

living planet symposium

BONN
23–27 May
2022

TAKING THE PULSE
OF OUR PLANET FROM SPACE



EO4Infrastructure : Validation activities over FRENCH AOI



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EO4INFRASTRUCTURE PROJECT

1

EO4INFRASTRUCTURE

The EO4Infrastructure project is focused on railways.

- ❖ The objective of the project is to demonstrate that the Copernicus Services combined with other EO derived products and in-situ data can assess the relevance, the utility, and the value of the usability of this method as a survey tool over the railway network.
- ❖ The project team is composed by EO services providers and End Users. The areas of investigation cover three European countries : France, Italy and Germany.
 - EO services providers : TRE Altamira (for France), e-GEOS (for Italy) and GAF (for Germany).
 - End-Users partners : SNCF RESEAU, RFI, DB NETZE



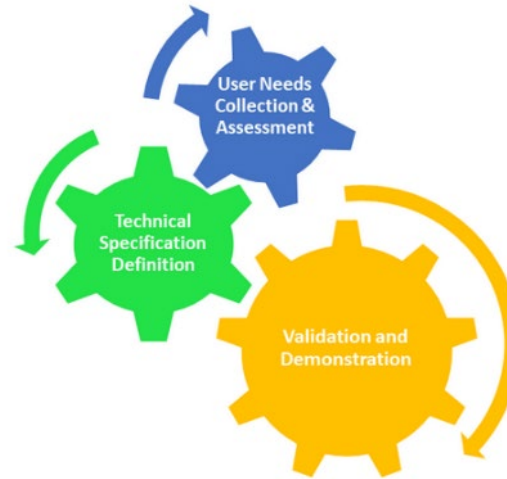
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EO4INFRASTRUCTURE

3 workpackages

- ❖ User needs collection and assessment
- ❖ Technical specifications definition
- ❖ Validation and Demonstration

→ End of the validation process June 2022

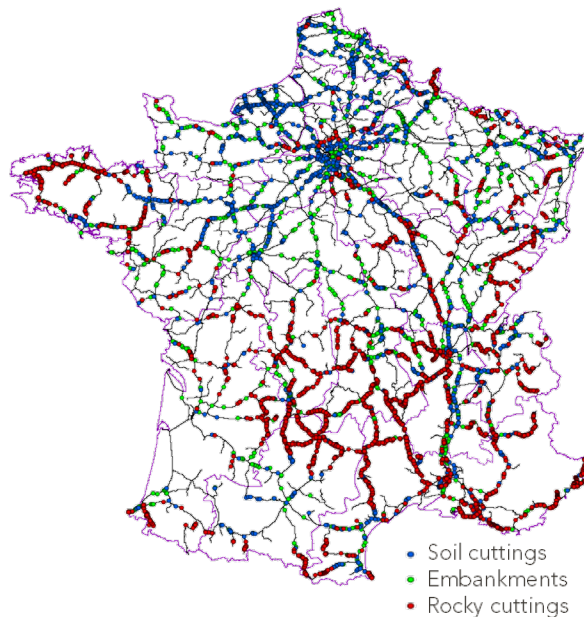
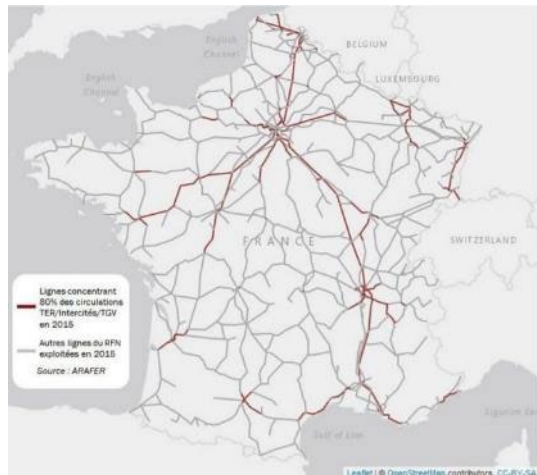


NATURAL HAZARD MANAGEMENT

A satellite view of Earth at night, showing the curvature of the planet and the glow of city lights across the continents. The text "NATURAL HAZARD MANAGEMENT" is overlaid in white, and a large, semi-transparent number "2" is in the bottom left corner.

