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Road maintenance and security with satellite-based displacement analysis

SATELLITE SLOPE MONITORING

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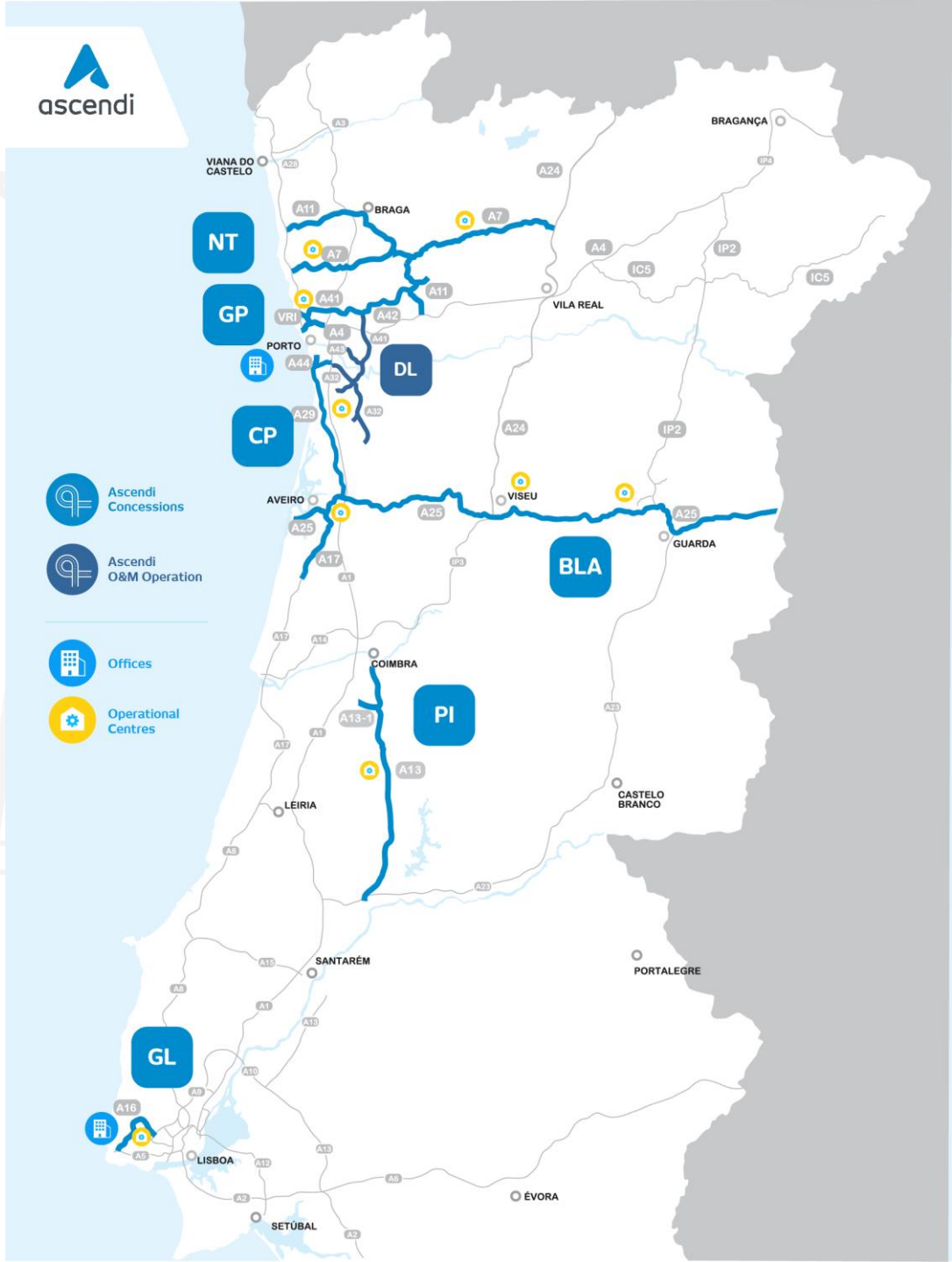
01 Ascendi Key Figures
#1 Overview

/ Ascendi, a leader in the road infrastructure market, **manages infrastructure assets** and provides **toll collection** and **operation & maintenance** services.

