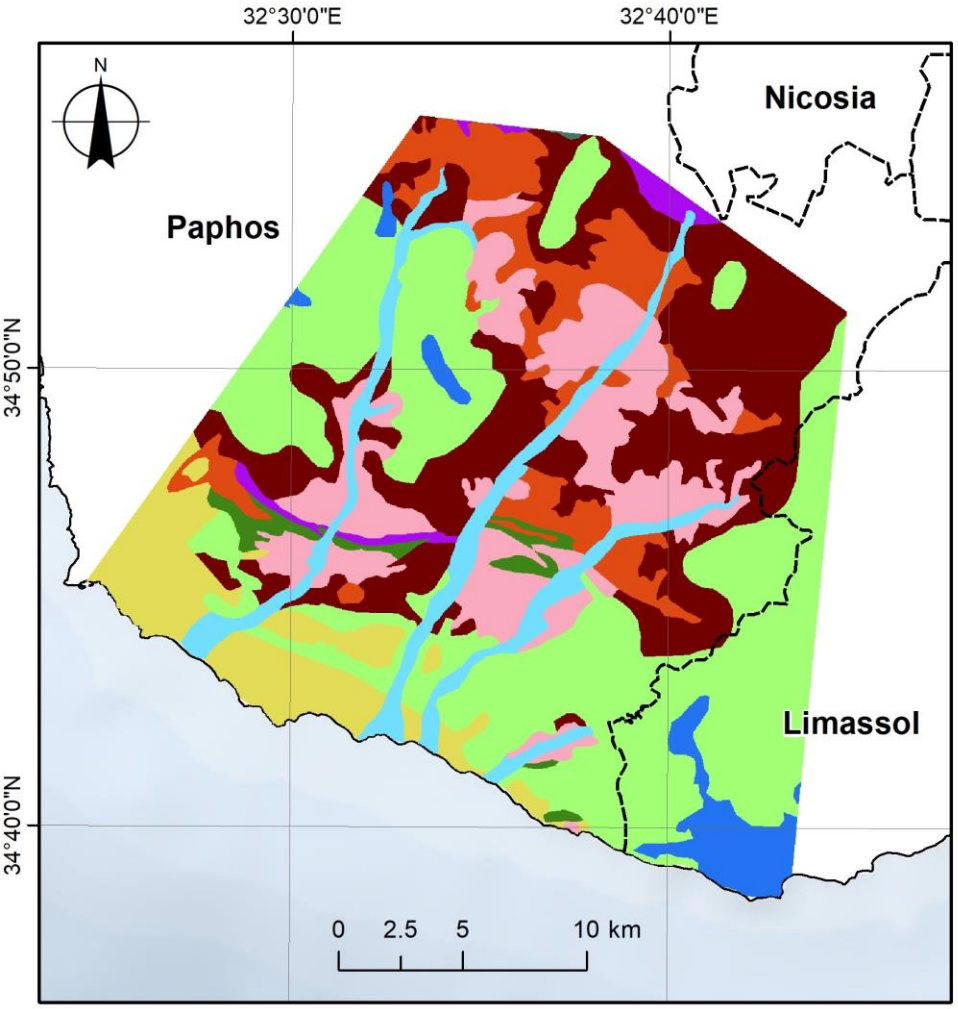
# Susceptibility to landslides




Mean annual ***horizontal*** velocity: mm/year

# Susceptibility to landslides

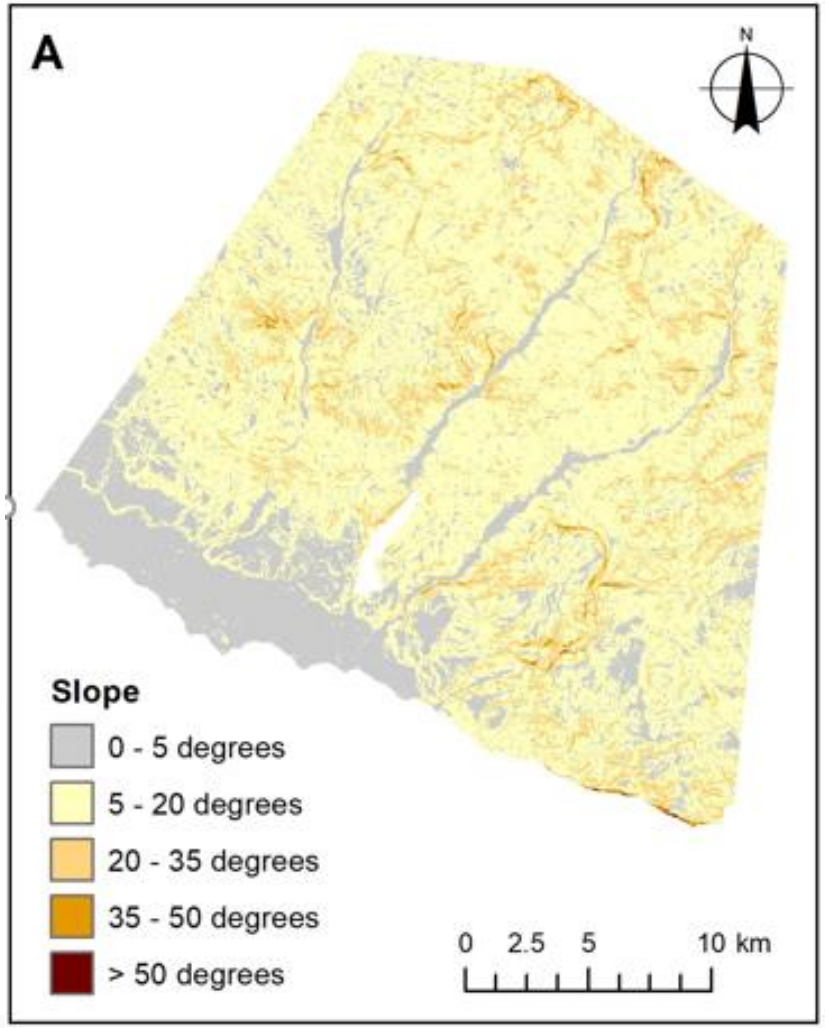



**Legend**

- Administrative Boundaries

**Geology**

- Sheeted Dykes (Diabase)
- Upper and Lower Pillow Lavas and Basal Group
- Alluvium - Colluvium
- Moni, Kannaviou and Pera Pedi Formations - Bentonitic
- Apalos, Athalassa, Kakkaristra and Nicosia Formations
- Kalavaso and Pachna Formations
- Terrace Deposits, Fanglomerate
- Lefkara, Kalogrea-Ardana and Lapithos Formations
- Mamonia Complex
- Harzburgite and Serpentinite

