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esa
Partners with the
European Space Agency

Determining infrastructure resilience to geohazards by satellite and AI

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CEO

GEOFEM is a leading satellite remote sensing consultancy firm that helps infrastructure stakeholders to:

1. Monitor current and ongoing ground movements in areas of interest.
2. Be alerted to potential issues before they become serious faults.
3. Visualise the susceptibility of areas to geohazards such as landslides and subsidence.

Who We Are

GEOFEM is a leading provider of innovative earth observation, GIS, and remote sensing solutions. Our analysis is complemented by 20+ years of geotechnical engineering experience to interpret the data, and provide recommendations to maximise the safety of infrastructure across the globe.

Send Us a Message

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Contents

- ***Soil moisture via satellite***
- ***Displacement monitoring - applications***
- ***AI for infrastructure susceptibility to geohazards***

The Problem

Geohazards can occur anywhere. How to check thousands of km of road and rail and whole cities?

Maintenance is often reactive which consumes budgets year after year.

Climate change resilience is low so the disruption will only get worse.

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The Solution

Reduce maintenance cost - proactive

Increase of utilization of network

Efficient use of resources for maintenance – identification of problematic locations

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Satellite basics

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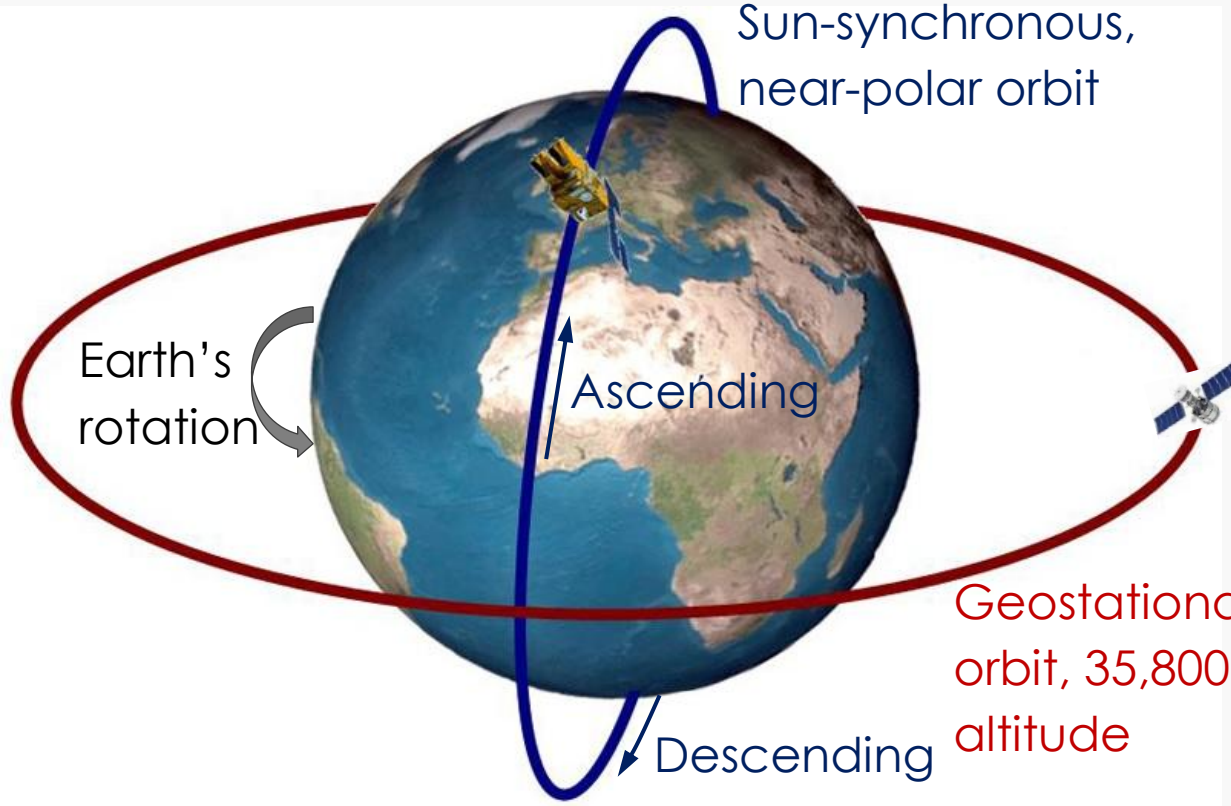
Satellite orbits



Sun-synchronous, near-polar orbit:

- 600-800km altitude
- 96-100 minutes per orbit
- Passes each latitude at same time of day
- Ascending and descending SAR images available for most locations

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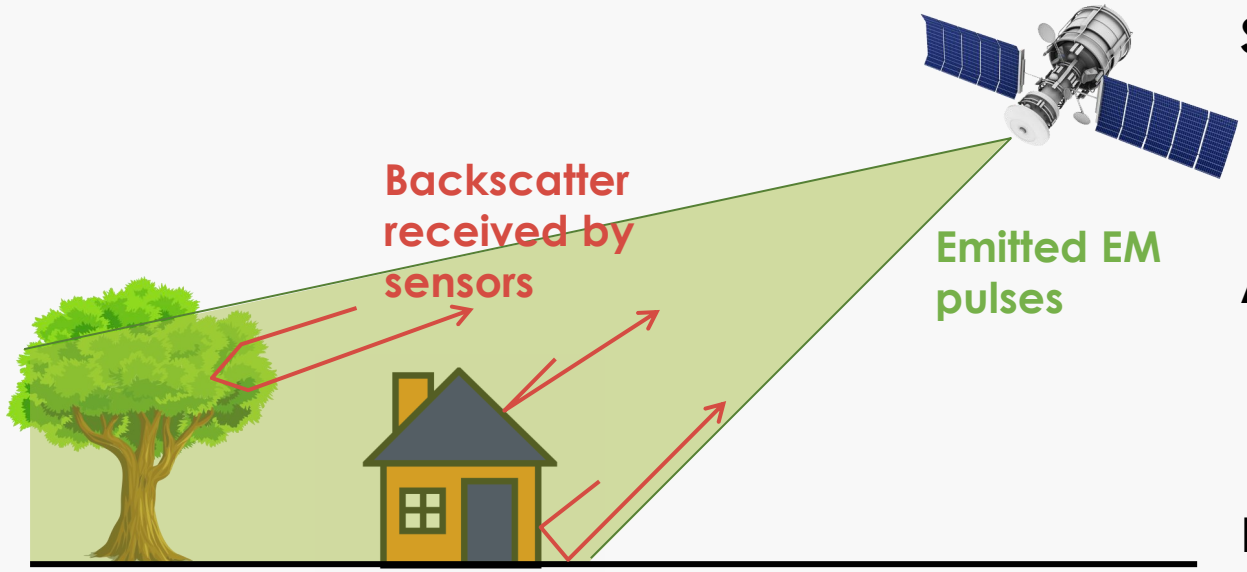
SAR



Synthetic A sequence of acquisitions from a shorter antenna as the satellite moves through space is used to simulate a larger antenna

Aperture Another term for the antenna that transmits and receives the electromagnetic energy – the bigger it is the better the spatial resolution

Radar Transmits electromagnetic waves and receives reflections from objects to determine their distance or range

Microwave and radio wave portions of EM spectrum, so:

- Unaffected by cloud cover
- Operates day and night

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Infrastructure resilience by satellite

- Cheaper
- **Faster**
- **More** accurate
- **High** frequency
- **Non-disruptive**
- **Automated**
- **Retrospective**

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What do we measure from SAR satellites ?

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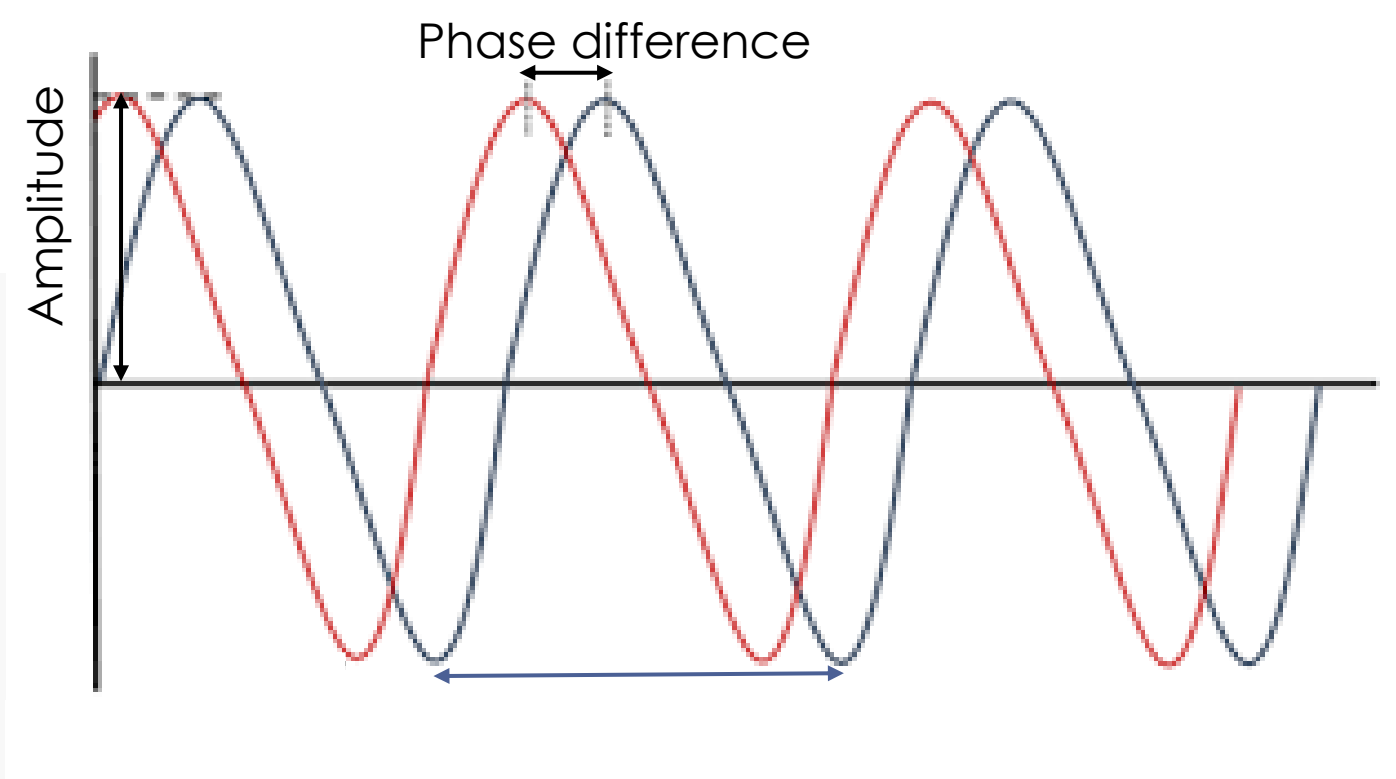
SAR wave



Amplitude: Soil moisture measurement

Phase: Displacement measurement

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Soil moisture via satellite

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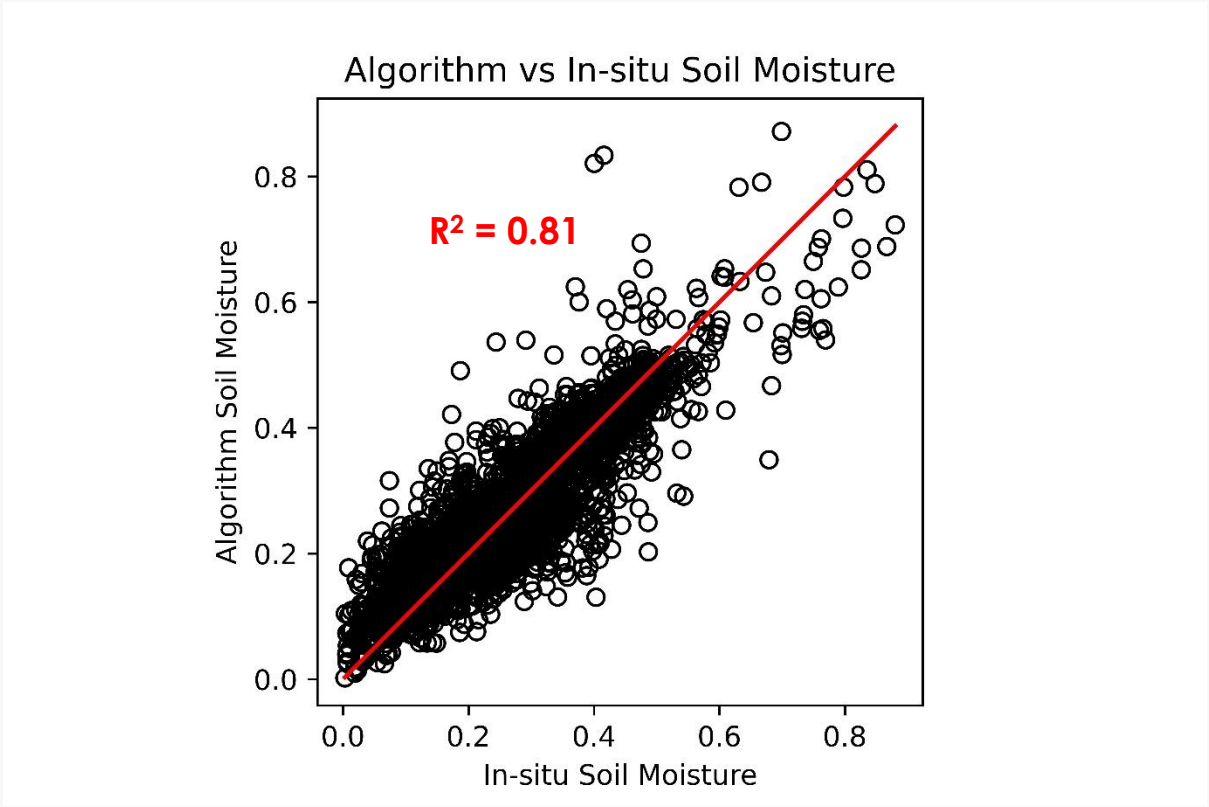
Algorithm for soil moisture via satellite