/ With 25 years of consolidated experience, Ascendi is recognized by its **innovative capacity** and **operational efficiency**.

7 Motorway Concessions

706 Km in operation



01 Ascendi Key Figures
#2 Business Areas

Asset Management

/ Control of **7** Concessions

/ **$3.6 Billion** Global investment in the 6 concessions CapEx

Operation & Maintenance

/ Road **Operation and Maintenance**

/ **Intelligent Transport Systems** (ITS)

/ **Maintenance Management**

Toll Collection

/ **3 traditional toll** operations

/ **7 electronic toll** operations

02. Objectives

- Conduct InSAR analysis over a 4km section with a buffer of 400 meters on Pinhal Interior Concession (A13)
    - three critical slopes

- Evaluate the effectiveness of the **Early Warning System** Detection on these slopes
    - apply Ascendi's thresholds to InSAR data

- Evaluate the effectiveness of slope repairs .

- Compare InSAR to traditional techniques for measuring soil deformation

KEY QUESTION:

Could satellite displacement observation (InSAR) replace traditional methods (topographic surveys)?

02. Study Case

1. EMBANKMENT SLOPE (PK: 180+715/181+95)

- Localized repairs carried out in 2017.
- Landslides in December 2019.
- Interventions in June 2020, which included the installation of topographic targets on the pavement.
- Between July 2021 and 2022, displacements in the topographic targets were observed.

2. NORTH EXCAVATION SLOPE (PK: 181+095/810)

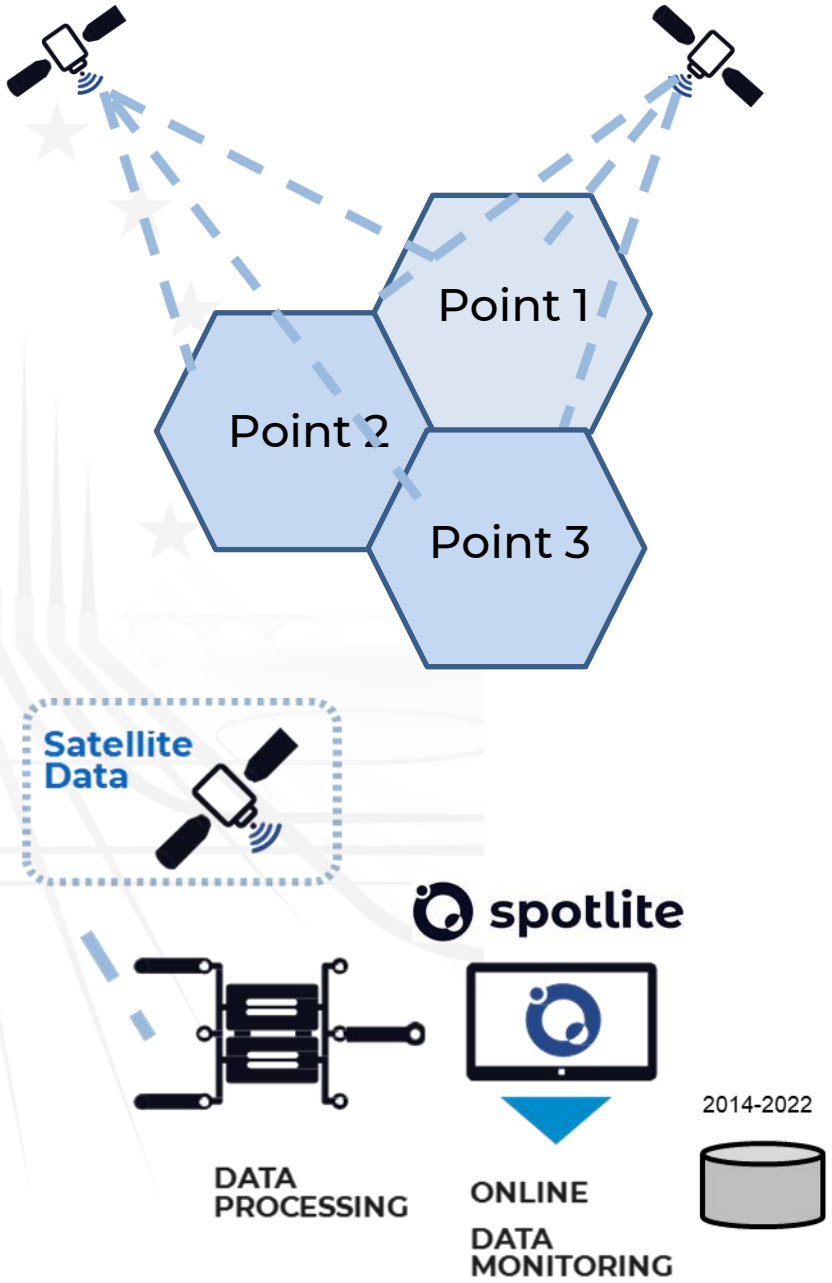
- Repair work conducted between 2016 and 2018.
- Landslides in December 2019.
- Intervention completed in 2021