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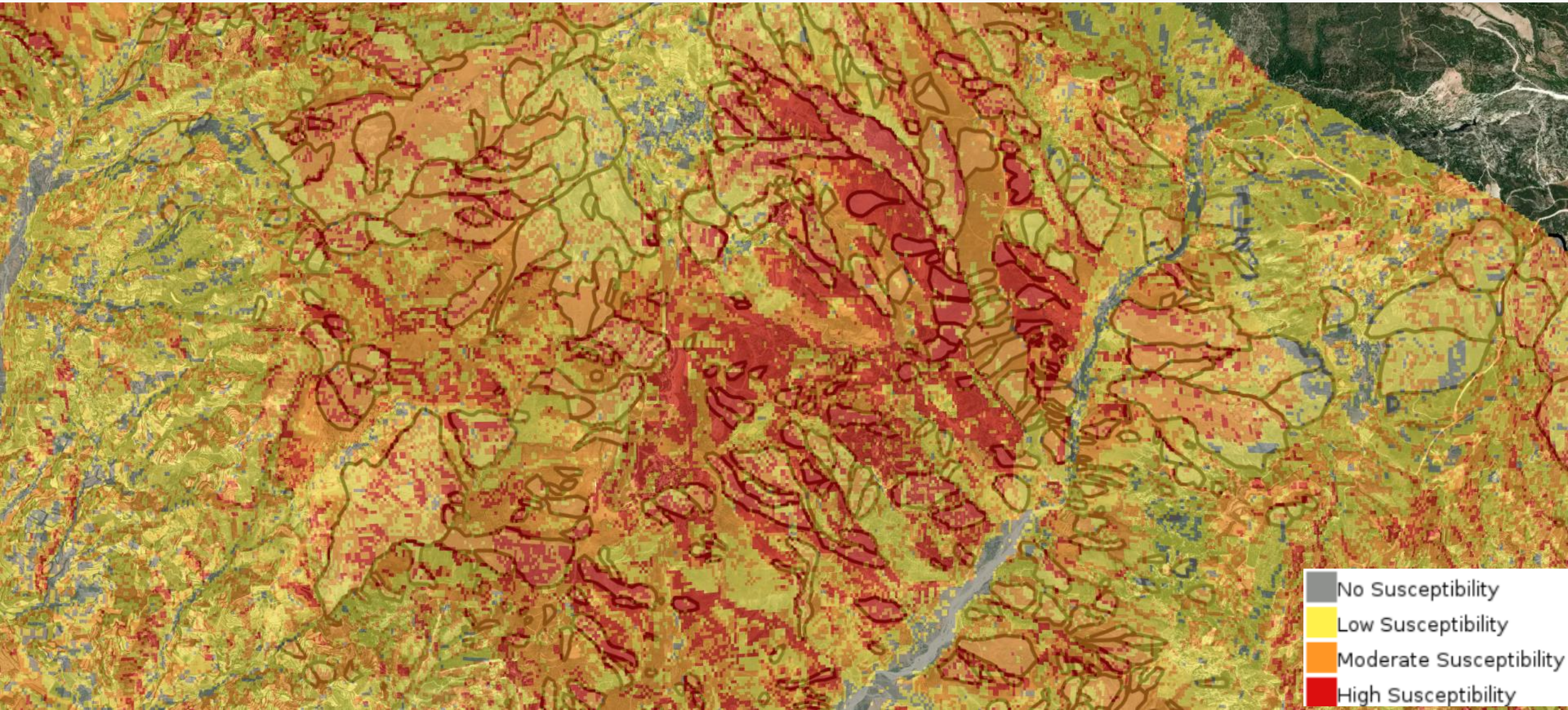
No Susceptibility
Low Susceptibility
Moderate Susceptibility
High Susceptibility

# Susceptibility to landslides

EYEGIS
Infrastructure Asset Management

Natural Hazards
https://doi.org/10.1007/s11069-020-04433-7

ORIGINAL PAPER

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## The application of DInSAR and Bayesian statistics for the assessment of landslide susceptibility

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**Abstract**
The use of an inventory map of past landslide events in the derivation of susceptibility models is considered common practice. However, evidence of landslide activity may be lost due to various degrees of modification by subsequent landslides, erosional processes, vegetation growth and anthropic influences. The timely detection of active landslides can form an effective supplement to landslide records for improving the accuracy of landslide susceptibility maps. In this paper, we present a landslide susceptibility assessment carried

# Susceptibility to geohazards:

# Swelling clays

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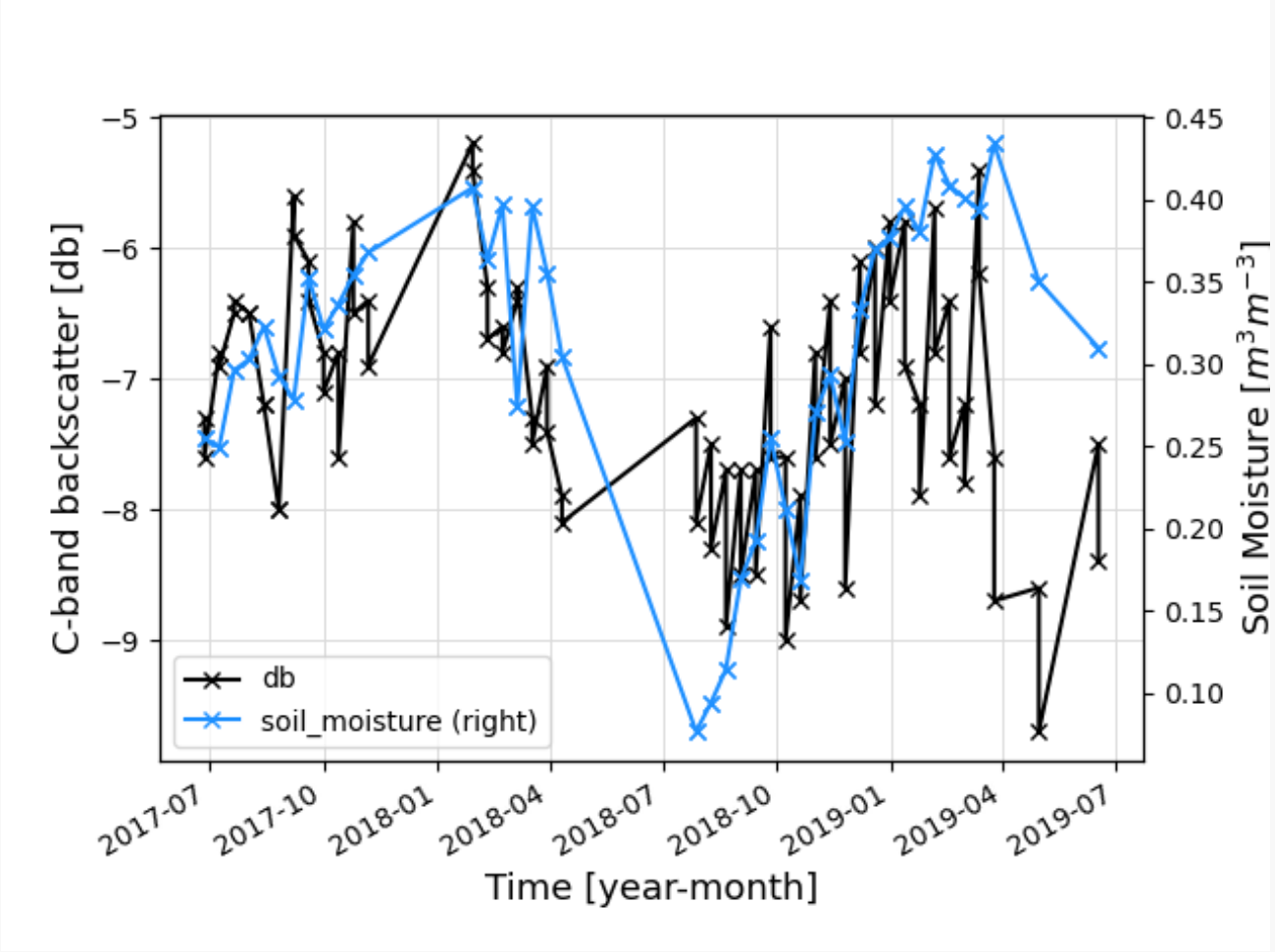
# Soil moisture content