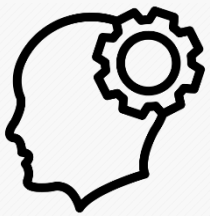
In-situ soil moisture data

Global data for different climatic conditions

More than 3 years of data



Artificial intelligence



Satellite derived data

Data from multiple sources

Data applied for anywhere in the world

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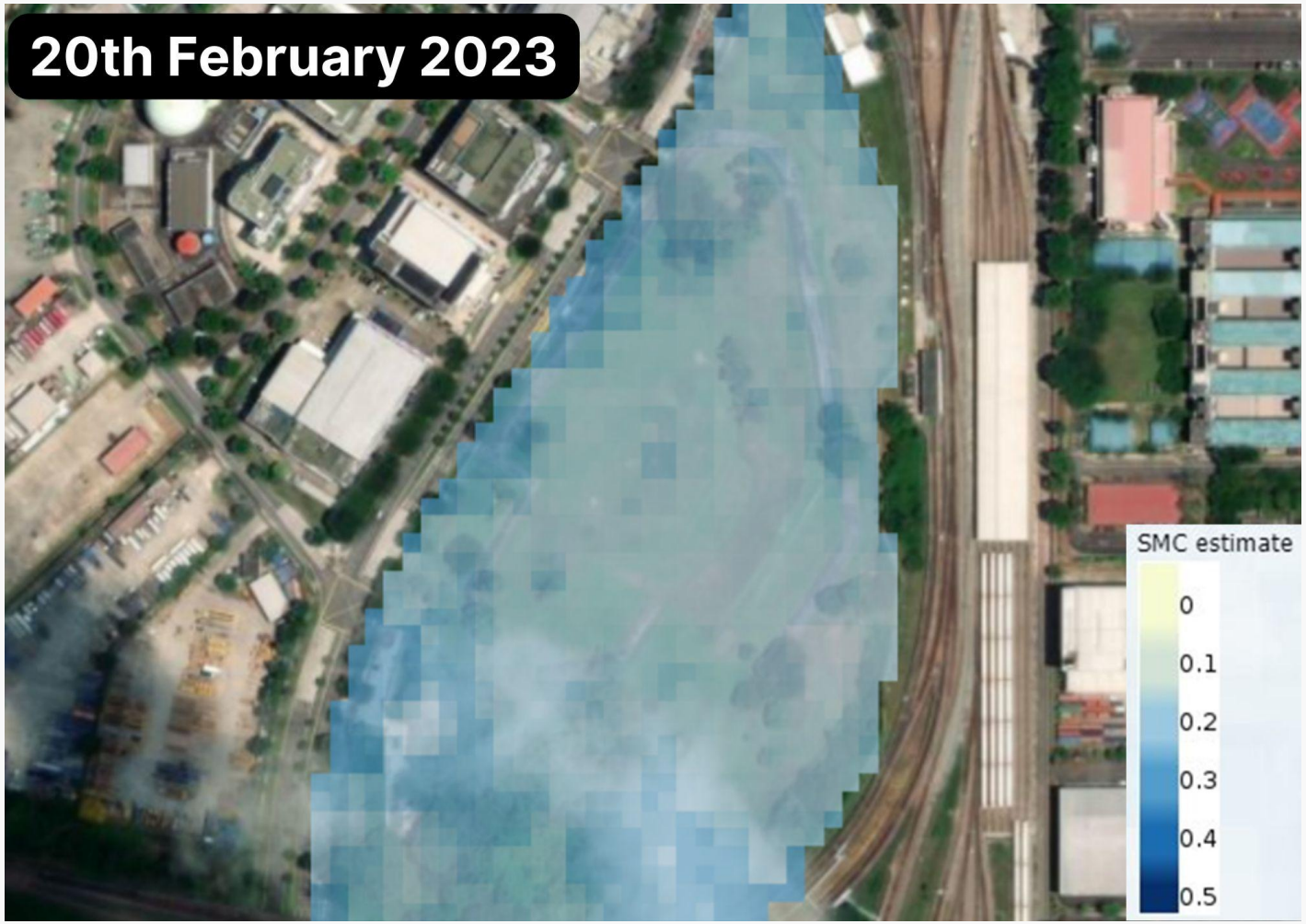
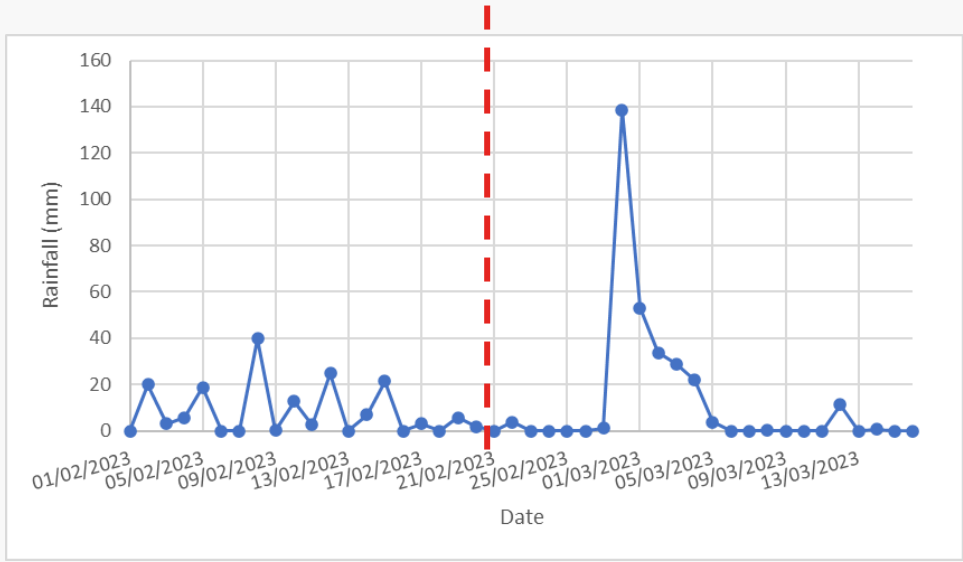
Soil moisture content outputs: maps

Soil moisture content outputs: maps





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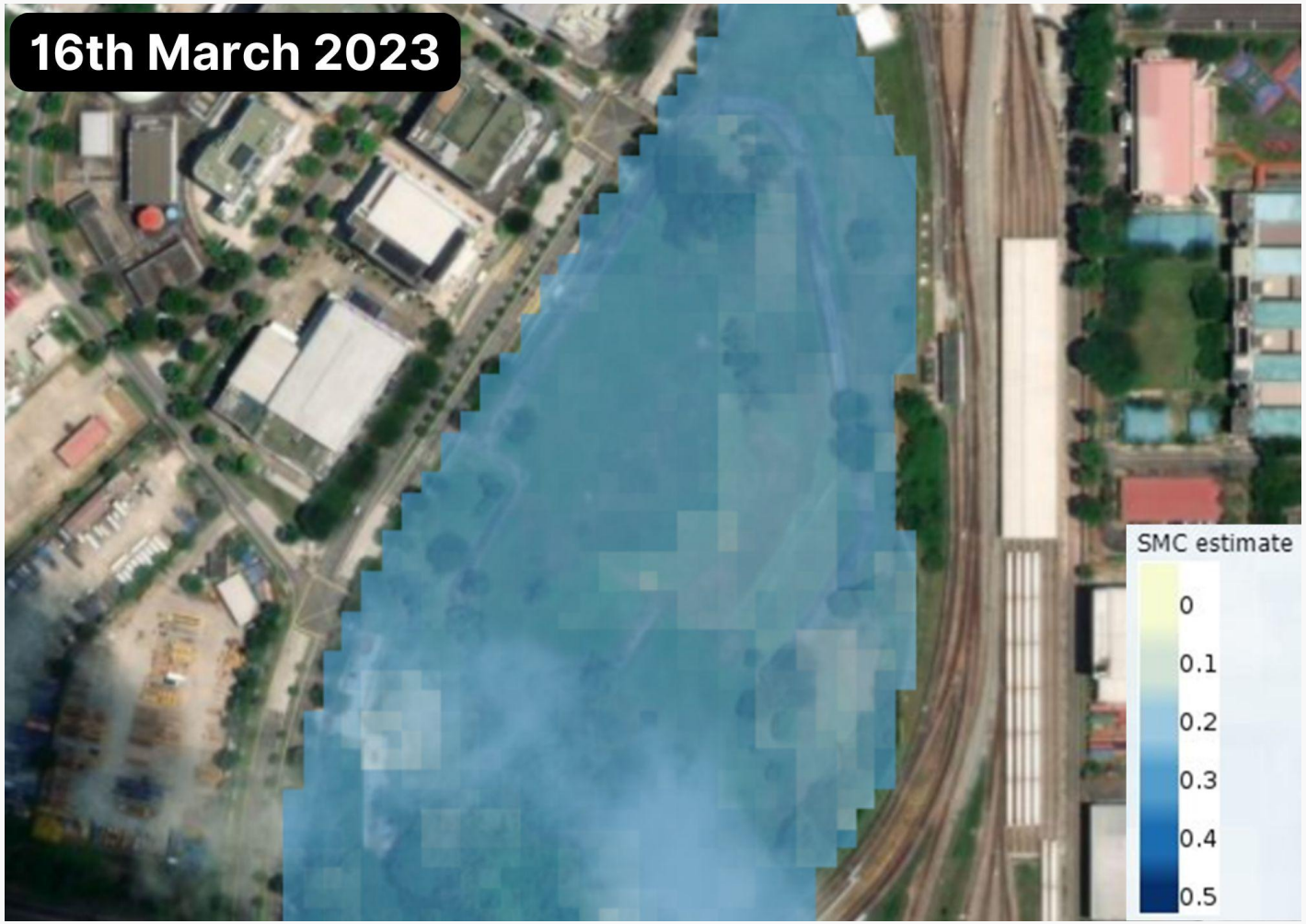
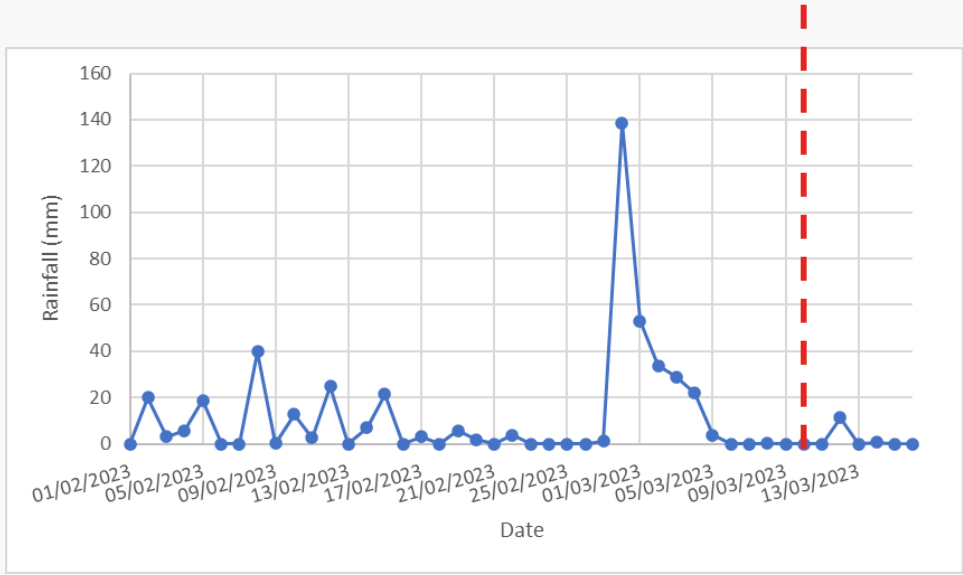
Soil moisture content outputs: maps





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Soil moisture content outputs: maps, New Zealand

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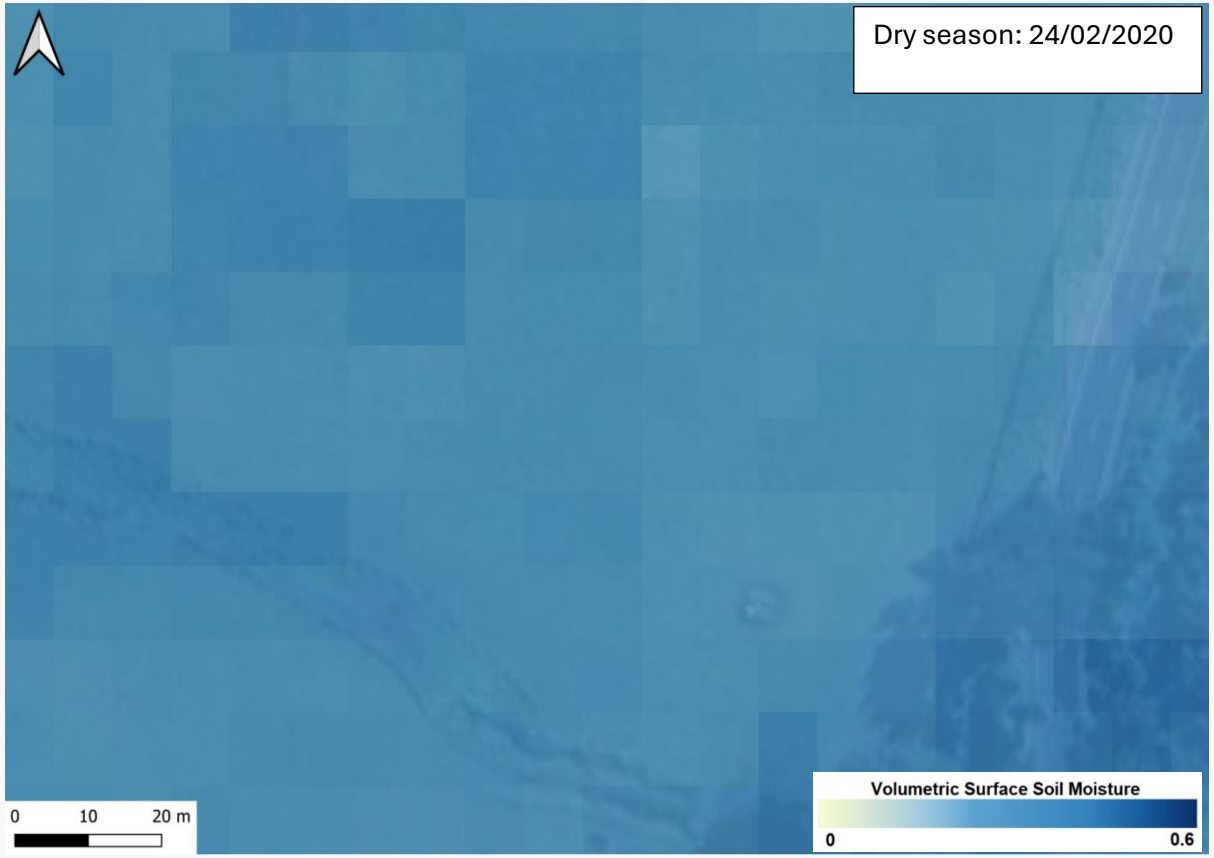
Soil moisture content outputs: maps



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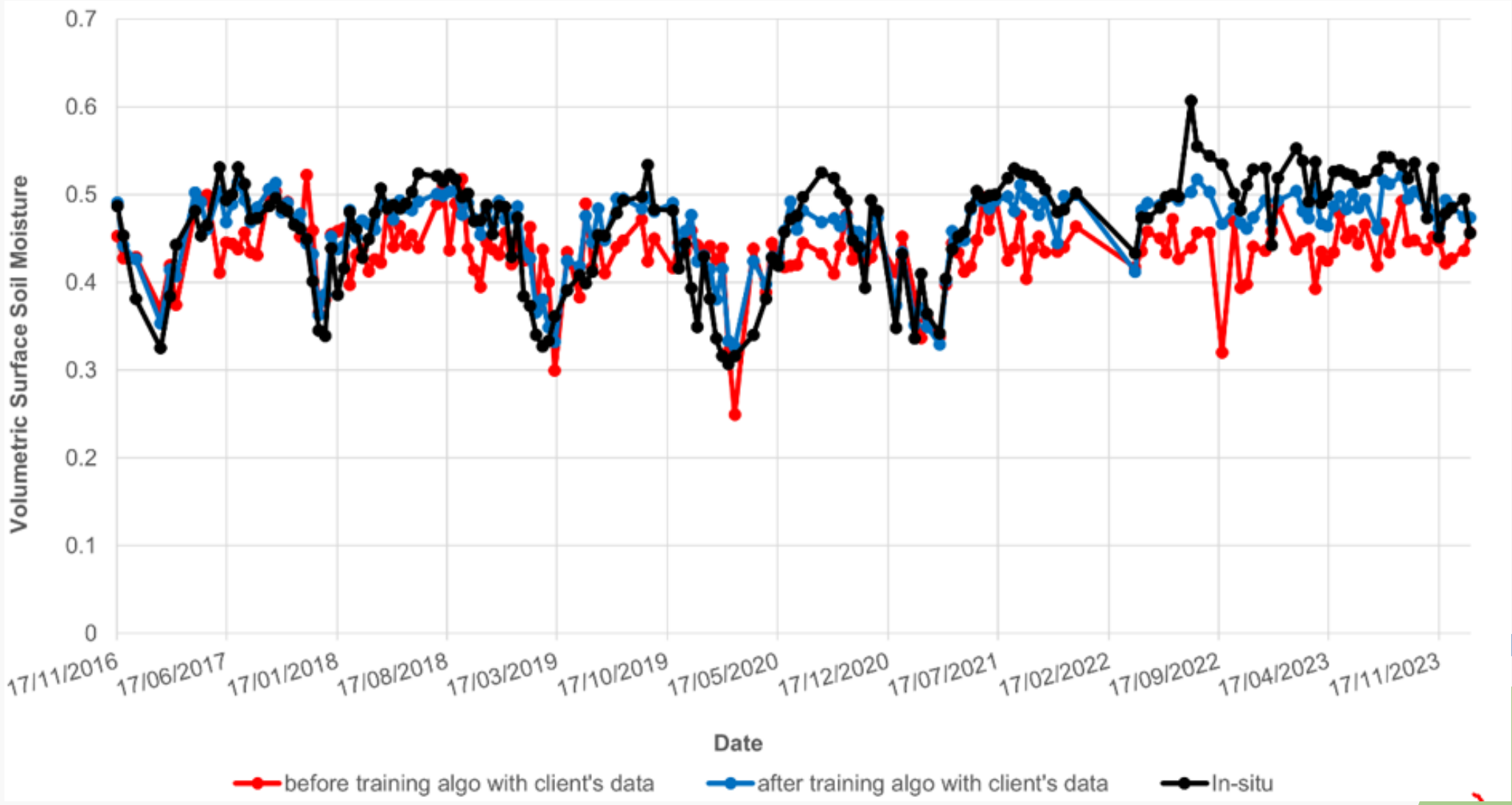
Soil moisture content outputs: maps