3. SOUTH EXCAVATION SLOPE (PK: 180+400/730)

- Intervention on the first slope bench in August 2018.

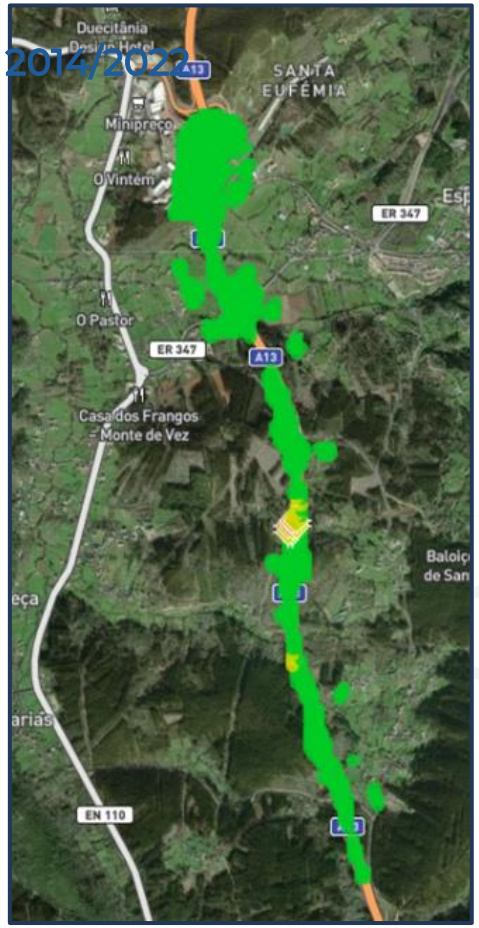
03. InSAR Technology

- **Satellite Radar (SAR) Technology:** Uses radar-equipped satellites that penetrate adverse weather, accurately measuring ground deformations.
- **Coverage:** Satellite image evaluates large areas rather than single points.
- **Reflectivity Considerations:** Elements like toll booths may appear more prominently due to their higher reflectivity.
- **Orbital Line of Sight:**
  - Ascending Orbit: South to North.
  - Descending Orbit: North to South.
- **Data Decomposition:** Analyzes horizontal (east-west) and vertical (up-down) displacements that can be compared with in situ values.