- SAR: analysis of the **amplitude** of radar waves to measure surficial soil moisture.

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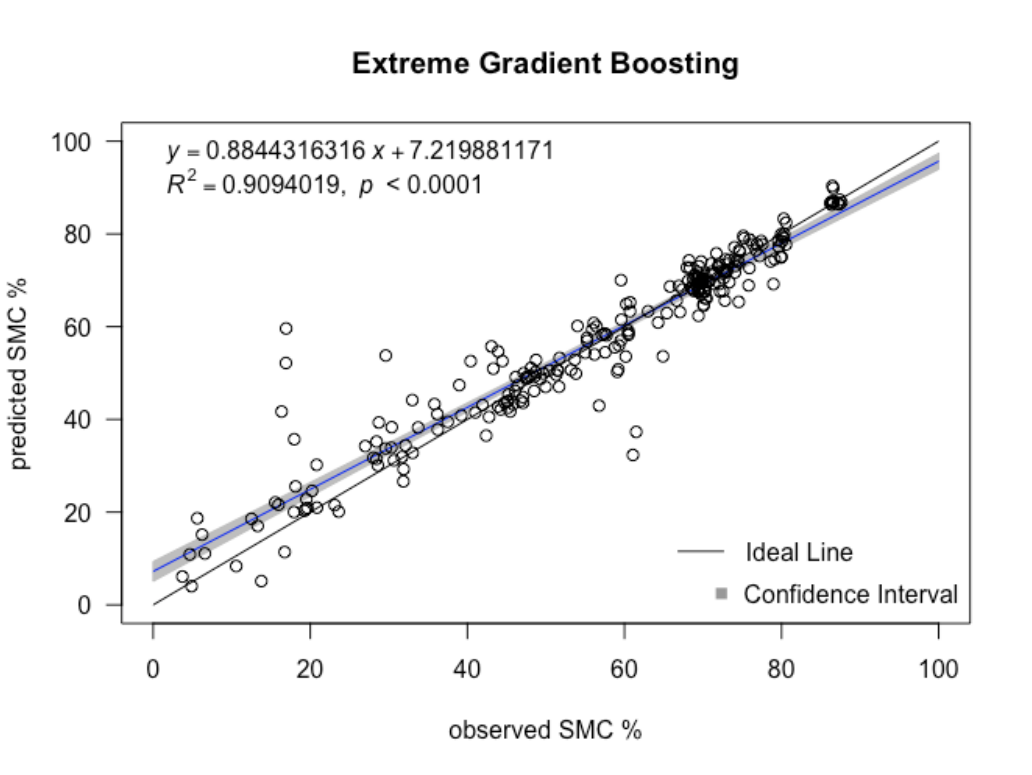
# Soil moisture content

- Installation of in situ sensors for satellite signal calibration.

- Use of machine learning to develop an algorithm for soil moisture estimation via satellite data.

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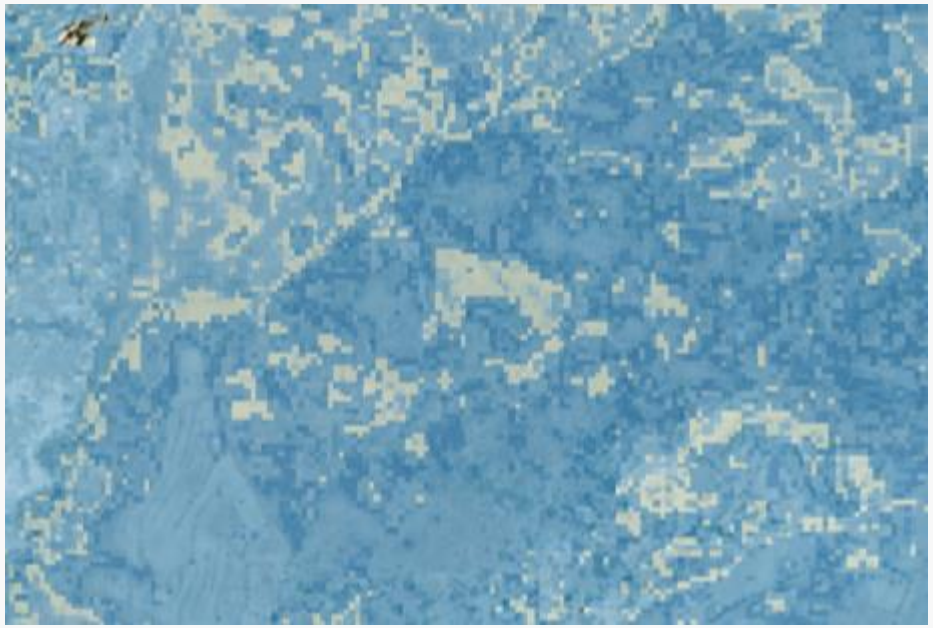
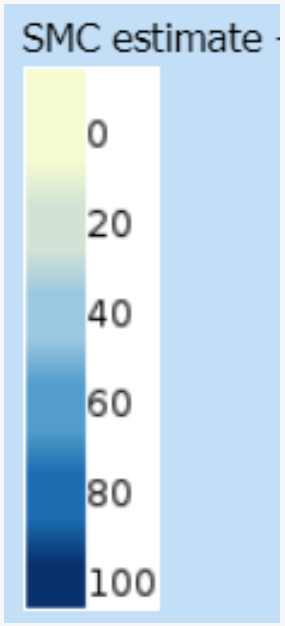
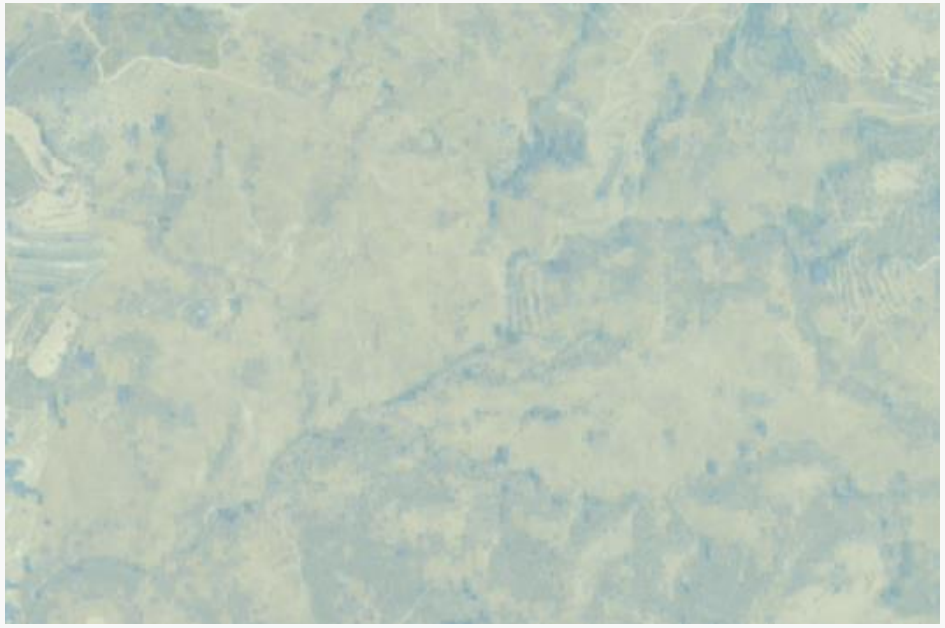
# Soil moisture content