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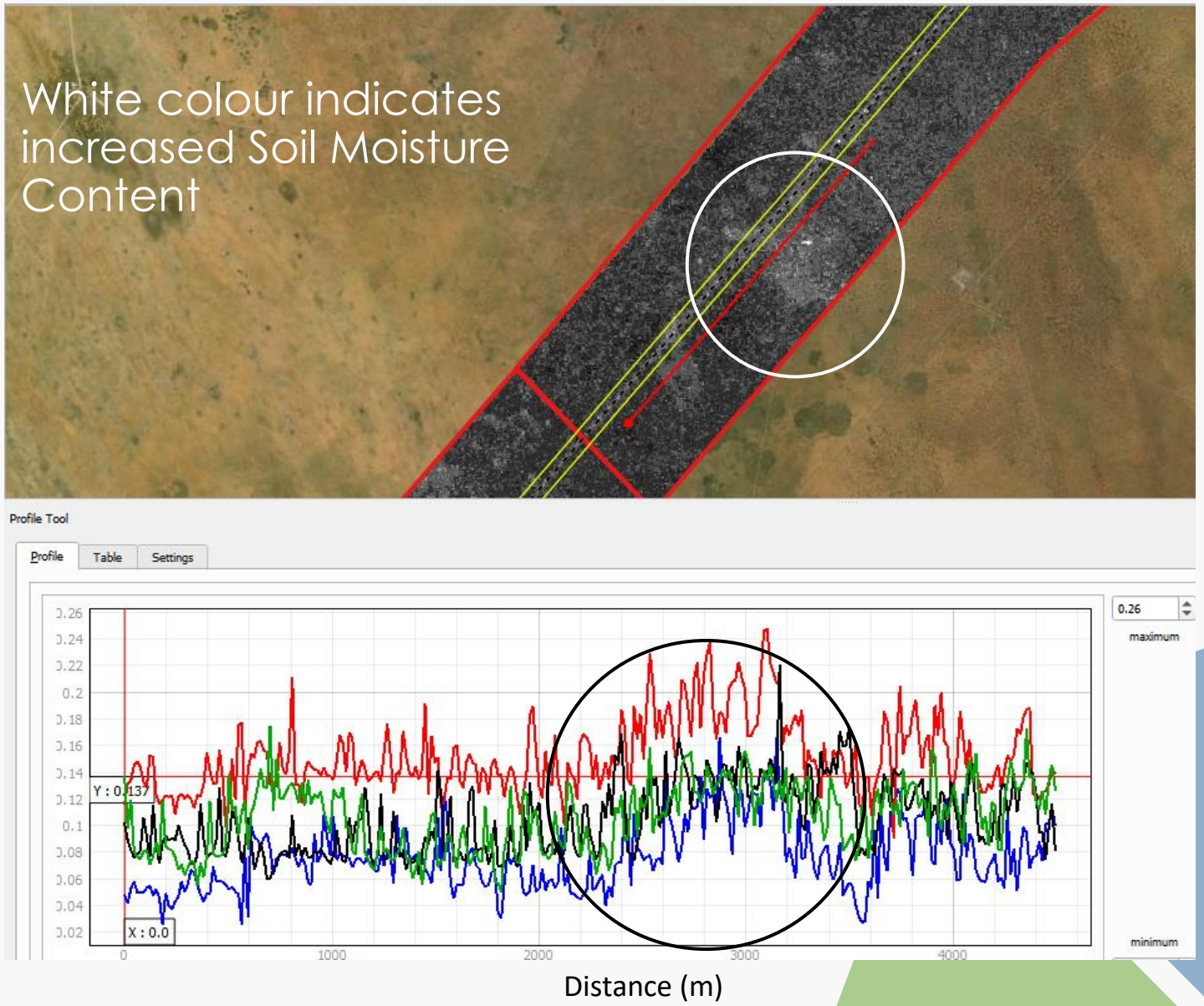
Soil moisture via satellite

Indicator of:

- Failed track drainage
- Ballast fouling



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Displacement measurements via satellite

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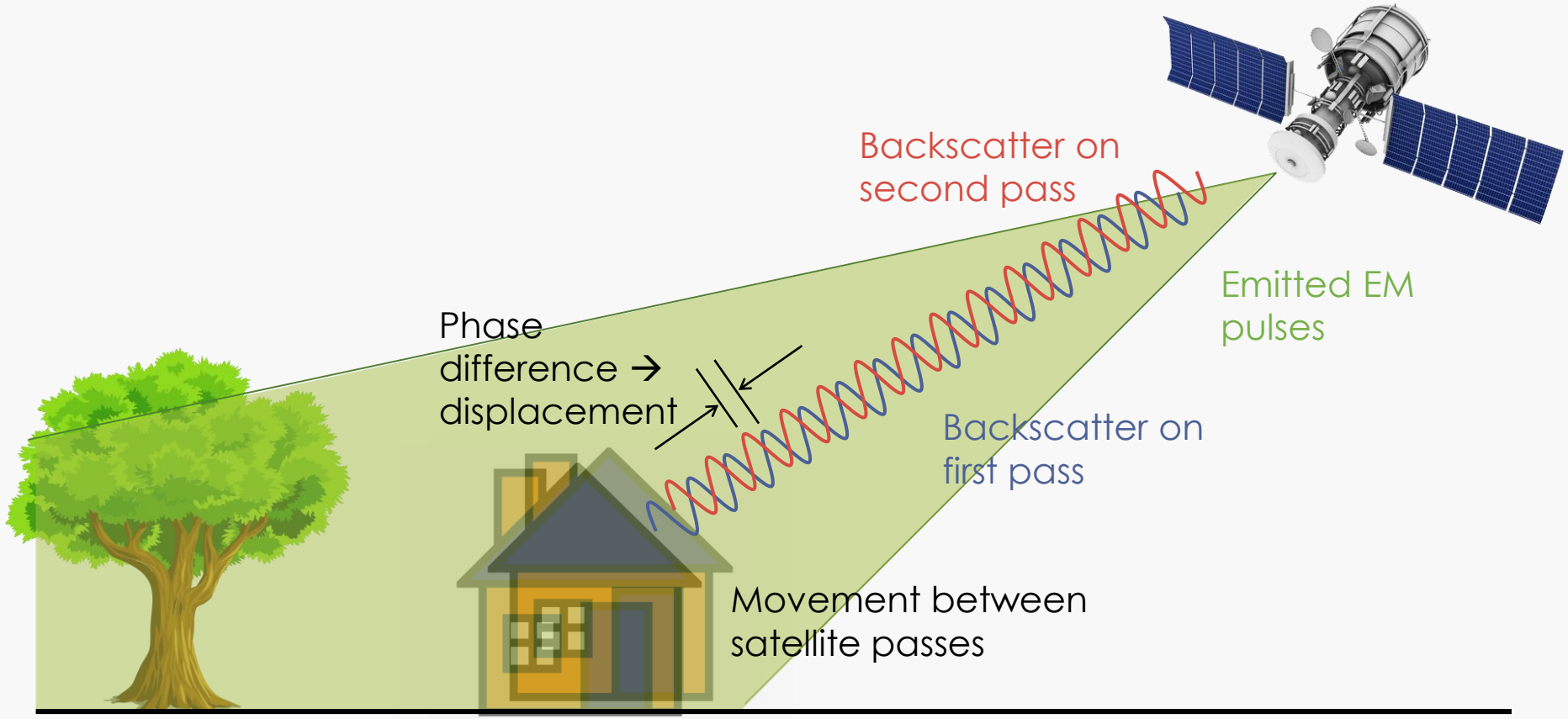
Displacement measurement



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Examples of applications

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EYEGIS
Infrastructure Asset Management
Project | Railway Monitoring
EYEGIS
3D
500 m
54° 21' 49.93584" N 6° 24' 26.74171" W
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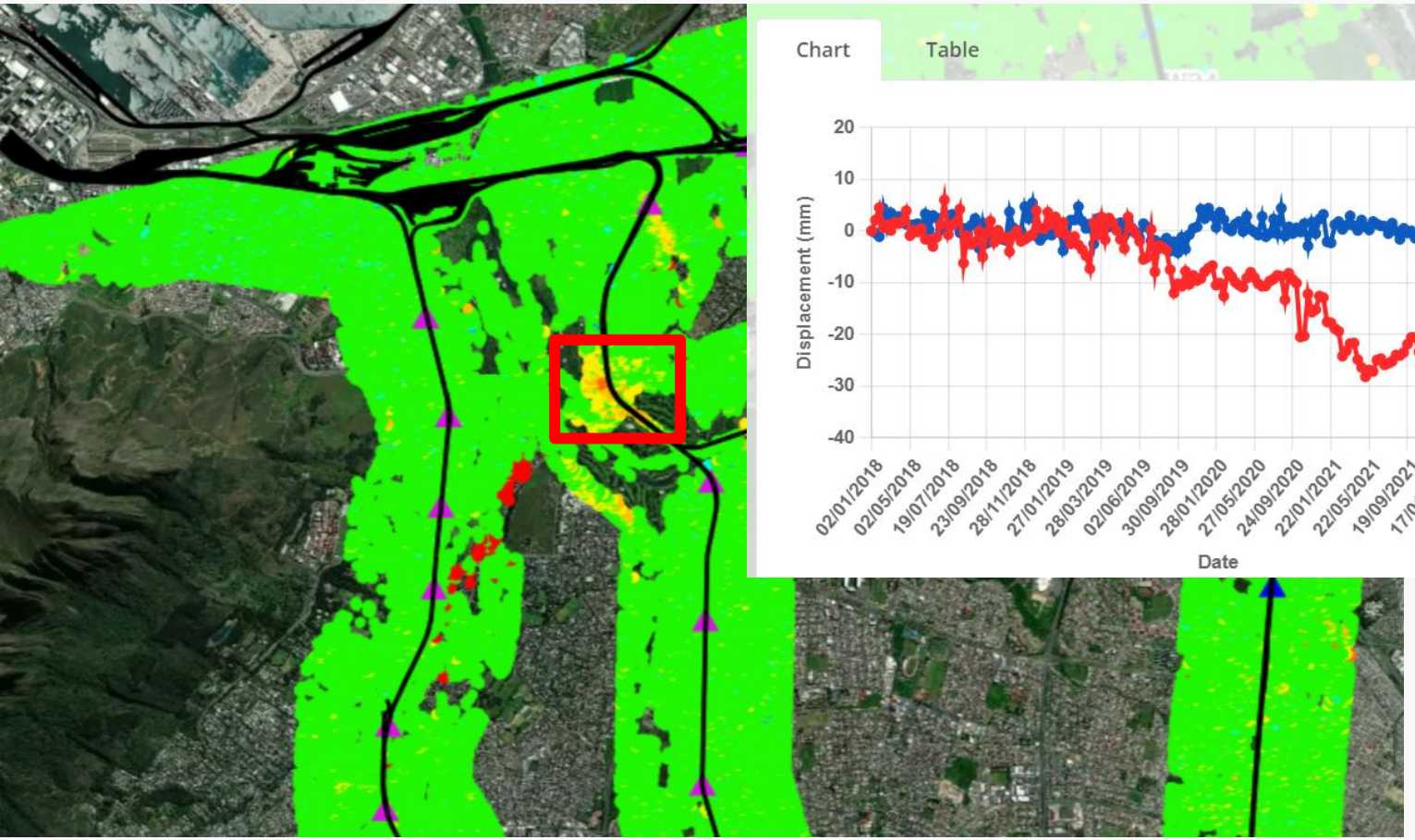
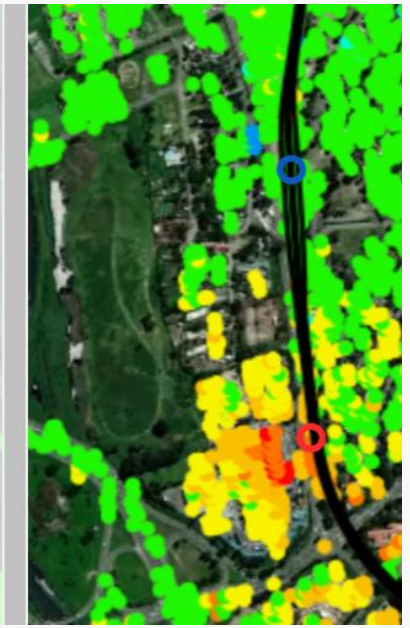
Displacement monitoring





Ground displacement, both historical and ongoing with millimetric accuracy.

Early warnings when defined thresholds are exceeded.

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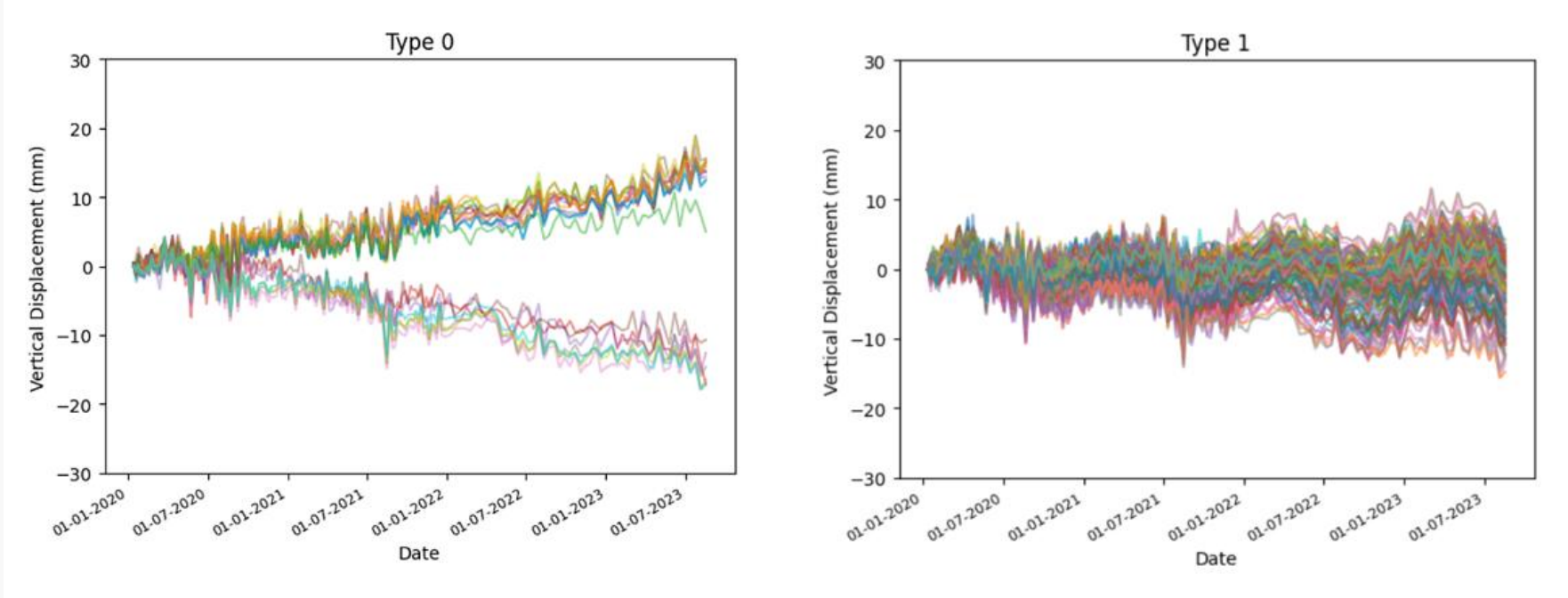
Automated identification of different types of movement

- Relative stability
- Linear increasing
- Seasonal
- Acceleration
- Deceleration