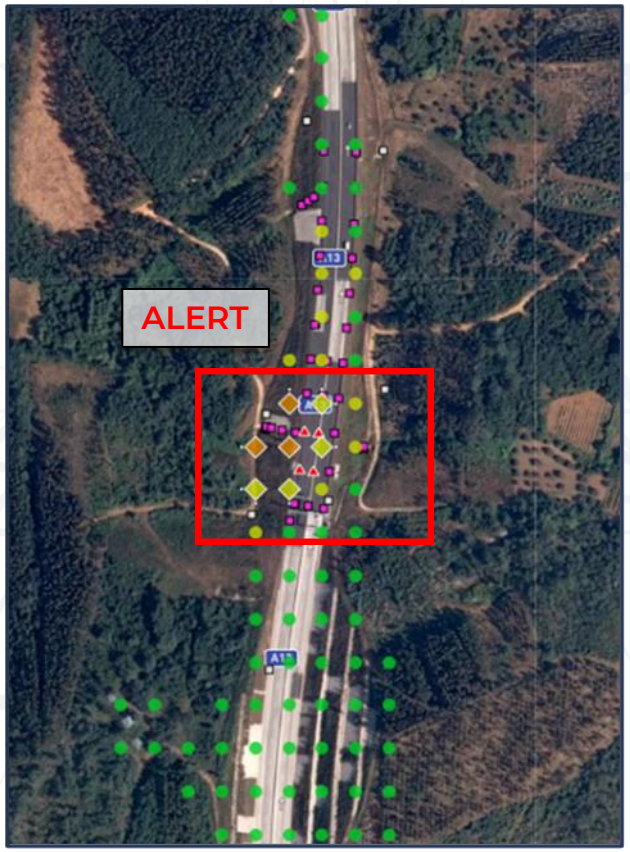
04. Overview Results

Area covered in the case study obtained displacements for a period of 8 years - 2014/2022

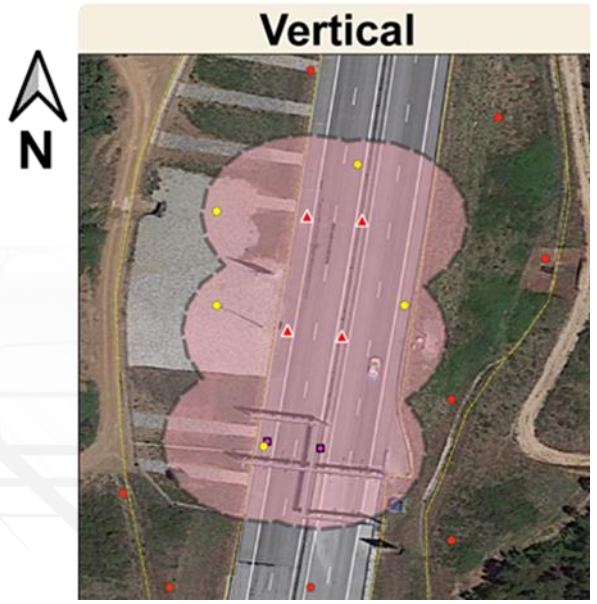


→ Alerts are InSAR points that **exceed** a determined threshold for either Displacement (mm) or Average Velocity (mm/year)

Automatic alerts (diamond shape) in Spotlite's Platform 2020/2022



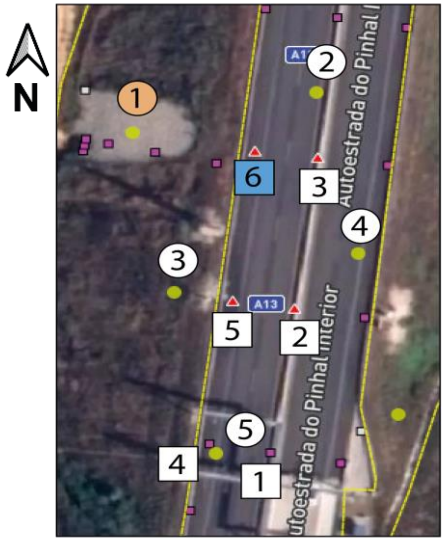
All topographic targets have at least one InSAR point within a 25-meter radius