March 2021

September 2020

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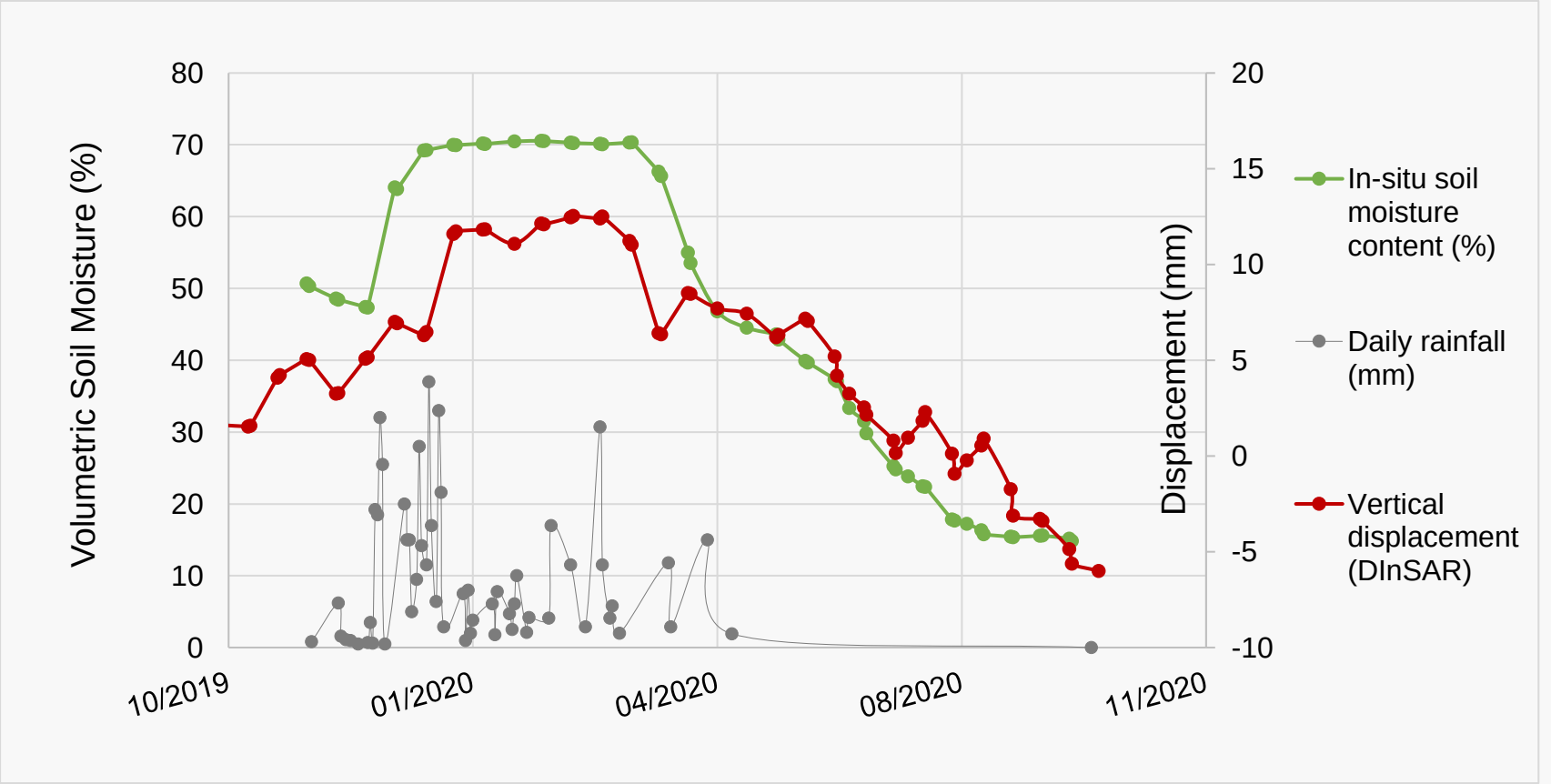
# Soil moisture Vs displacement