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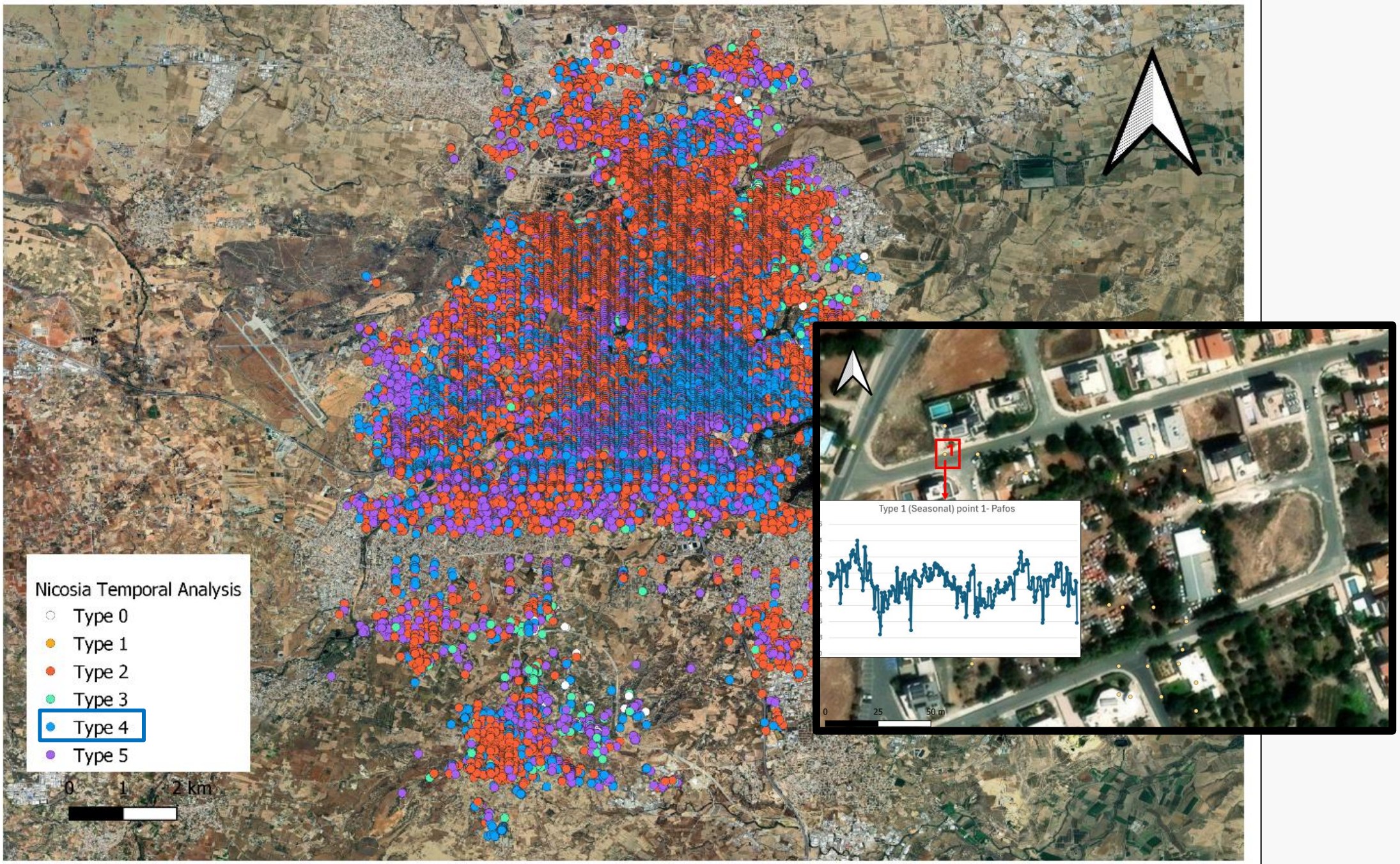
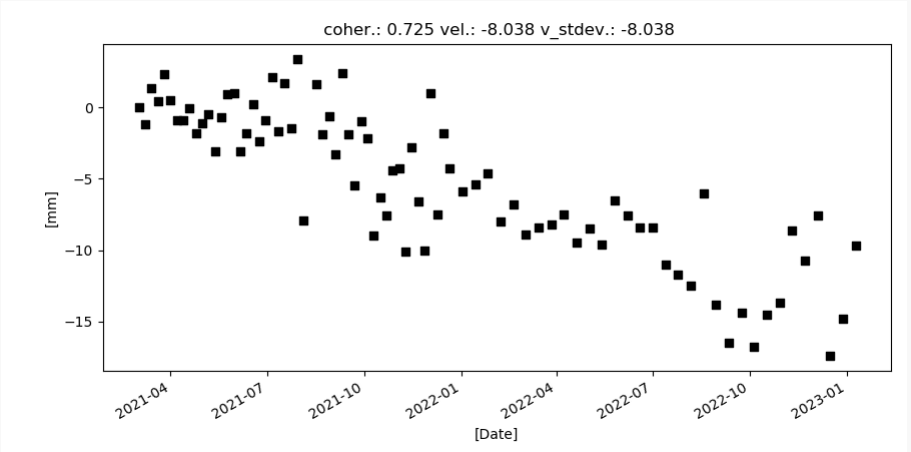

Nicosia Temporal Analysis
Type 0
Type 1
Type 2
Type 3
Type 4
Type 5
0
1
2 km
Type 1 (Seasonal) point 1- Pafos
0
25
50 m

Displacement monitoring

Hook, United Kingdom

A section of the main rail line between Basingstoke and London suffered a sizeable collapse in January 2023, having a major impact on services. The 44-metre-long landslip, which occurred near Hook in Hampshire, undermined a track, leaving only the London-bound tracks safe to use.

Increasing displacements at the location of failure before the event.



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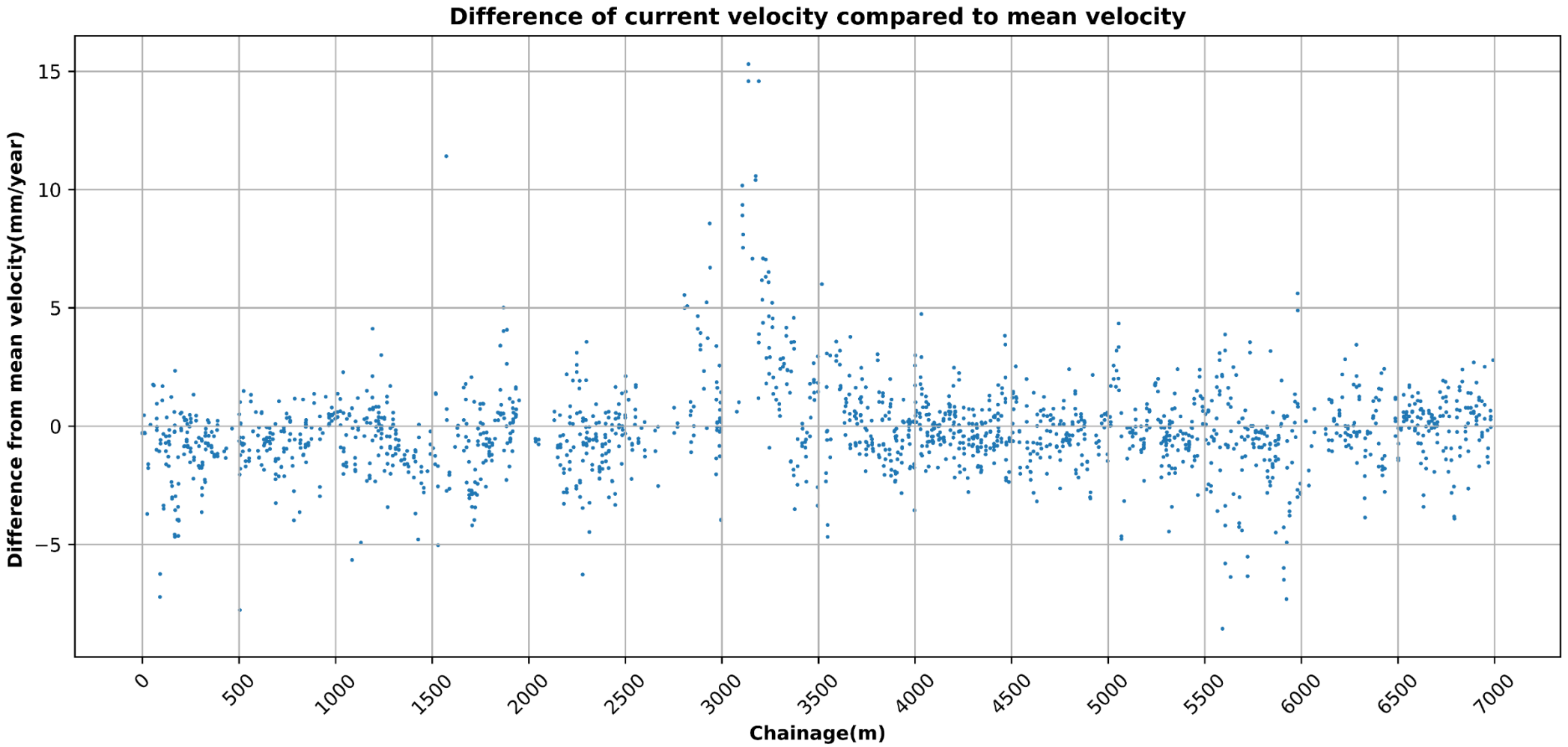

Track roughness

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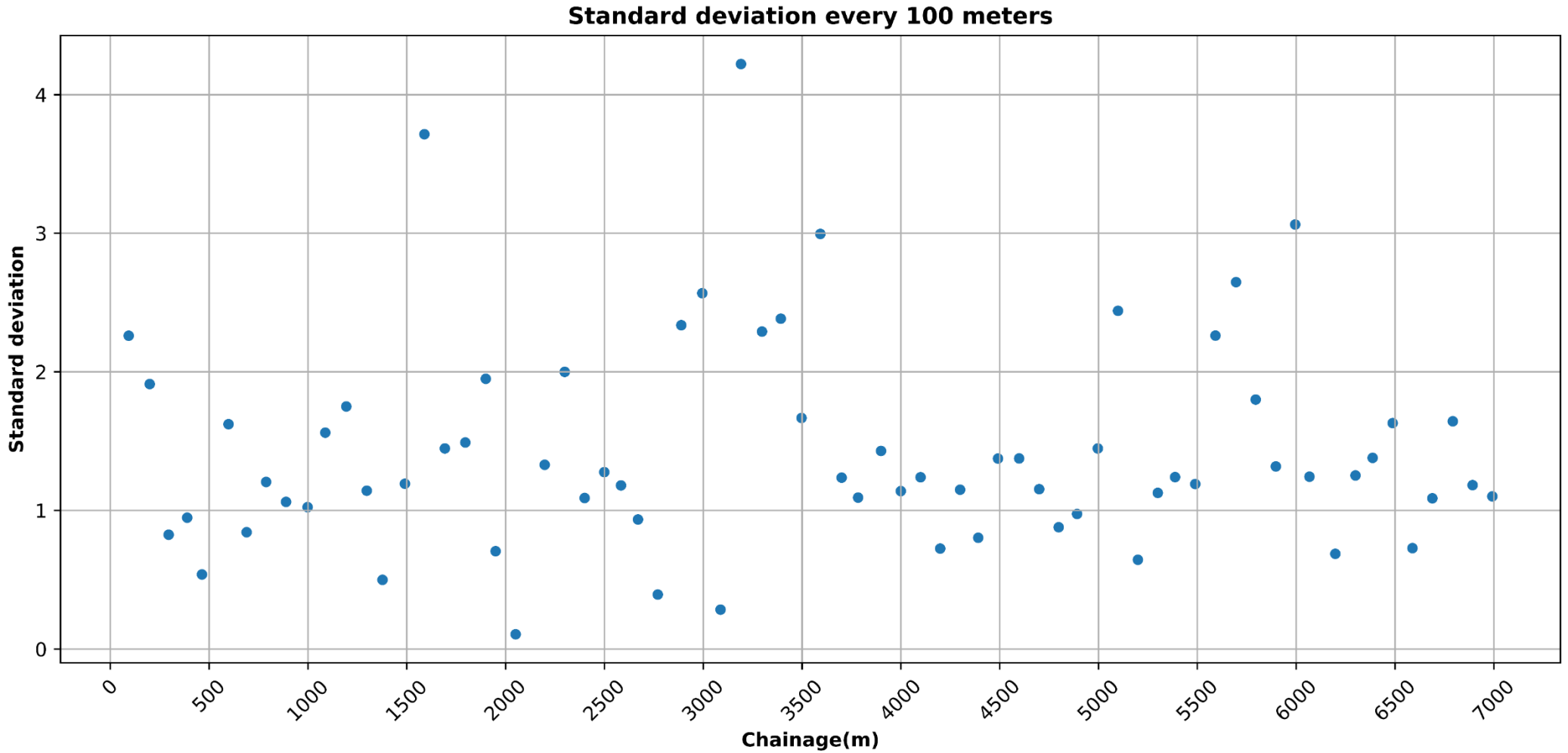
Standard deviation every 100 meters
Standard deviation
Chainage(m)
0
1
2
3
4
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

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Road network. Detecting movement, Prioritizing Maintenance

Dubai-Fujairah Freeway, UAE

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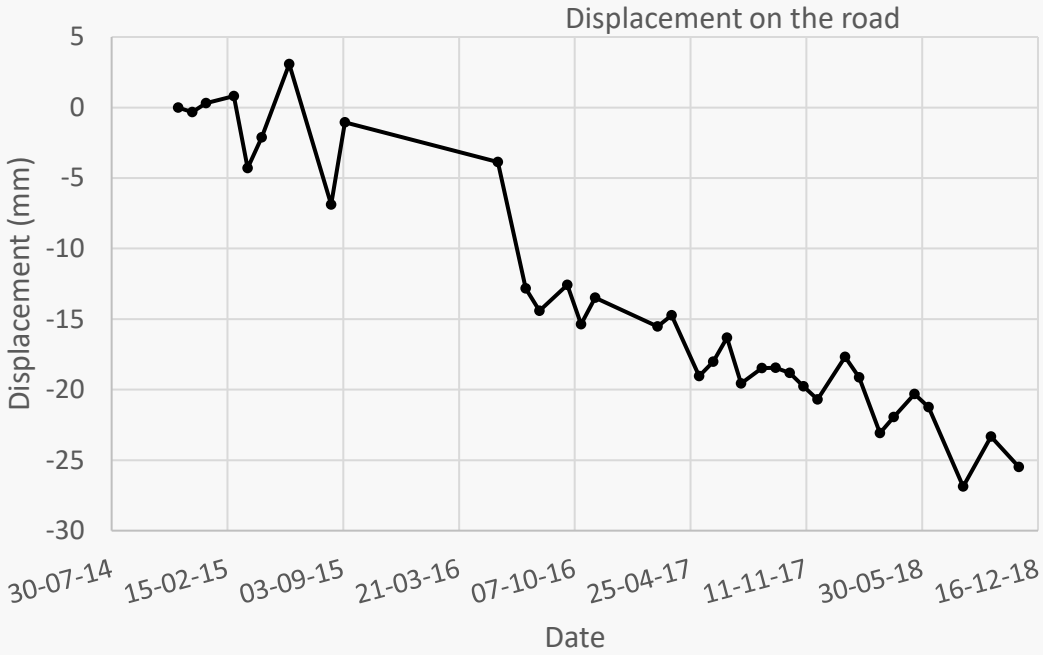
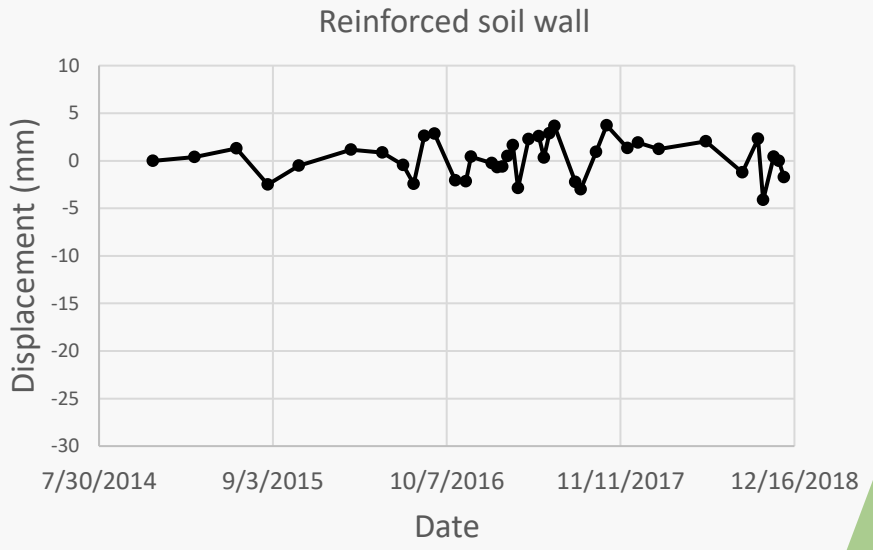
Road network. Detecting movement, Prioritizing Maintenance

Velocity (mm/year)

-11.0 **+6.0**





Robroyston, Glasgow

- New road embankment on soft peat pockets with variable geological conditions.
- In situ monitoring (hydrostatic profile gauge HPG) instruments malfunctioning.
- Need settlement monitoring of entire embankment.

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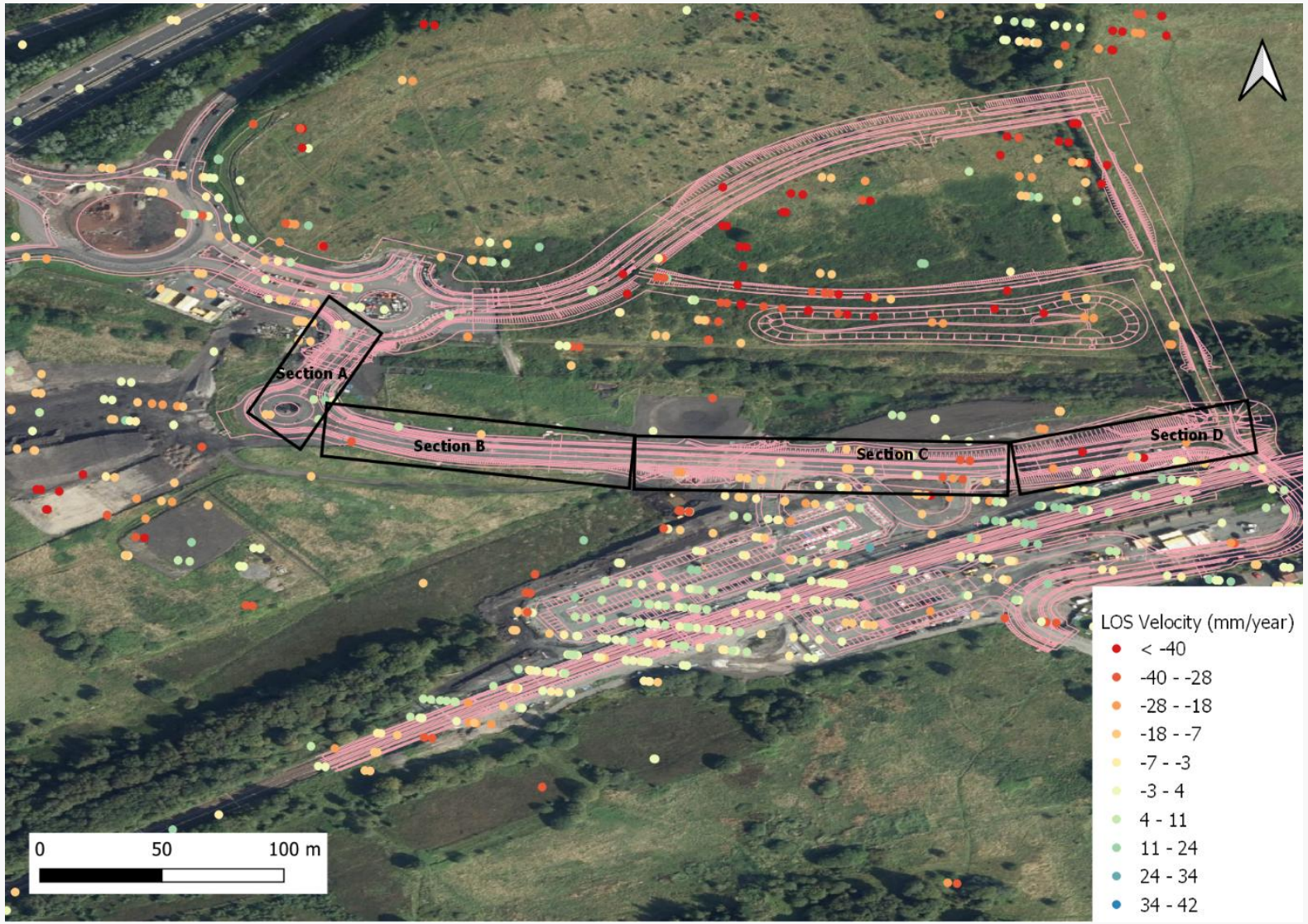
Robroyston, Glasgow



- Updated monitoring and reporting.
- Recorded settlement values fall within the range predicted in the original design.
- Outputs were compared with FEA predictions.