Topographic targets

Satellite points

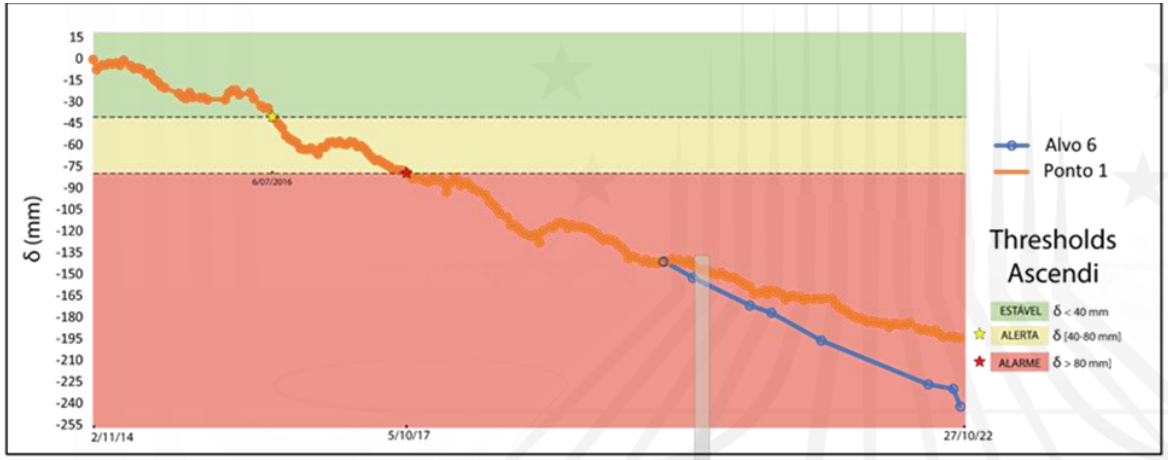
04. Results – Embankment Slope (PK: 180+715/181+95)

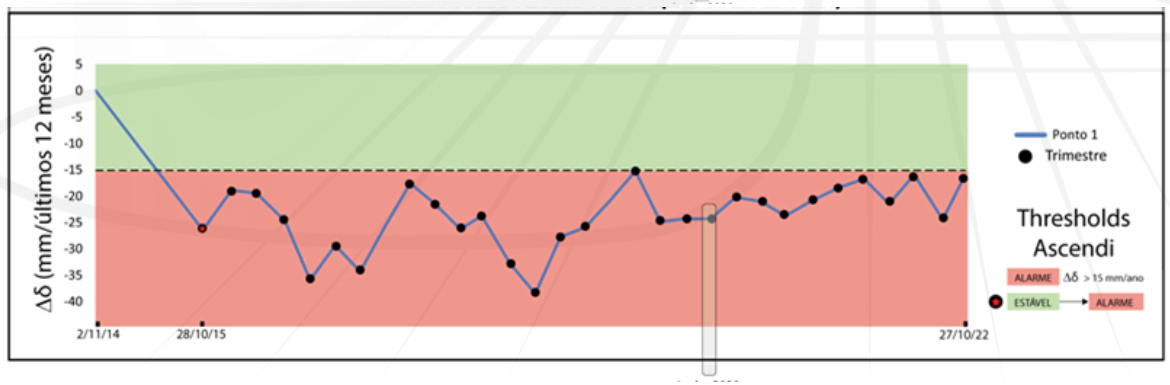


○ Satellite Points

□ Topographic Targets

Observed Vertical Displacements – InSAR versus Topographic Targets





Rock fill in June 2020

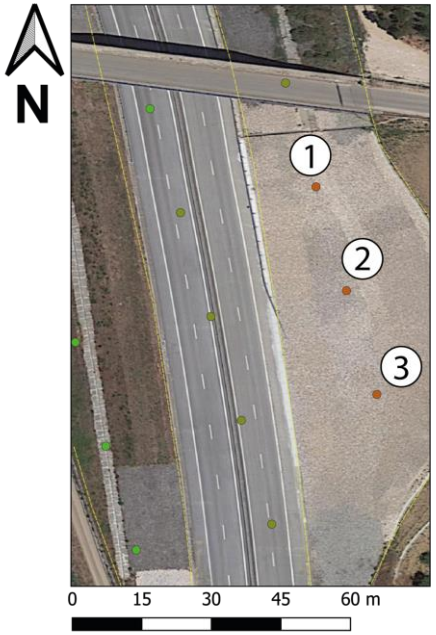
Cumulative Displacement

- Vertical displacements range from -20 to -23 mm/year over the past 7 to 8 years.
- The alarm value was obtained on 5/10/2017 (δ > 80mm)