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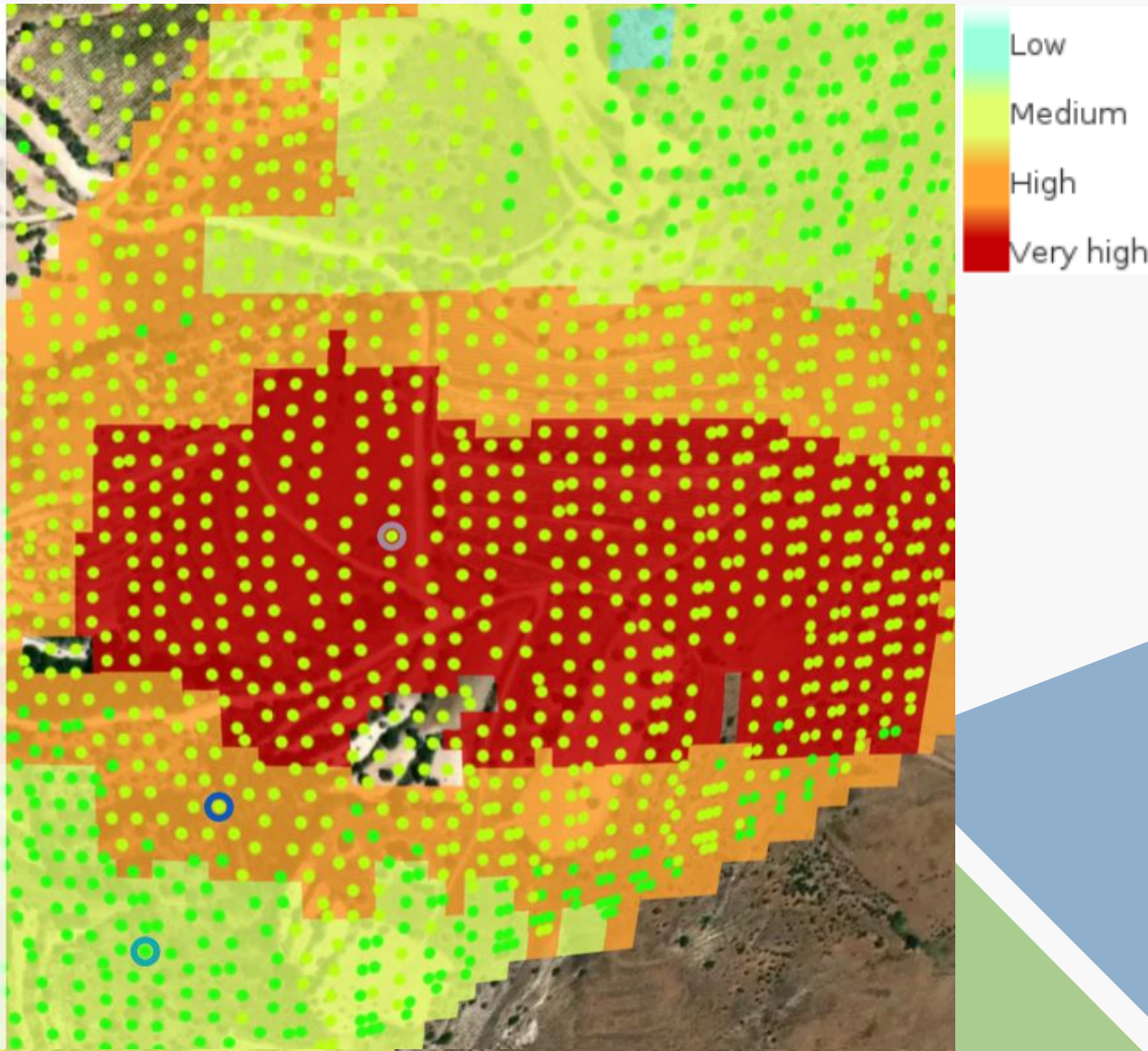
# Susceptibility to swelling clays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# Summary

- Assess whole networks for geohazard susceptibility
- Identify problematic locations
- Target investigation and monitoring resources at the high-risk locations
- Detect trends for improved planning and proactive maintenance
- Improve resilience to climate change

# THANK YOU

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# Introduction to ENVI SARscape

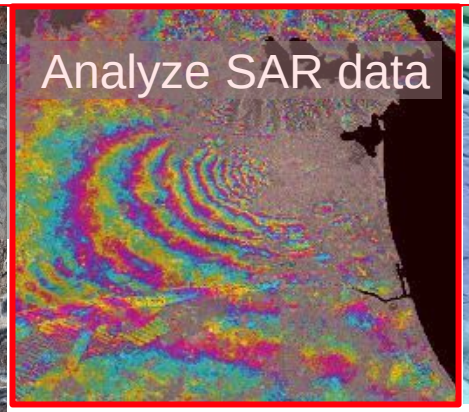
# ENVI

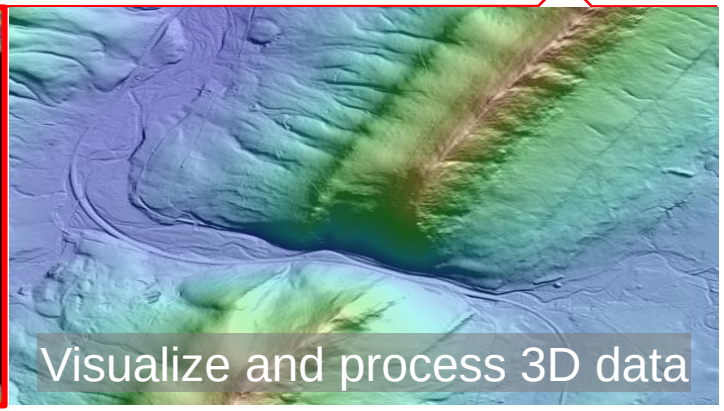
## Process and analyze all types of imagery and data

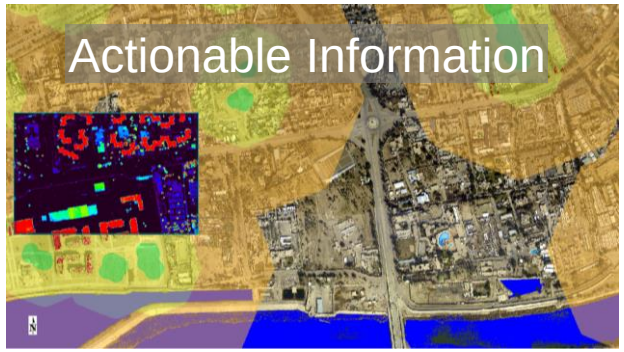
The industry standard for image processing and analysis, used to extract accurate and timely information from remotely-sensed data

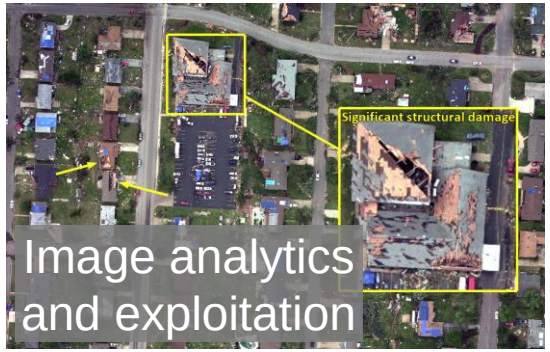
ENVI has remained on the cutting edge of innovation for more than three decades