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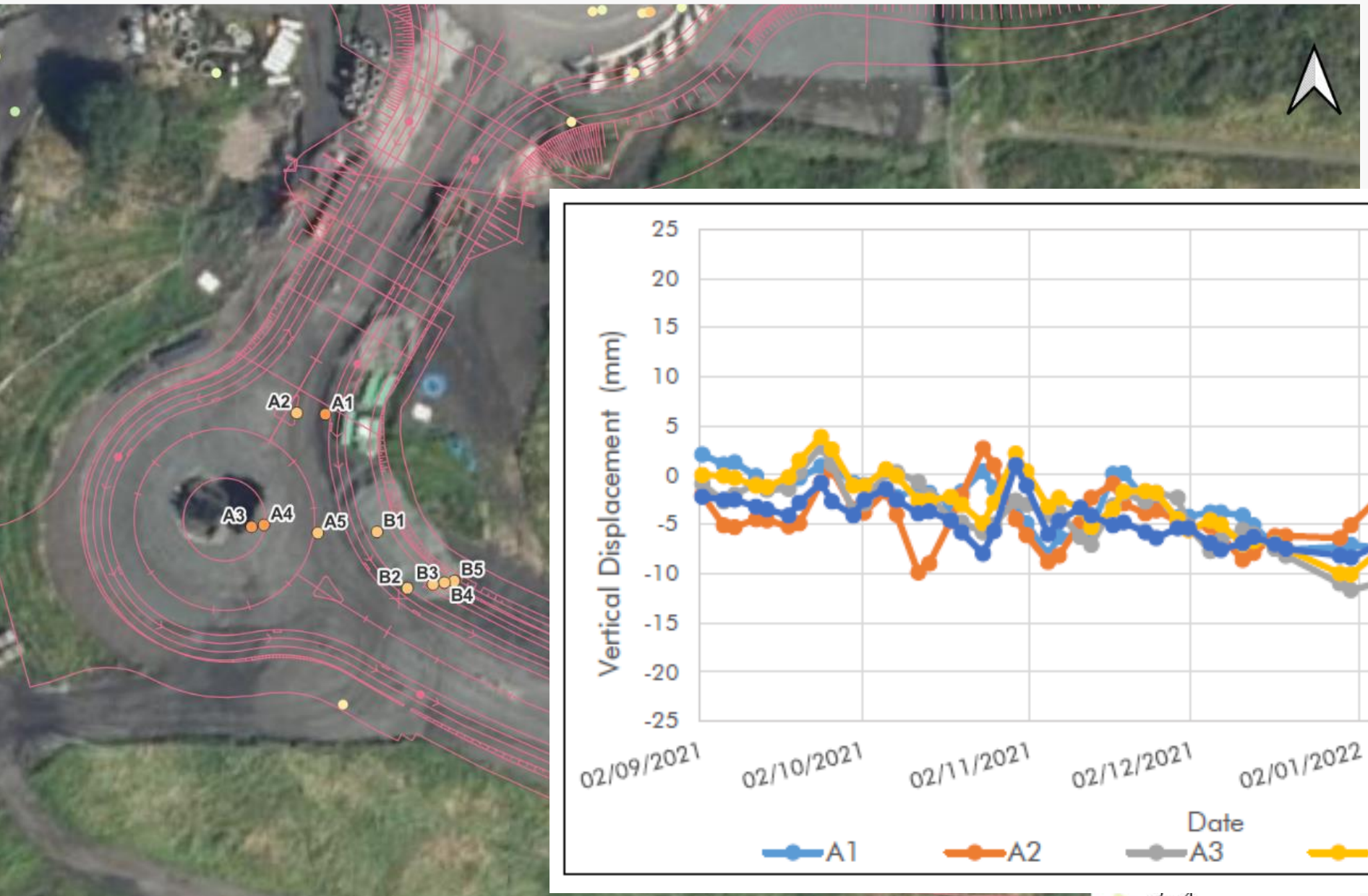
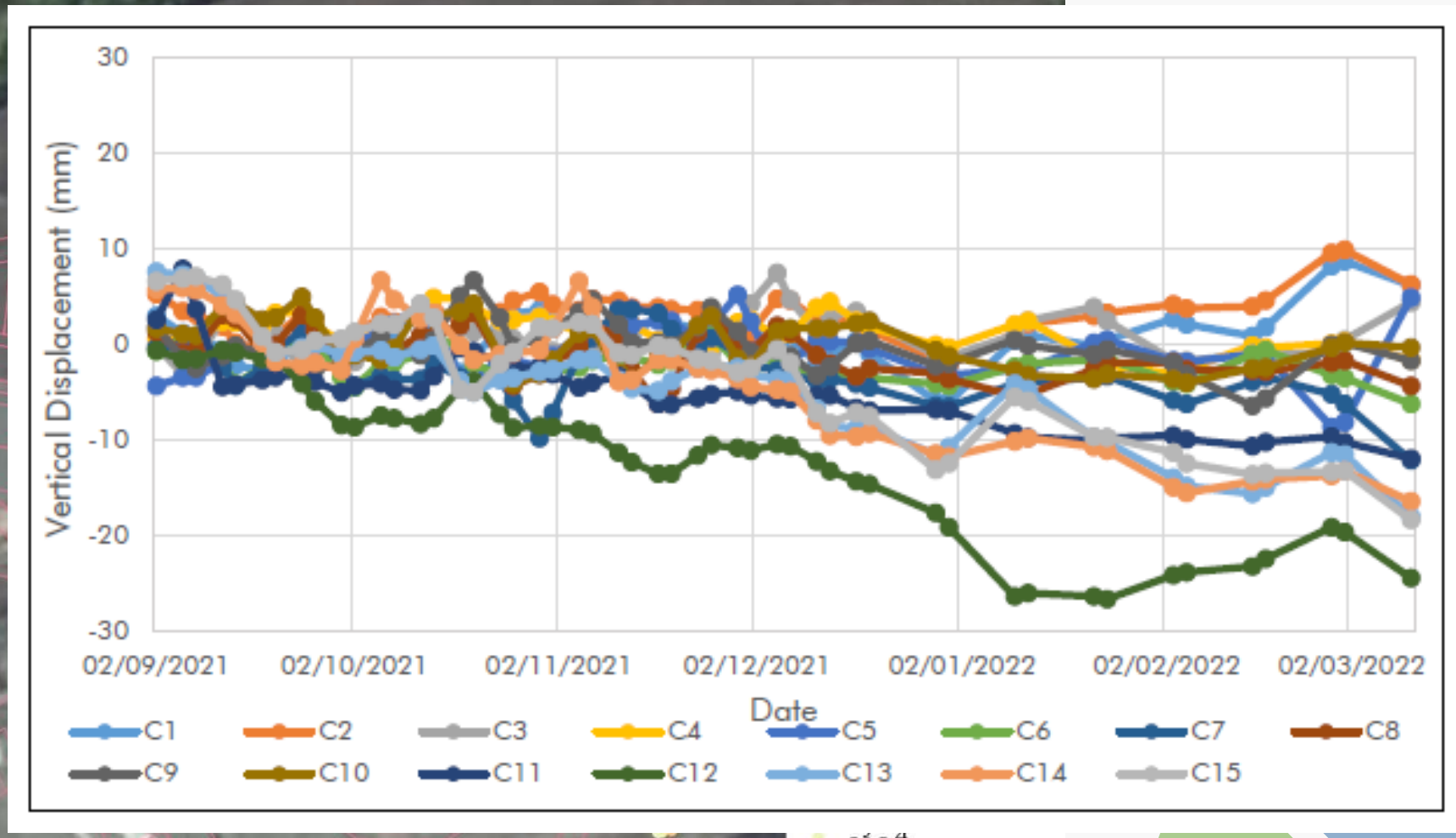
Section A



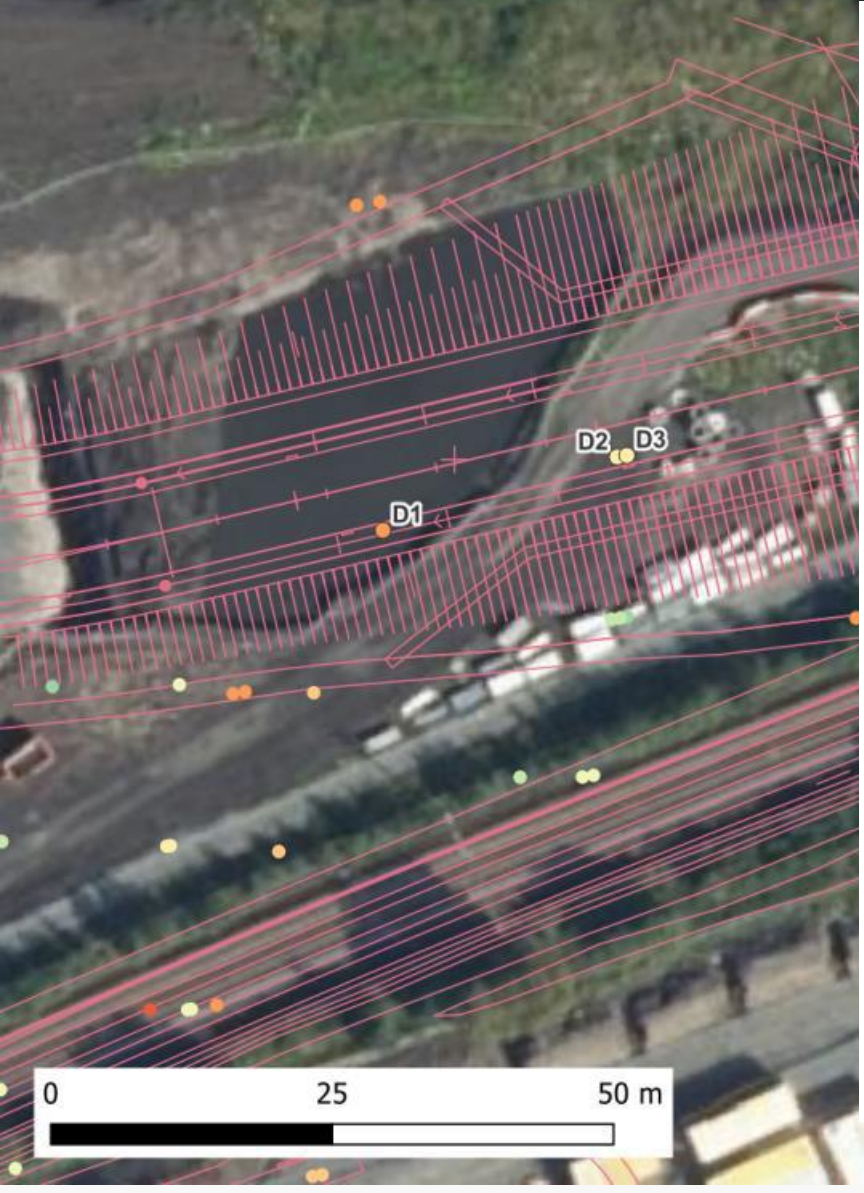
-3 - 4
4 - 11
11 - 24
24 - 34
34 - 49

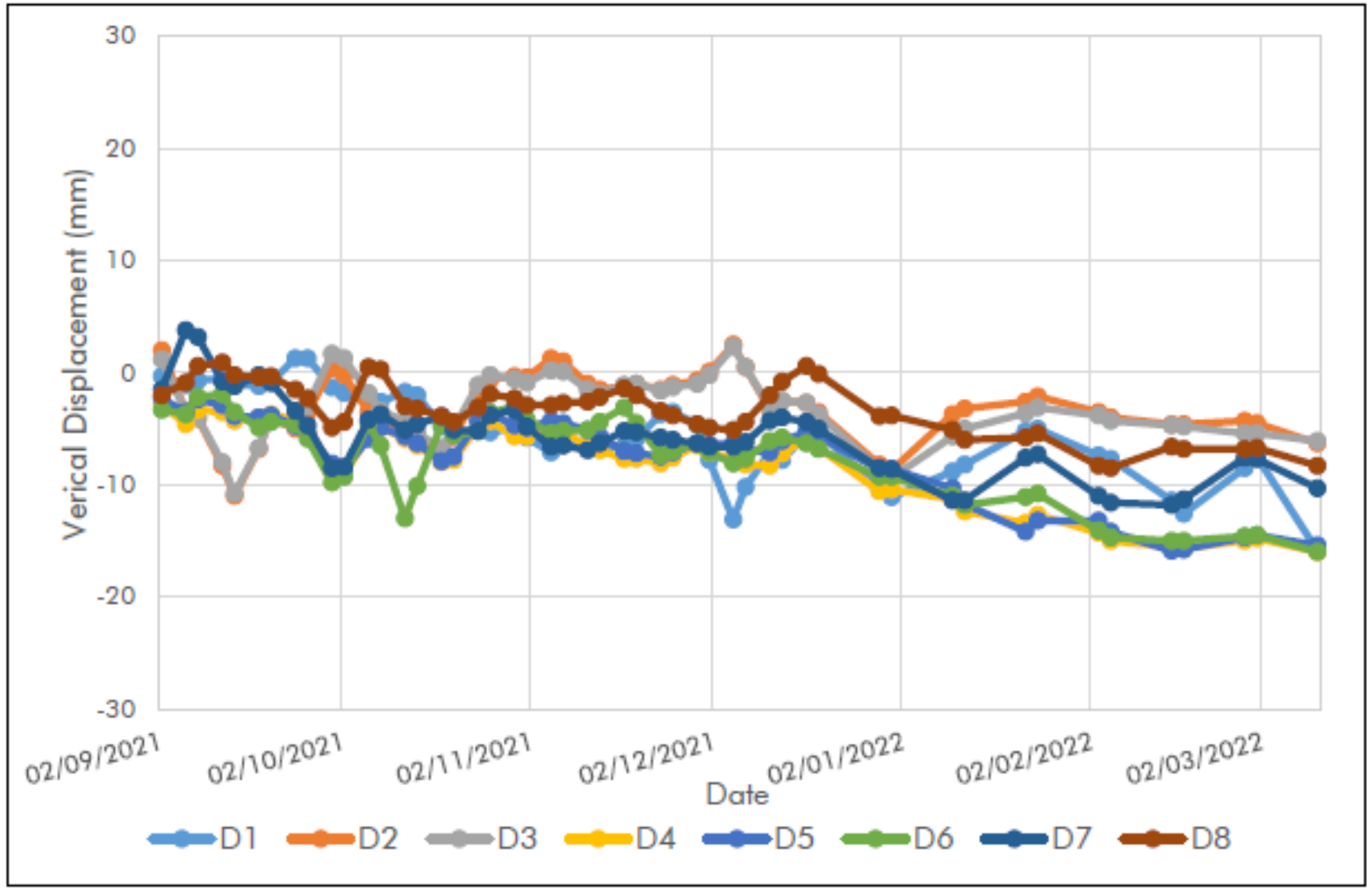
Section C


Vertical Displacement (mm)
30
20
10
0
-10
-20
-30
02/09/2021
02/10/2021
02/11/2021
02/12/2021
02/01/2022
02/02/2022
02/03/2022
Date
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15