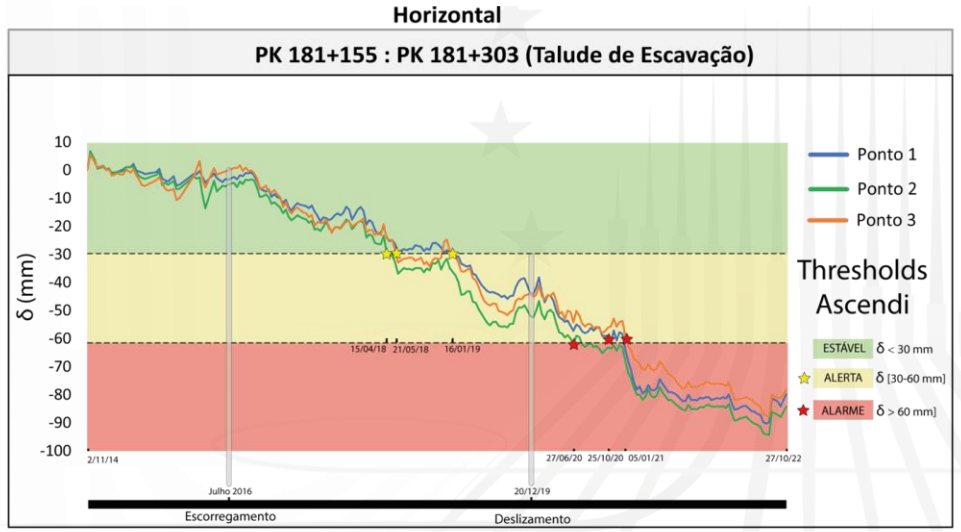
Deformation Rate (Quarterly)

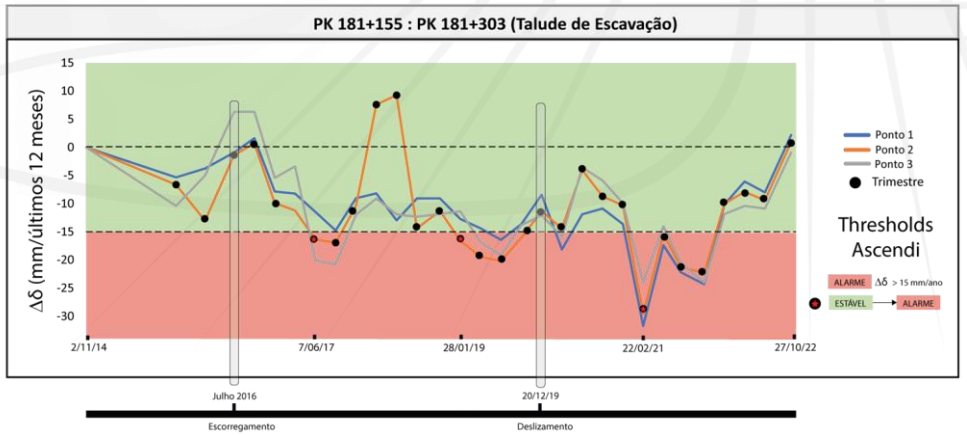
- Alarm levels began in 2015 and remain in a state of alert status.
- After the application of rockfill in June 2020, a stabilization trend was observed.