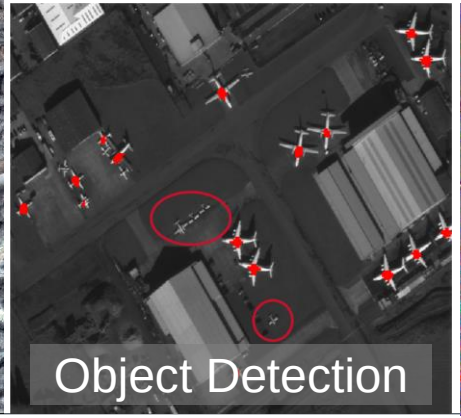
ENVI makes image analysis accessible and requires no prior experience or programming

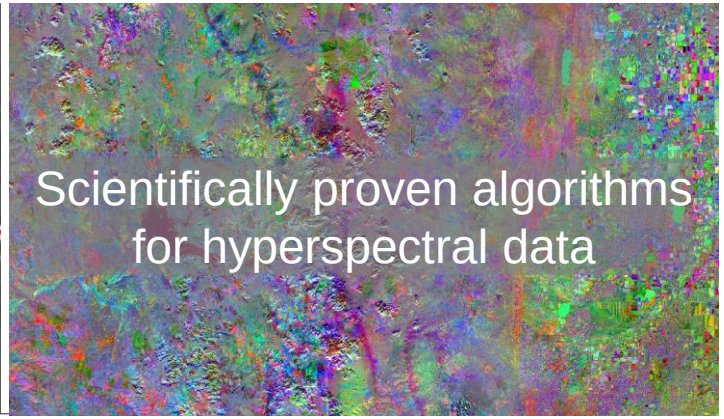



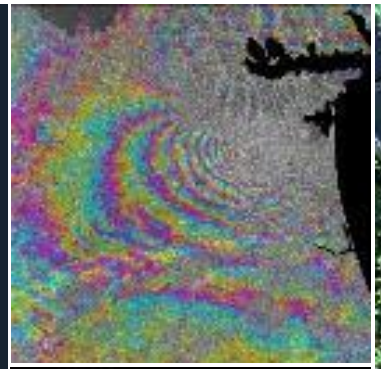
# ENVI SARscape

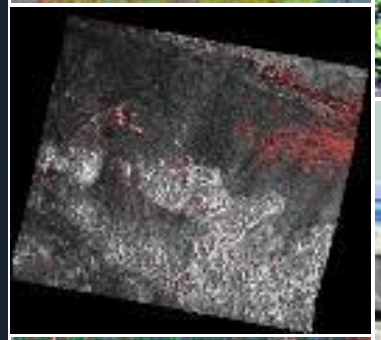
## Easily process and analyze SAR data

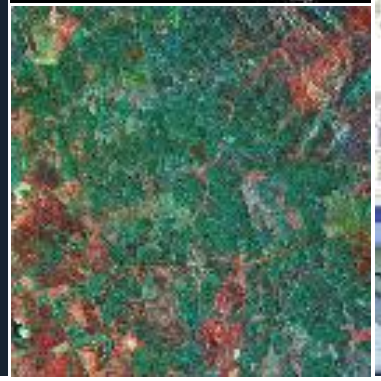
ENVI integration brings advanced image processing and analysis together with SAR processing in one package

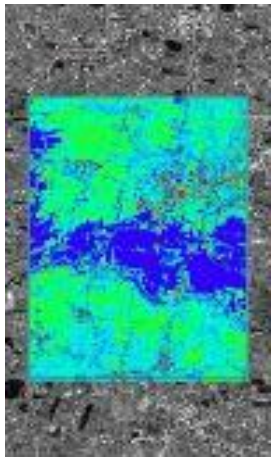
Generate products (like DEMs or surface deformation maps) that can be integrated with other geospatial products

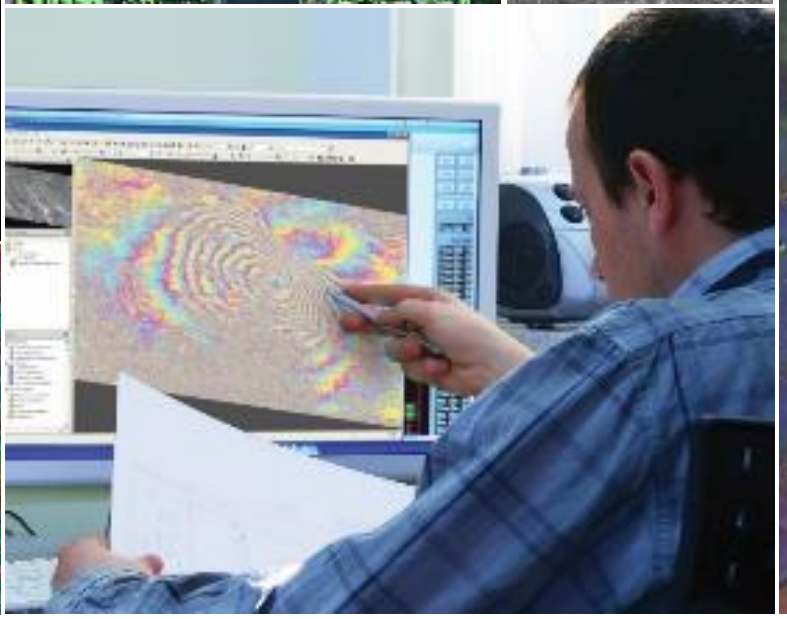
Built-in workflows and modules simplify processing and can be customized