C1
C2
C3
C4
0
25
50 m
-3 - 4
4 - 11
11 - 24
24 - 34
34 - 49

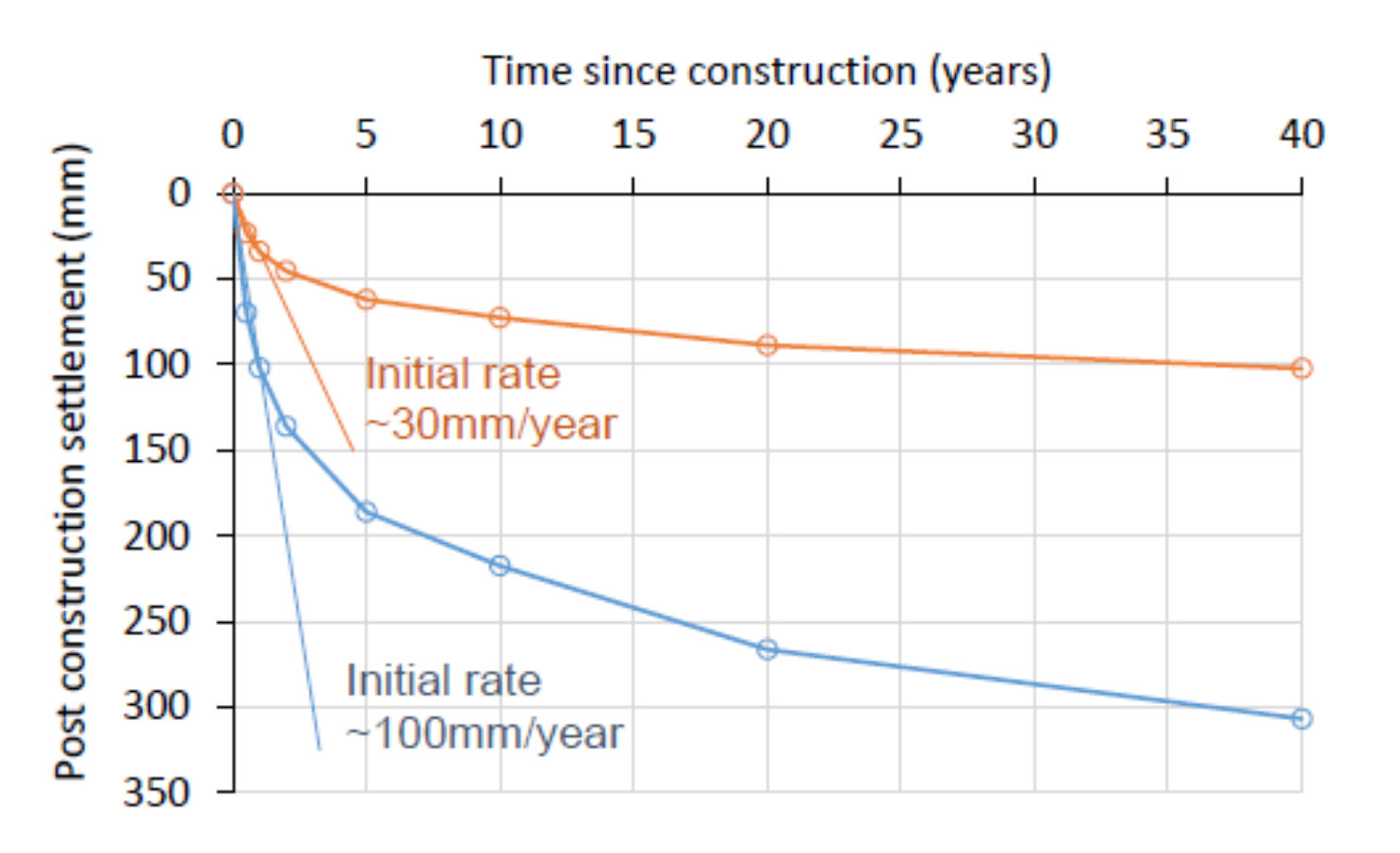
Section D





34 - 49

Predicted post-construction displacements due to consolidation and creep settlements in the foundation soils shows initial rates of between 30mm and 100mm per year (for different geological scenarios).



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Road network monitoring

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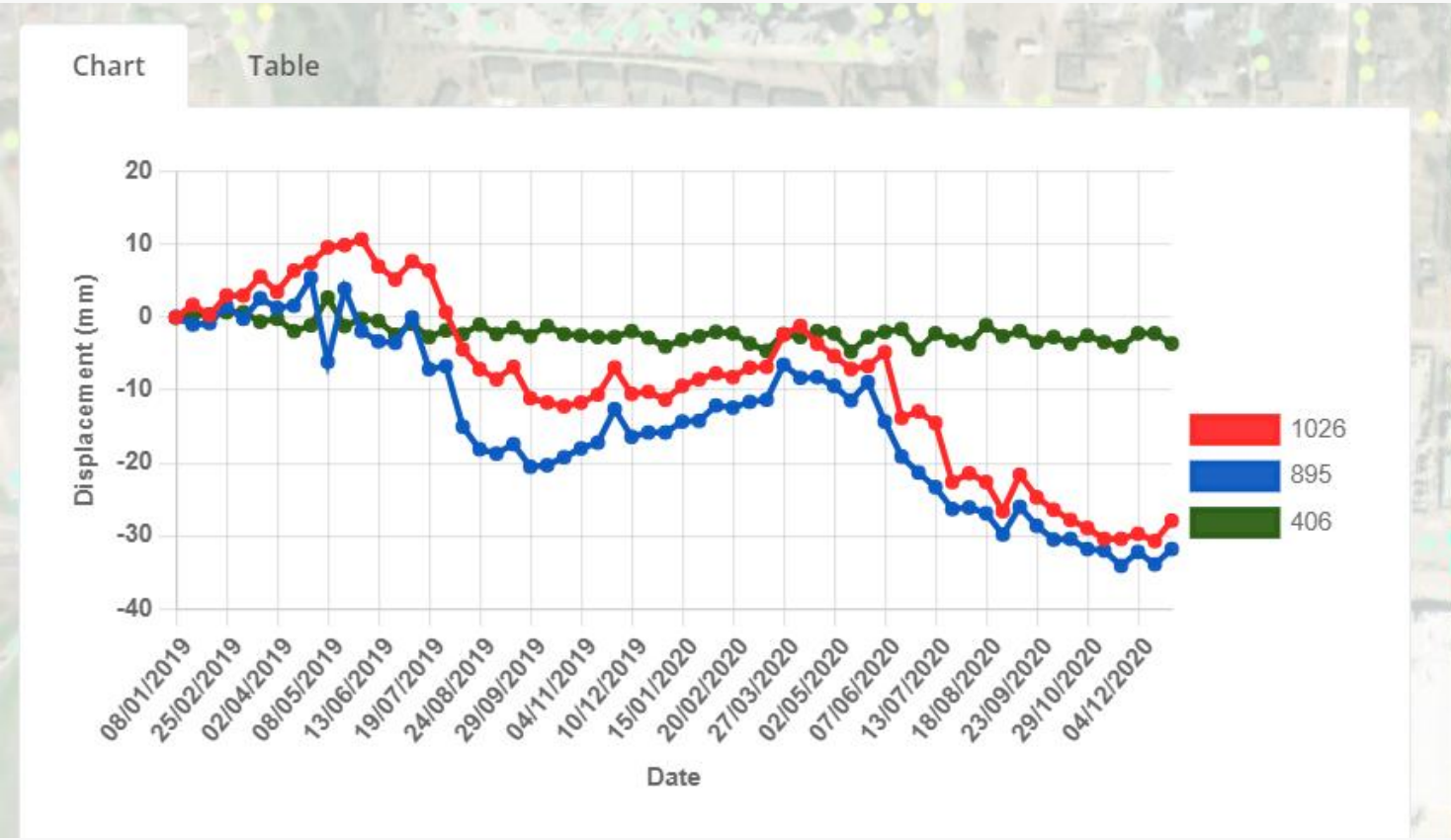
Road network monitoring



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Infrastructure susceptibility to geohazards

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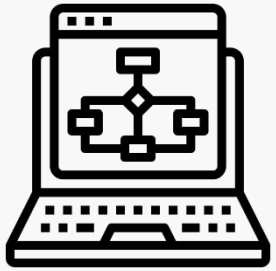
Satellite data with engineering insight

Satellite data

- Displacement data
- Soil moisture data
- Topographical data

Asset susceptibility scores

Landslides	★ ★ ★
Swelling clay	★ ★
Sinkholes	★ ★ ★ ★



Artificial intelligence

Engineering know-how

Other data

- Geological maps
- Asset damage data
- Ground truth data

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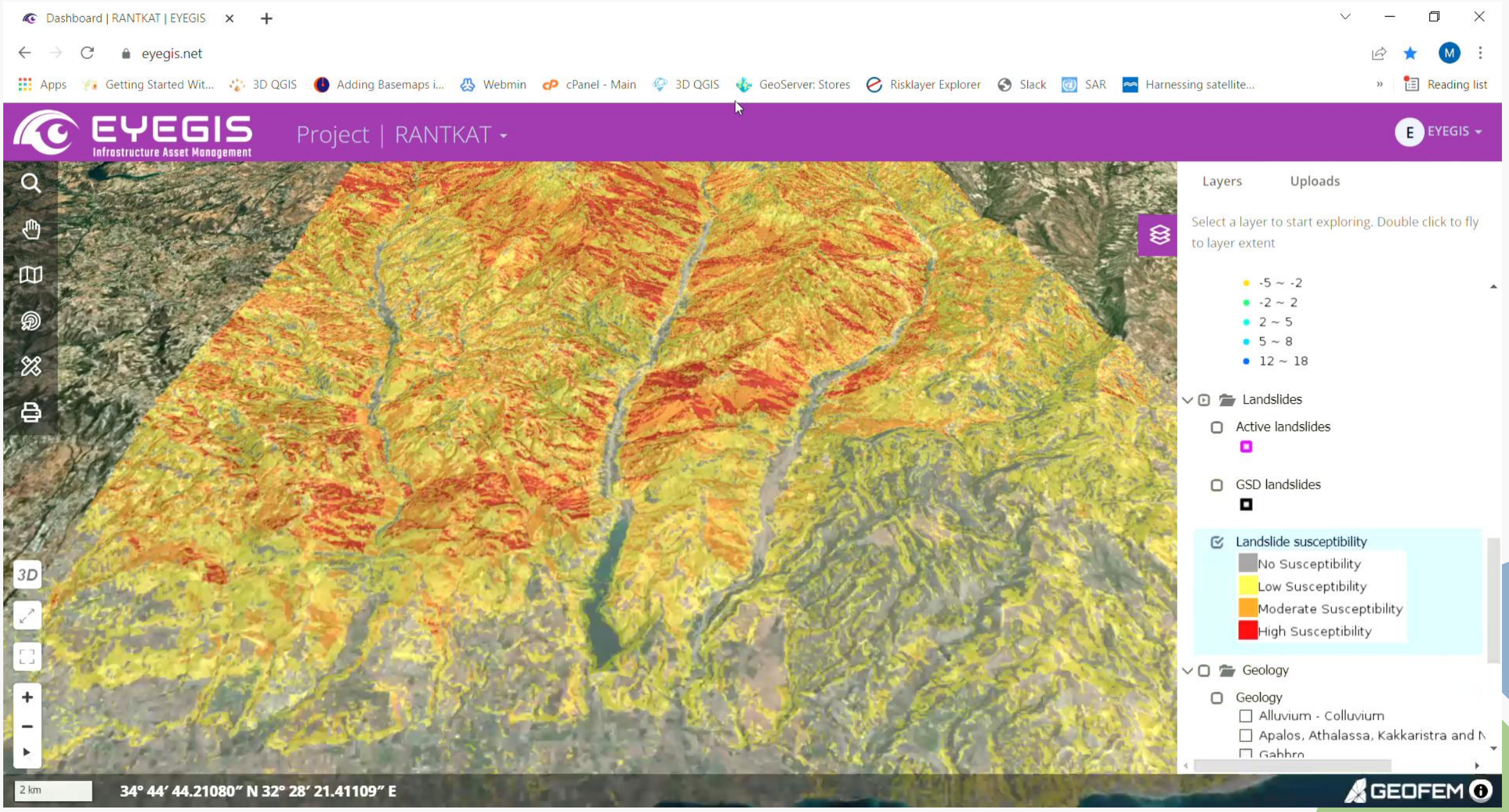
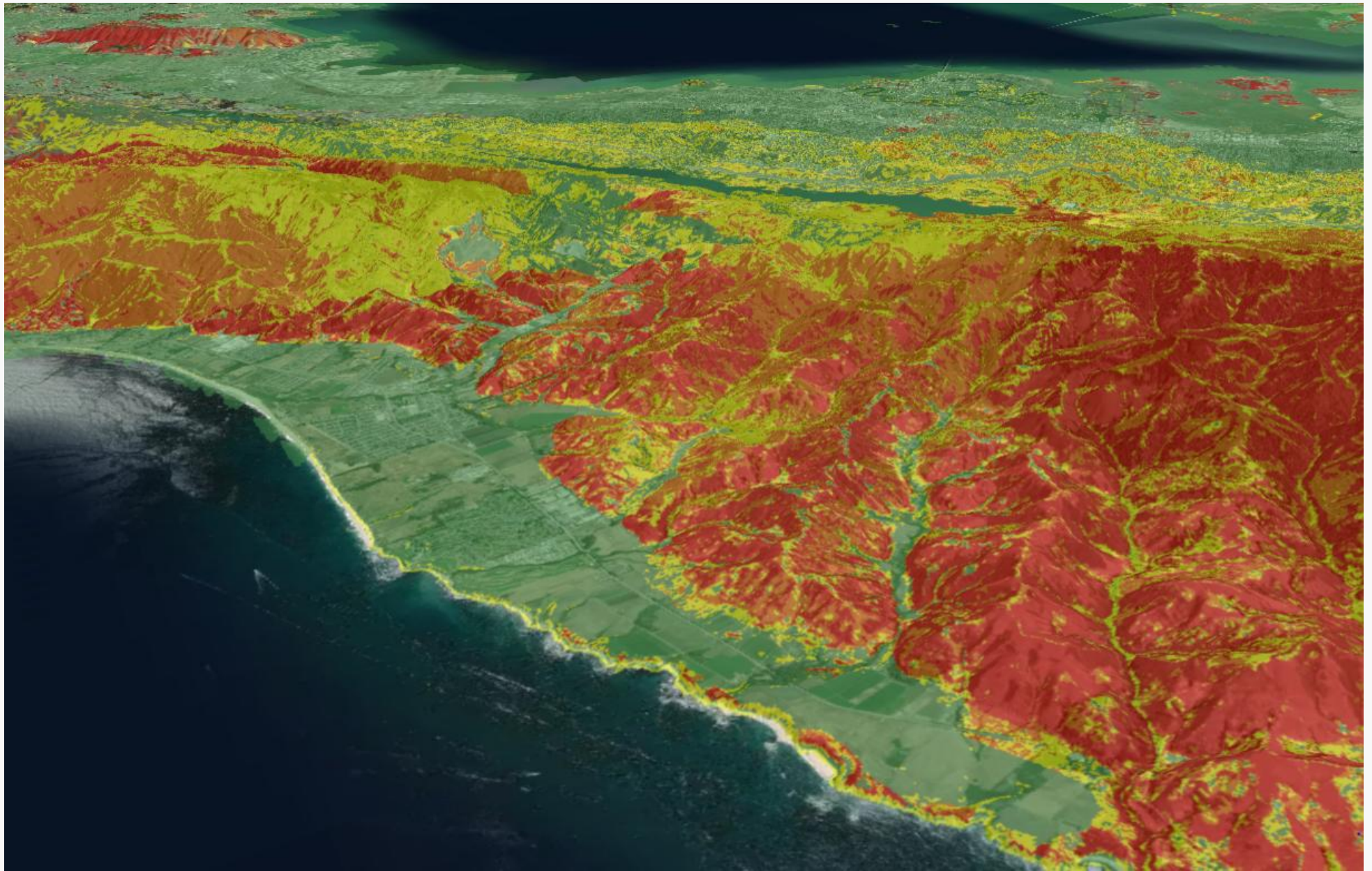
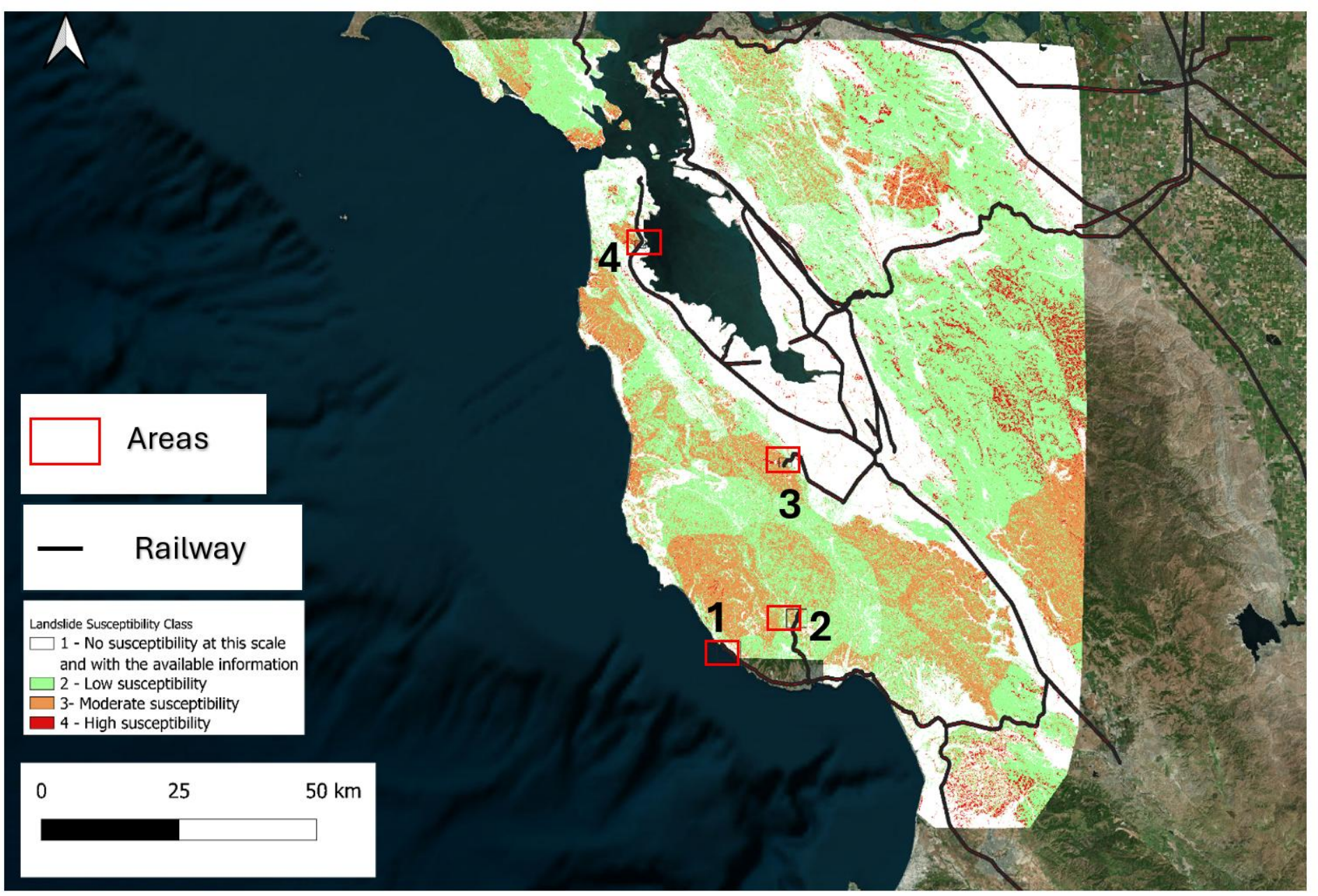
Susceptibility to landslides