04. Results – North Excavation Slope (PK: 181+095/810)



Observed Horizontal Displacements - InSAR





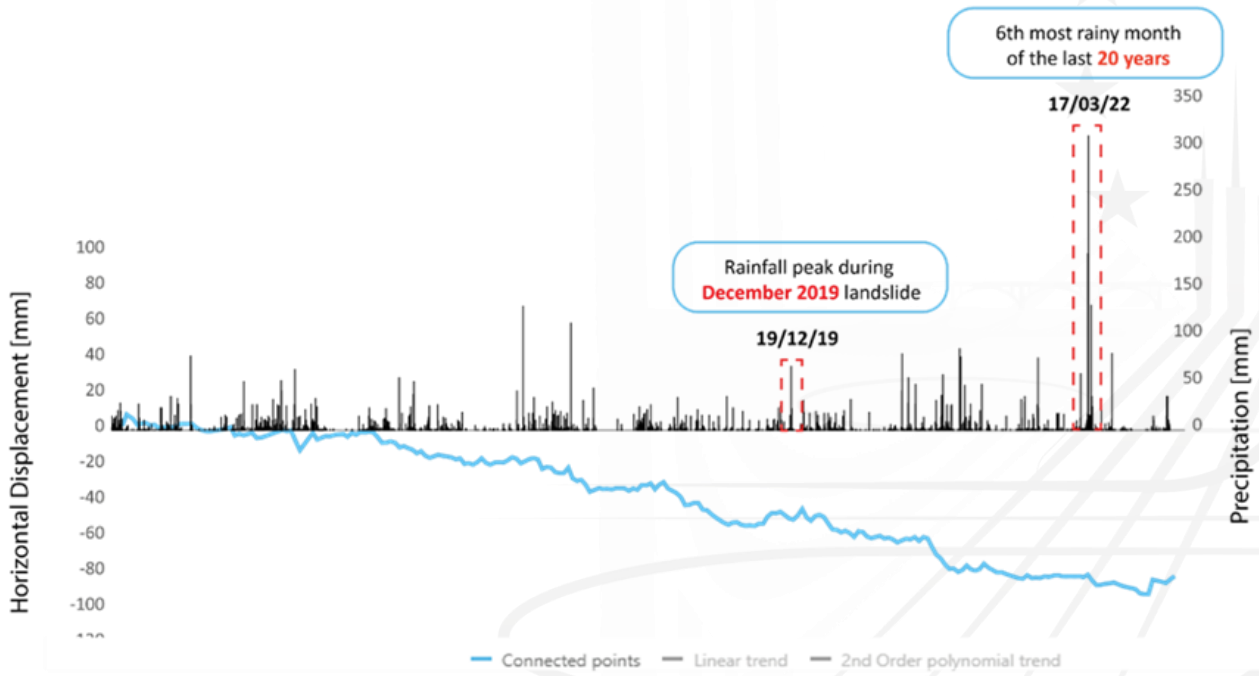
Cumulative Displacement

- Alarms went off from 2020 (displacement > 60 mm), with earlier alerts noted in 2018.
- After the intervention in 2021, the slope showed a stable behavior in 2022.

Deformation Rate (Quarterly)

- The stabilisation work from 2016 to 2018 does not appear to have been fully effective.
- The highest displacements were observed in 2020 and 2021.

04. Results – North Excavation Slope
(PK: 181+095/810)



Weather Data versus InSAR Data

- Utilizing satellite rainfall data with a 4 km spatial resolution enhances the InSAR analysis.
- By combining cumulative displacement data with daily precipitation records, we identified a significant rainfall peak in December 2019, coinciding with landslide.

05. Conclusions

InSAR Findings (2014-2022)

- Identified stable and unstable areas on embankment and excavation slopes, capturing the main instability scenarios.

- Similar movement trends comparing with topographic targets
  - with variations in displacement amplitudes

- Integration with Precipitation Data enhances its potential as an Early Warning tool
  - improving understanding of the relationships between displacement, rainfall, and landslide.

05. Conclusions

ADVANTAGES

- **Wide Coverage**: Capable of covering extensive areas to diagnose infrastructure and identify the most vulnerable areas.
- **Back Analysis Capability:** Facilitates retrospective analysis of past events.
- **Preventative Asset Management:** Helps reduce intervention costs, contributing to decarbonization, sustainability, and resilience.
- **Safety:** Minimizes risks during data collection campaigns, reducing technician exposure to hazards.

DISADVANTAGES

- **Data Accuracy:** Accuracy levels are not as high compared to topographic targets because the values are relative to an area. When measuring an area, the values obtained may be distorted due to the existence of other elements (vegetation, other structures, etc.)

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THANK YOU

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