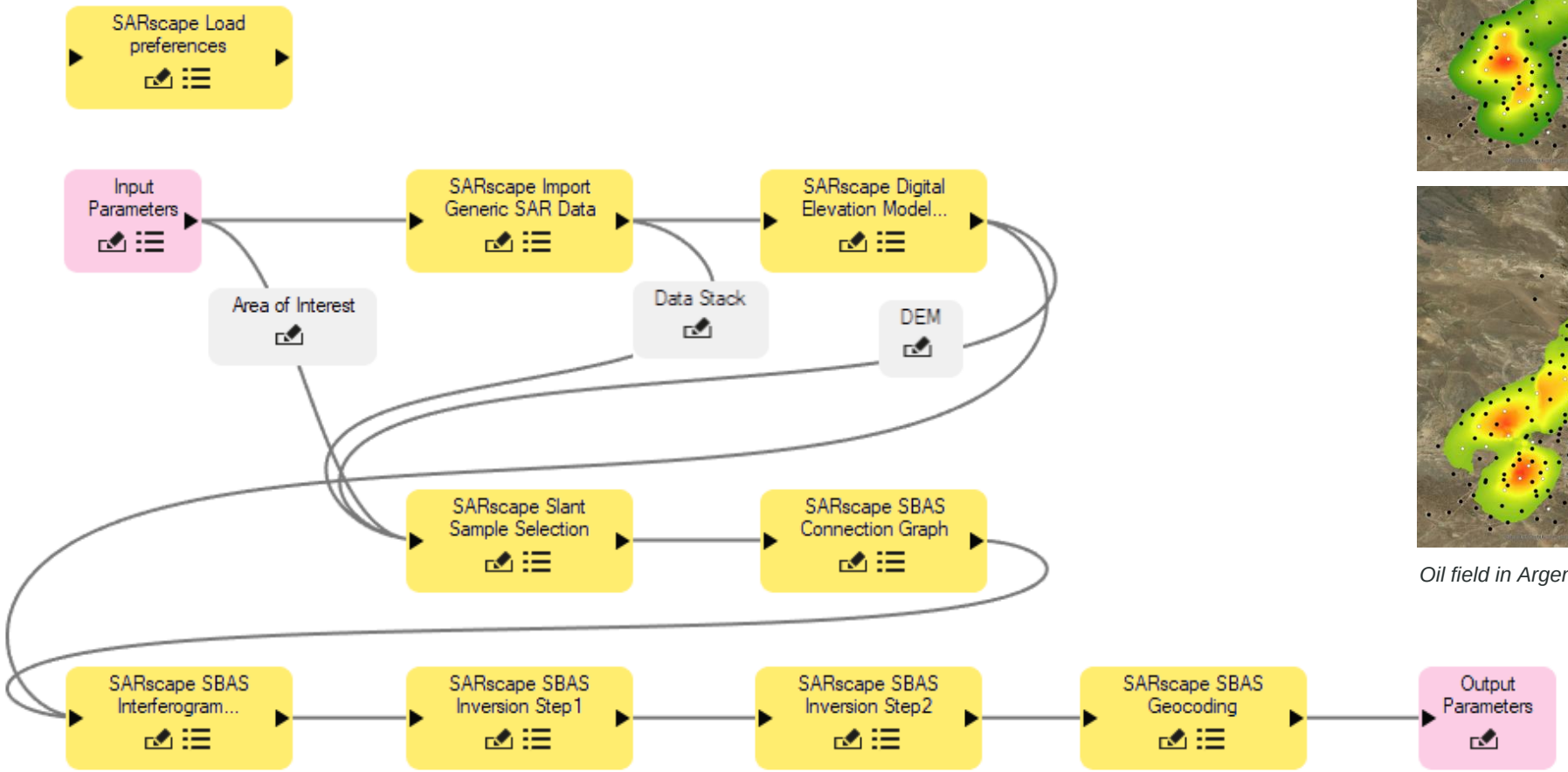


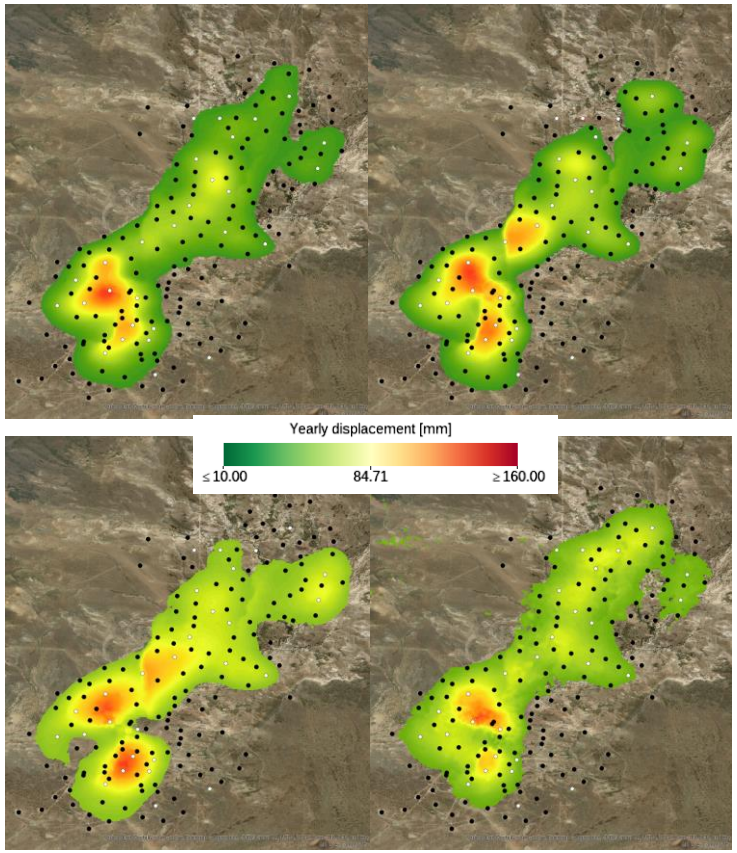


# ENVI SARscape Operational Processing

## SBAS – Automatic Processing

SARscape tasks enables the automatic execution of the SBAS processing chain, allowing the monitoring of the temporal evolution of surface deformations