Susceptibility to landslides



Landslide susceptibility map California



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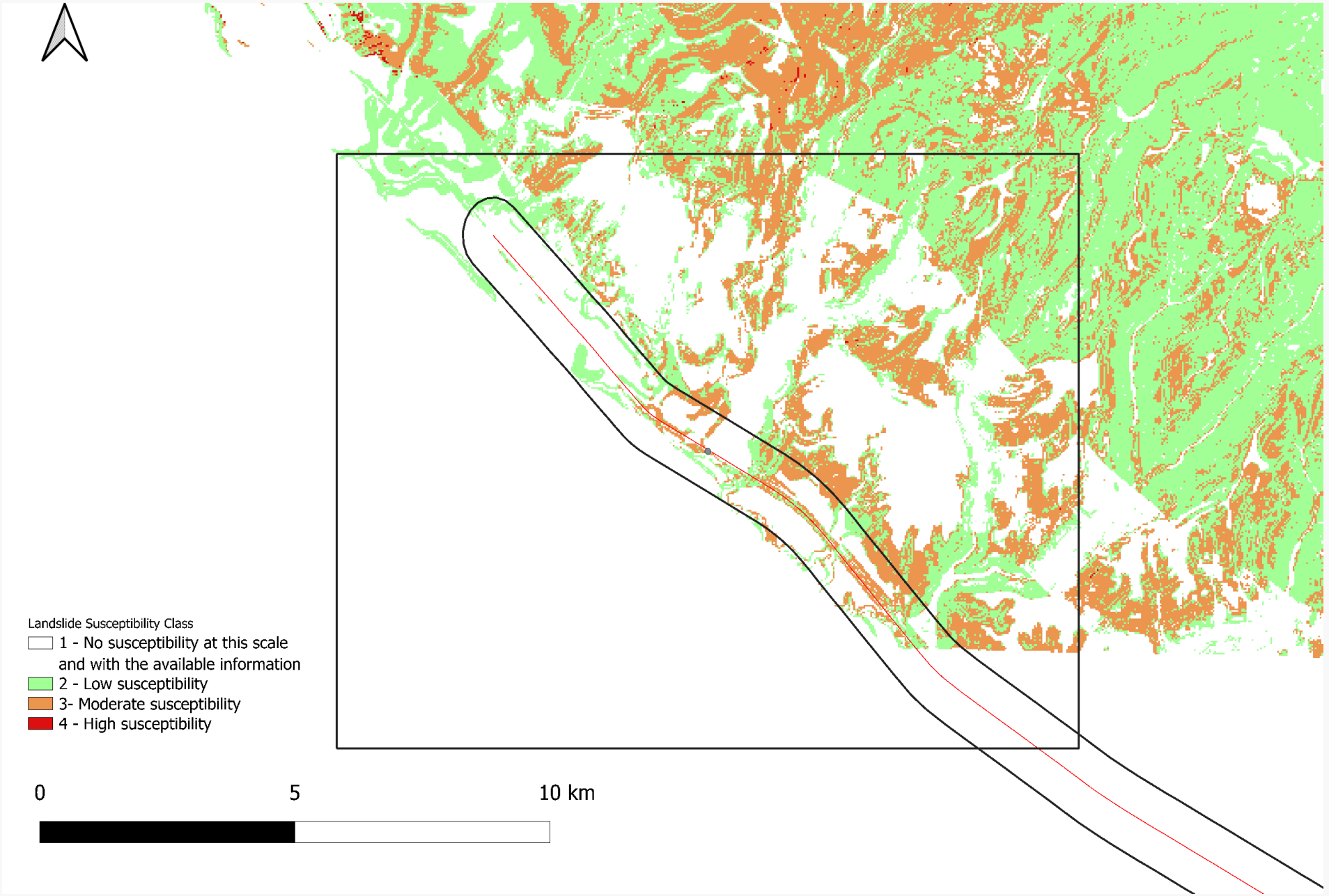
Area 1



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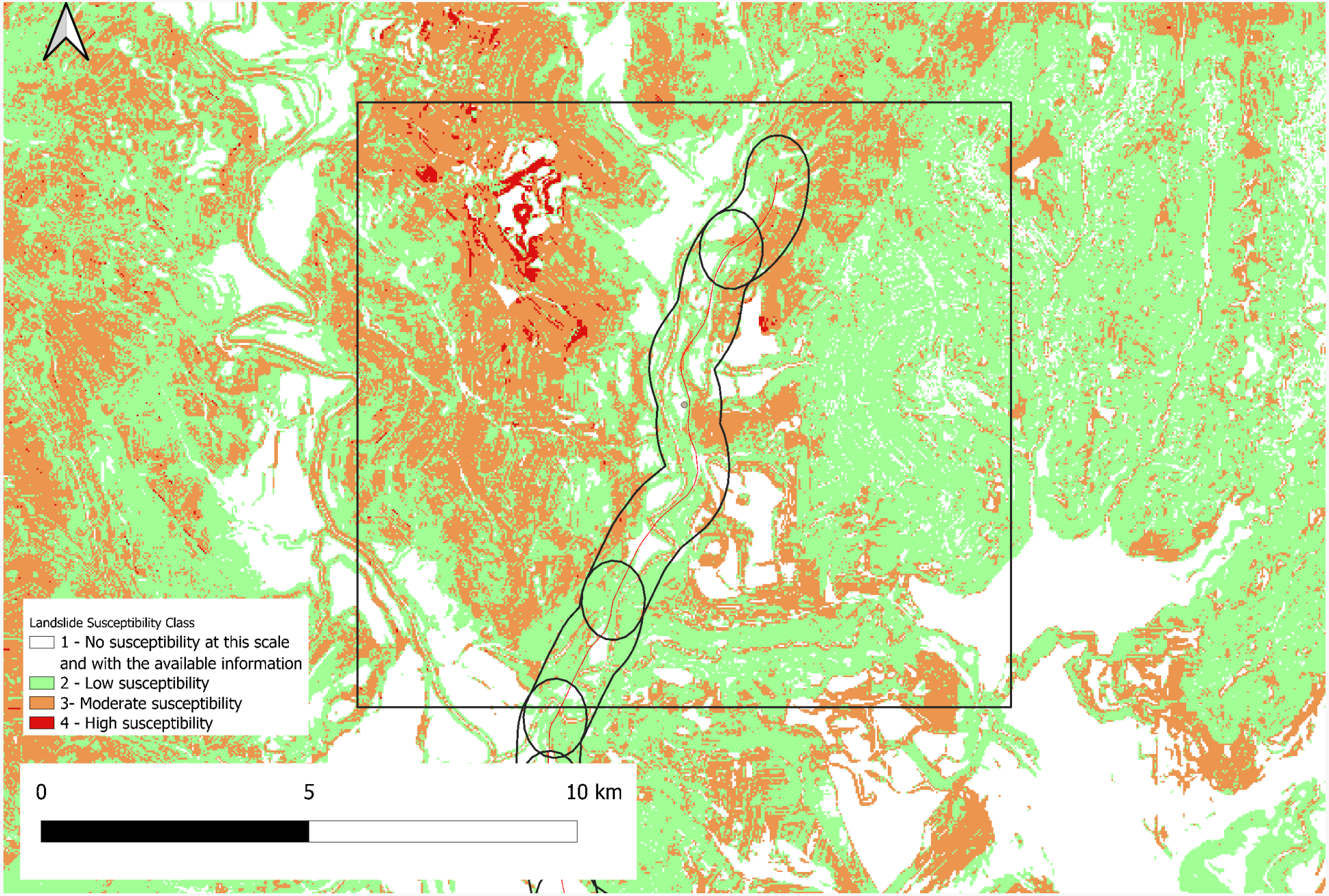
Area 2



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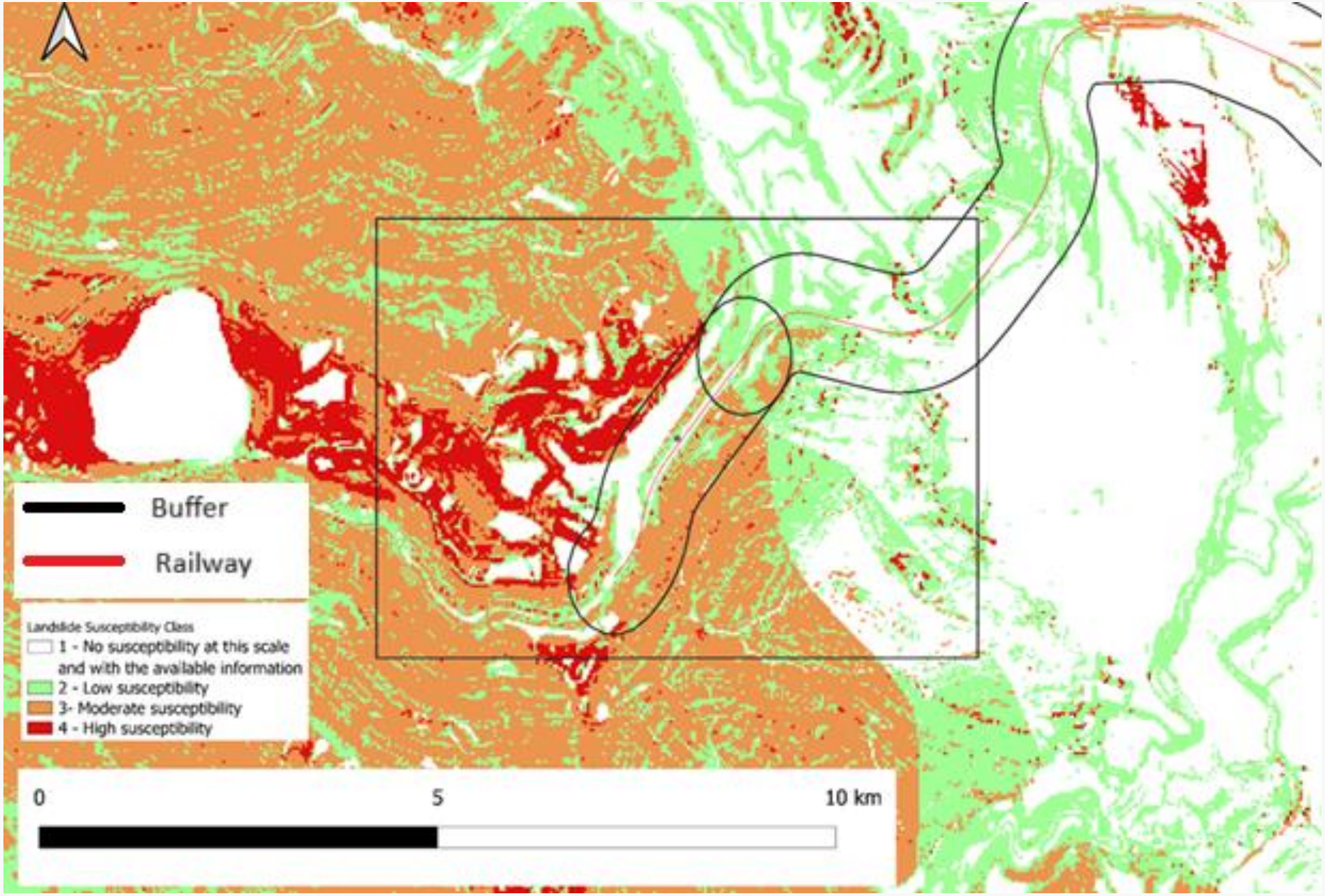
Area 3



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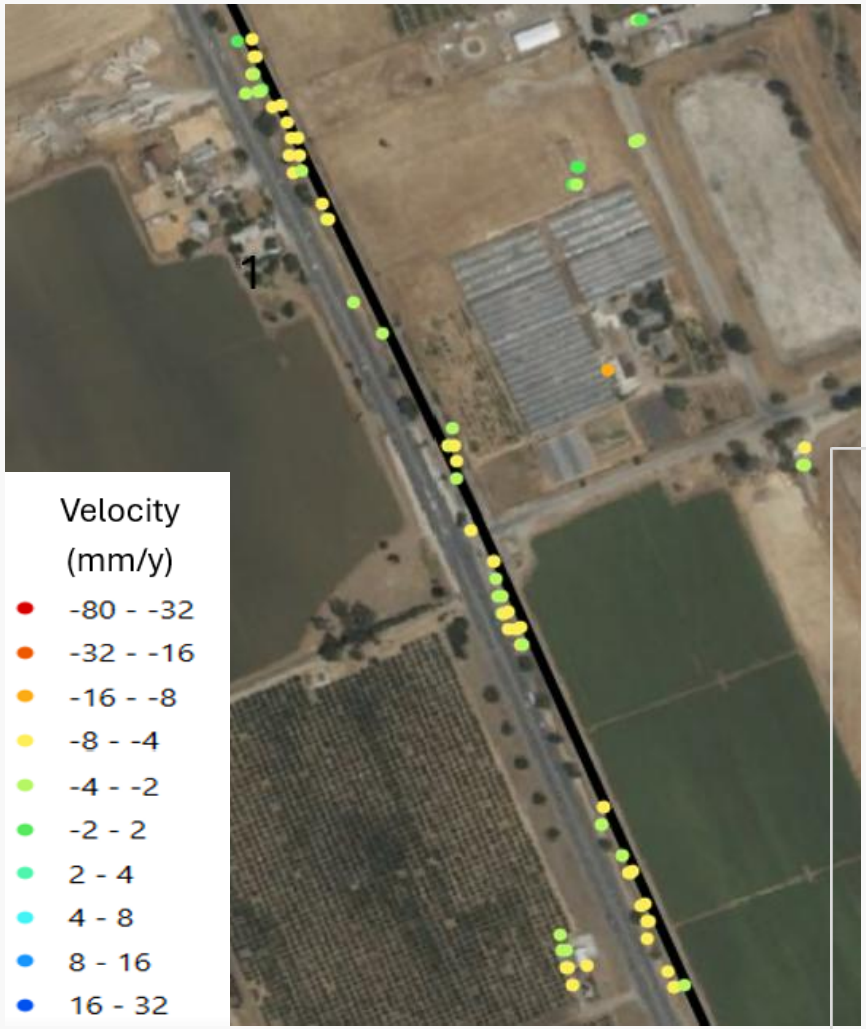
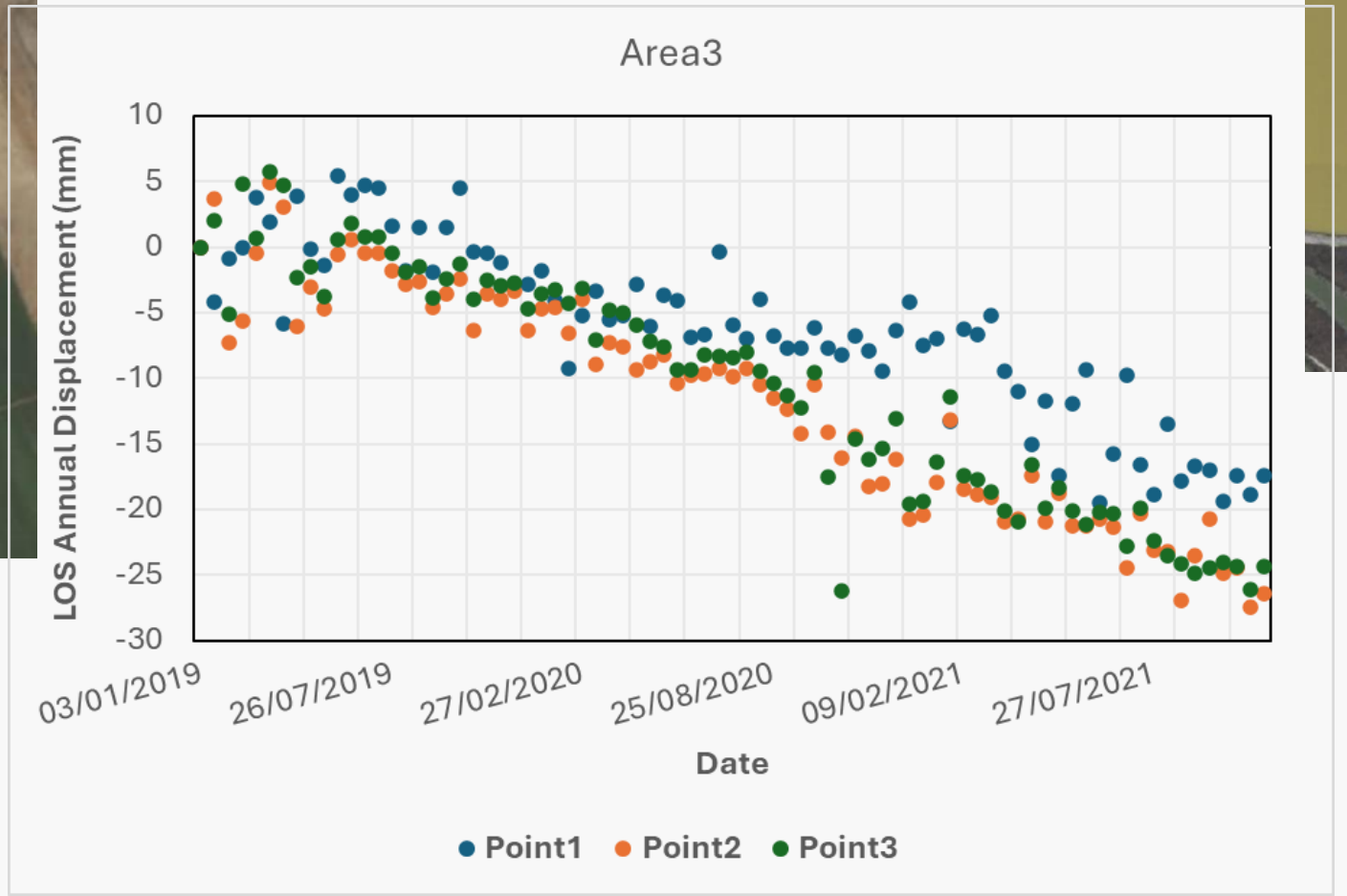
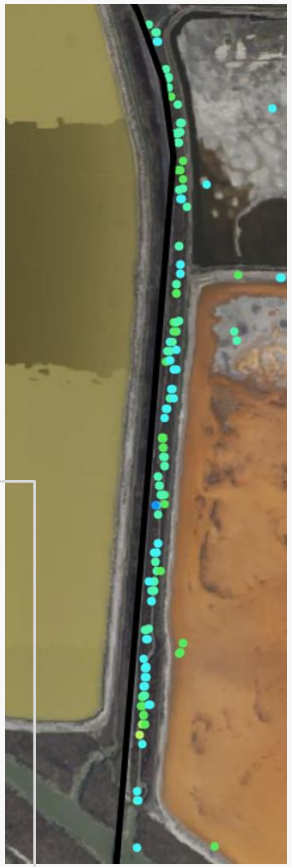

1
Velocity
(mm/y)
-80 - -32
-32 - -16
-16 - -8
-8 - -4
-4 - -2
-2 - 2
2 - 4
4 - 8
8 - 16
16 - 32


Area3
LOS Annual Displacement (mm)
10
5
0
-5
-10
-15
-20
-25
-30
03/01/2019
26/07/2019
27/02/2020
25/08/2020
09/02/2021
27/07/2021
Date
Point1
Point2
Point3



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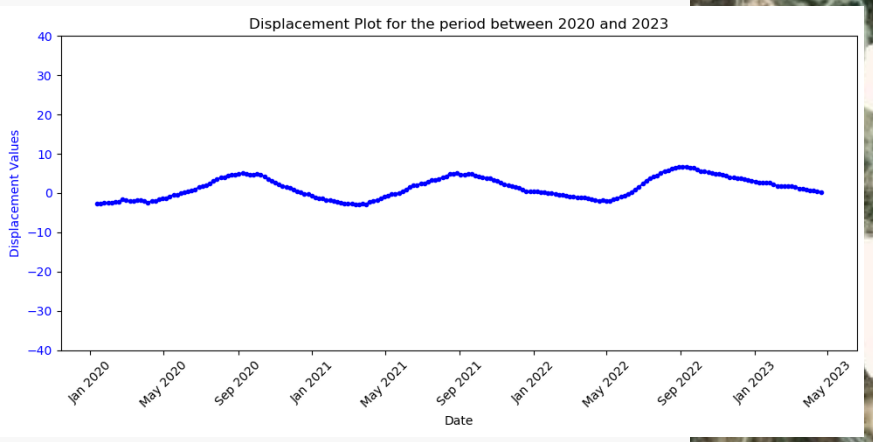
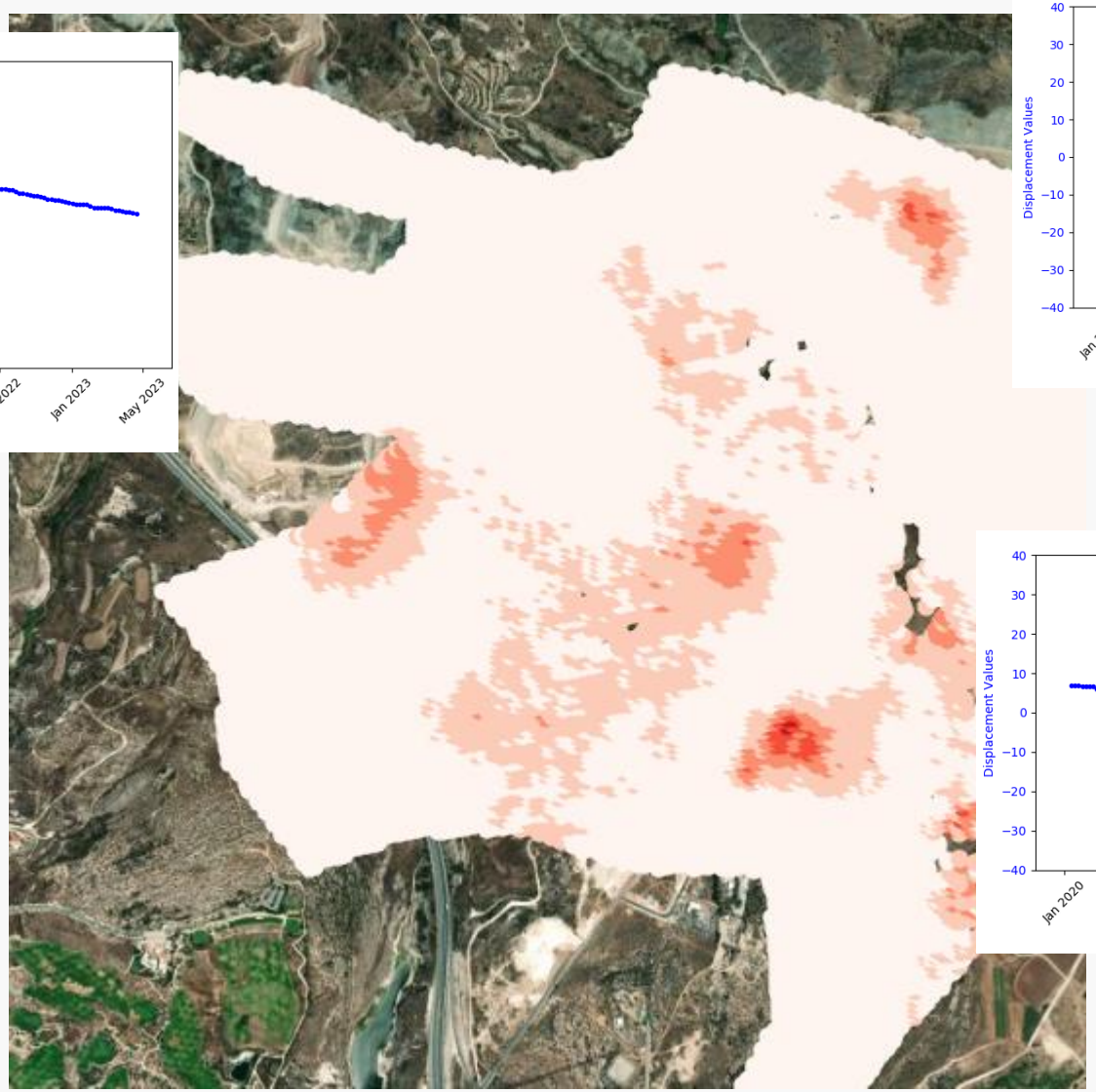
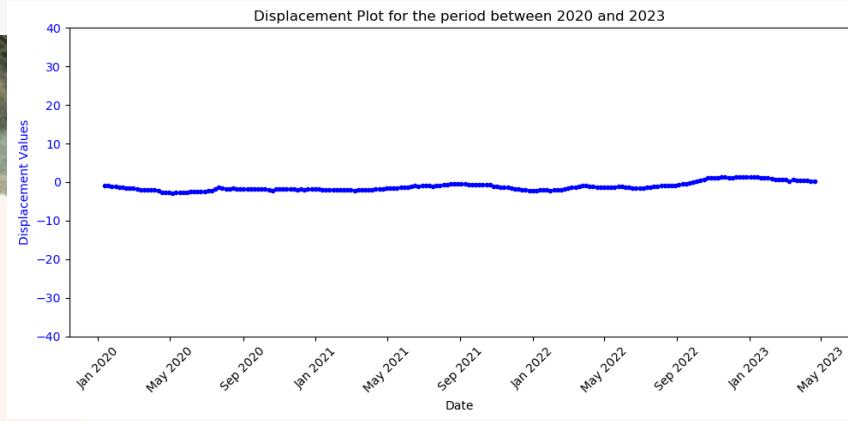
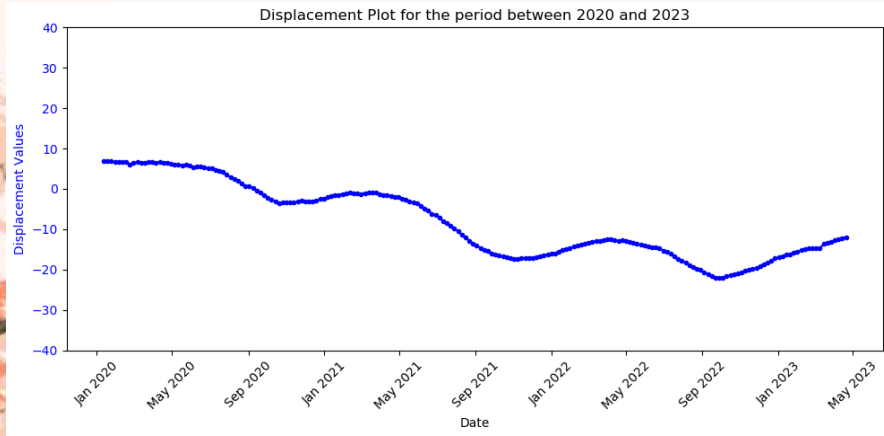
Susceptibility to swelling clays









Severity score

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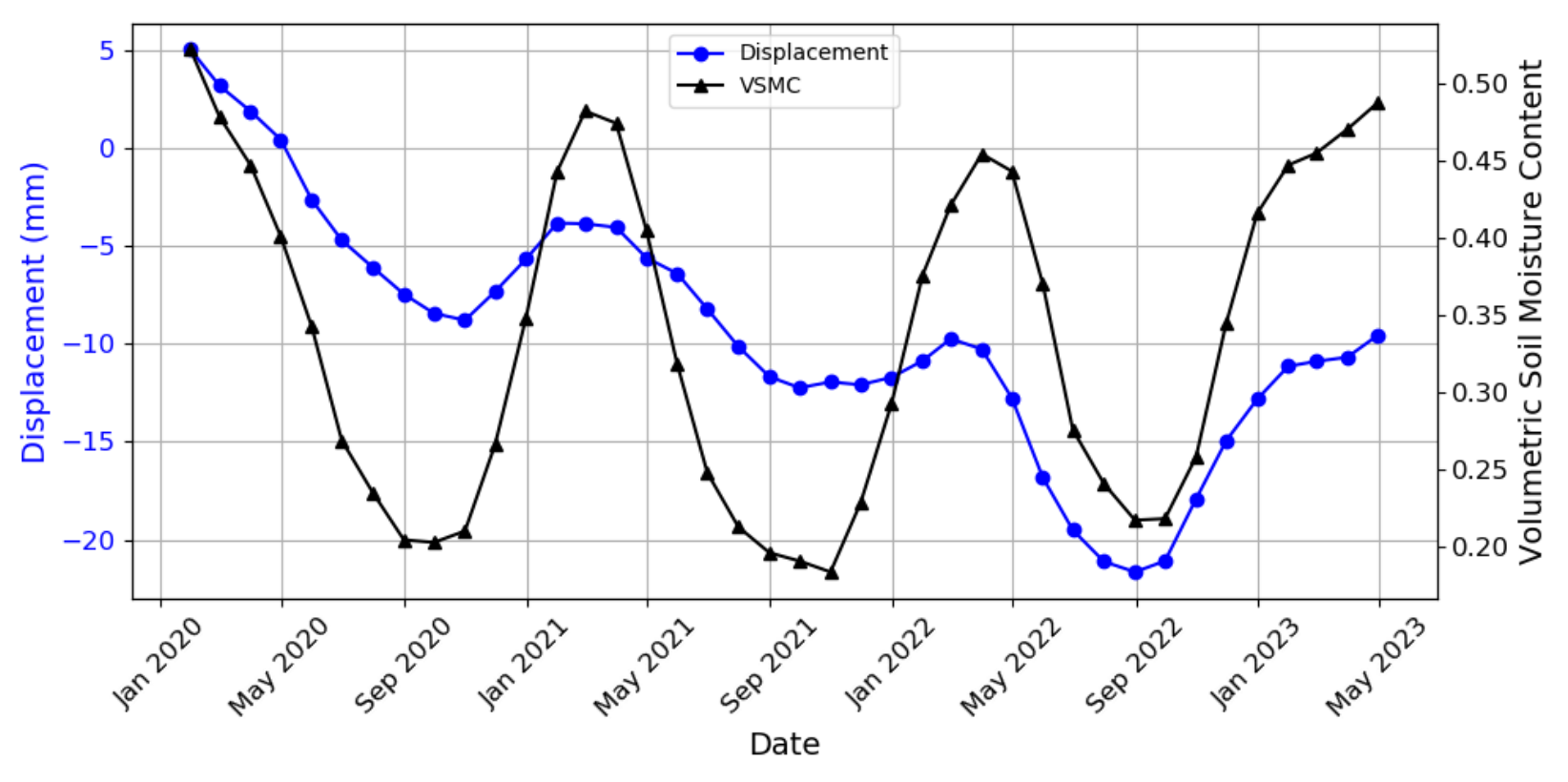
Susceptibility to swelling clays

Correlation between soil moisture content and seasonal displacements.



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Conclusions

- *Soil moisture via satellite can provide wide coverage, updated with every satellite pass. Globally applied.*

- *Effective monitoring of geotechnical and infrastructure assets, which can be combined with in situ instrumentation and FEA for added value.*

- *AI for infrastructure susceptibility to geohazards can cover whole network and be regularly updated:*
  - Climate change
  - Reduction of carbon footprint

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THANK YOU

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