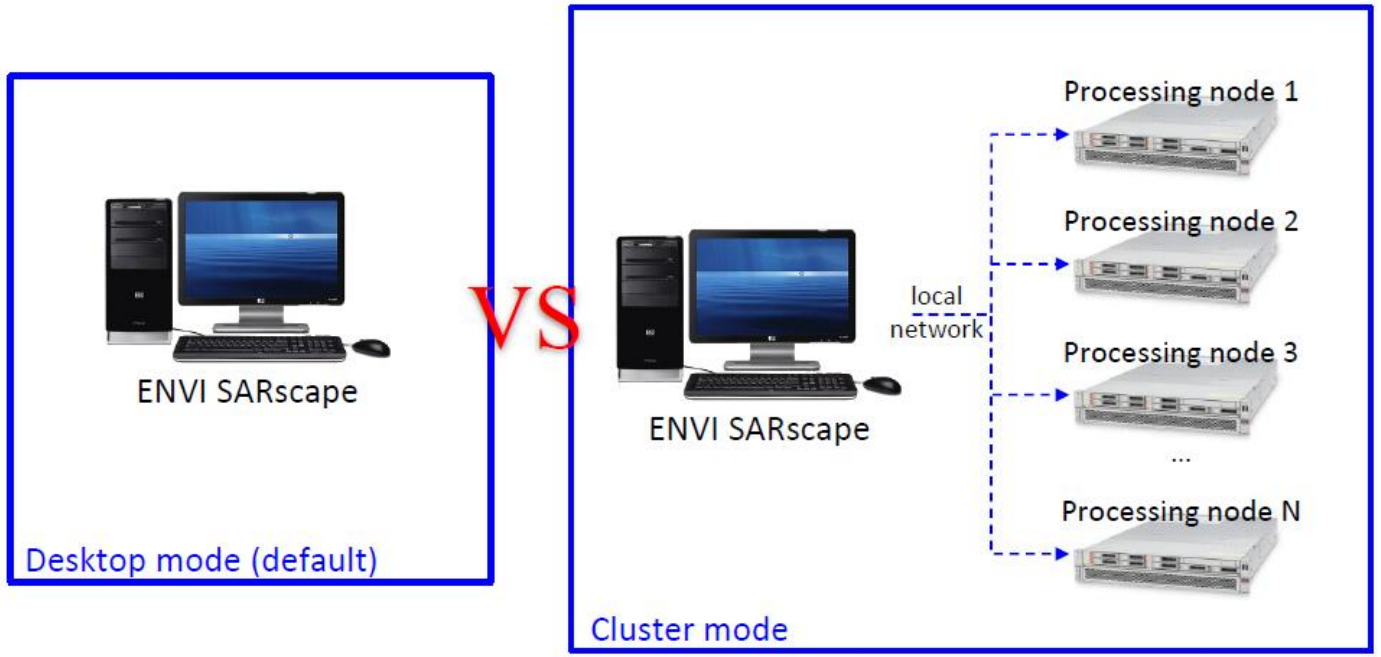



*Oil field in Argentina, black points are wells injection and extracting*

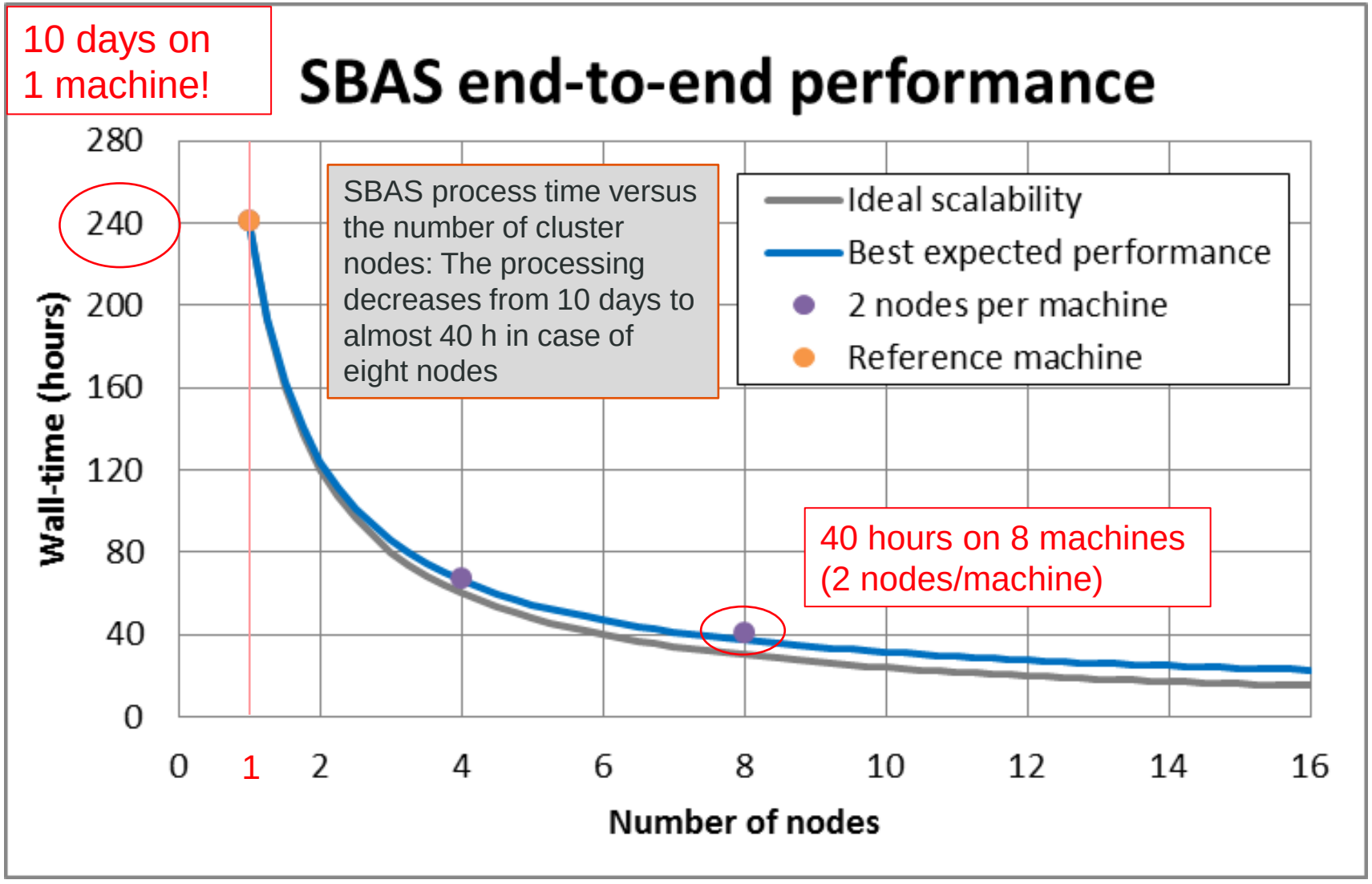
# High-level Parallelization with SARscape Cluster

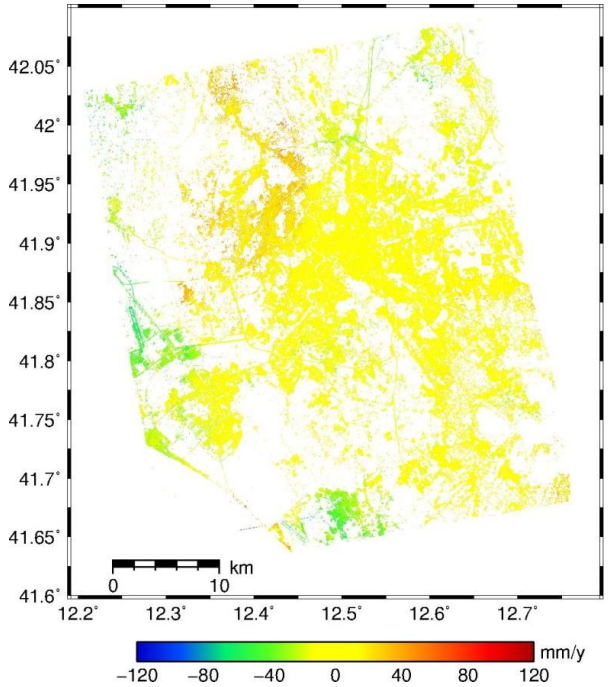
- SARscape Cluster is an extended functionality of ENVI SARscape that distributes computationally-intensive tasks over a series of processing nodes
  - Uses hardware resources of multiple machines (vs. single machine)
  - Particularly recommended for SBAS & PS processing pipelines
- SARscape Cluster is about speed
  - Speed-up as maximum as possible the execution of a single, resource intensive job



# SARscape Cluster – SBAS Processing Performance

10 days on
1 machine!




- COSMO-SkyMed 25-image stripmap stack
- 30 km x 40 km urban area (Rome, Italy)
- 150 interferograms
- DEM-assisted co-registration
- 3 x 3 multilooking
- 2D phase unwrapping
- 5 m x 5 m geooding

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