2

SNCF RESEAU NETWORK

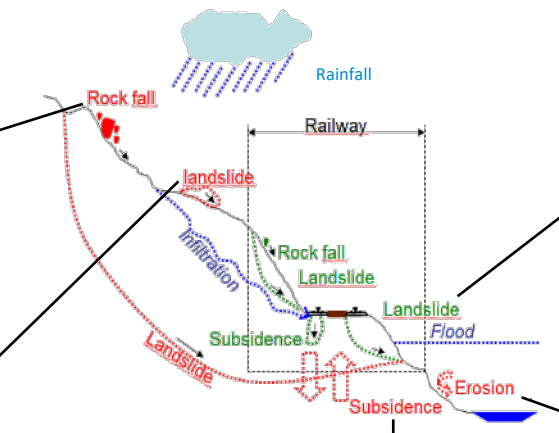


~ 30 000 km of lines (including 2600 km of high speed lines)

~ 100 000 earthworks :

- 6782 controlled earthworks (that can be affected by critical event = train traffic safety)
- ~3420 km

THE MAIN NATURAL HAZARDS



Over 300 critical events / year are classified in four categories regarding their consequences on train regularity and safety

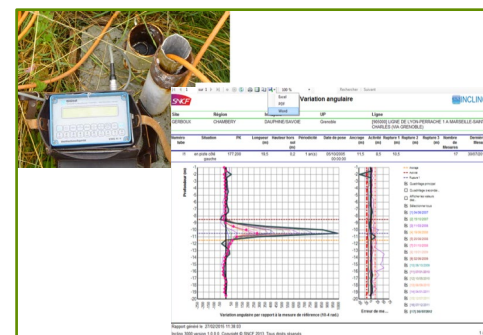
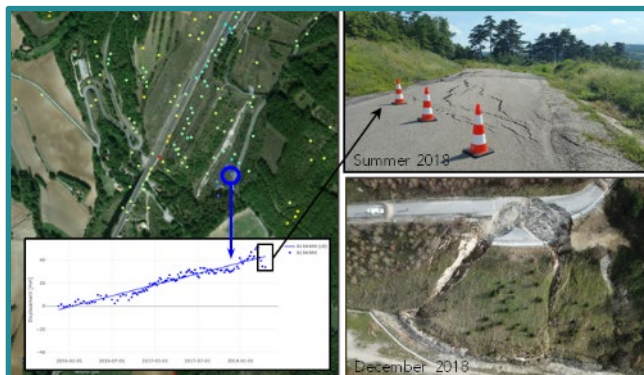
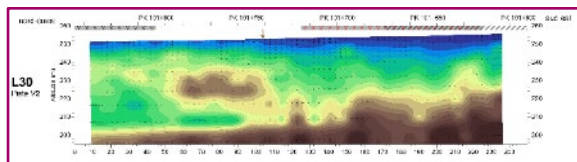
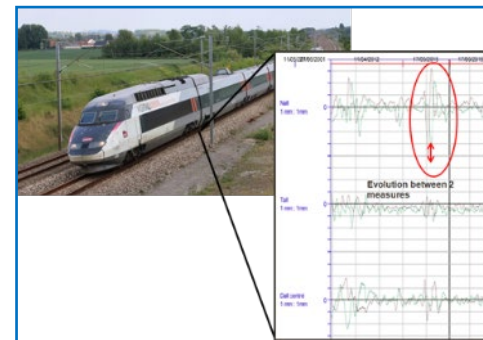
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REGULAR INSPECTIONS



- + Foot patrol (each 2 months to 6 years for expertises – visual inspection)
- + Track geometry automated inspection (every 2 weeks on HSL and every 8 weeks on classical lines)
- + Periodic Topographic Survey on some controlled earthworks
- + Inclinometric monitoring
- + Geophysical monitoring
- + Medium and High resolution InSAR monitoring



CURRENT MONITORING



SNCF R has to be aware of land coverage change in the environment of the lines that may cause an increase of runoffs and erosions which can generate serious damage on the earthworks.

Current Monitoring :

- + Foot patrol for visual inspection :
Big changes such as a construction or an excavation are notified. But the land use changes which are not visible from the platform cannot be identified.
- + Helicopter inspection :
The HSL (and some critical lines) are inspected with an expert once a year by helicopter.
- + On-going Investigation project based on earth-observation :
Collaboration with CNES based on SENTINEL 2 and PLEIADES images + agriculture data base + construction data base.



END-USER NEEDS

A satellite view of Earth at night, showing the curvature of the planet and the glow of city lights across the continents. The lights are concentrated in major urban centers and along coastlines, creating a pattern of yellow and orange spots against the dark blue and black of the night sky and oceans. The horizon is visible at the top of the frame, with a thin layer of atmosphere.

2

NEED

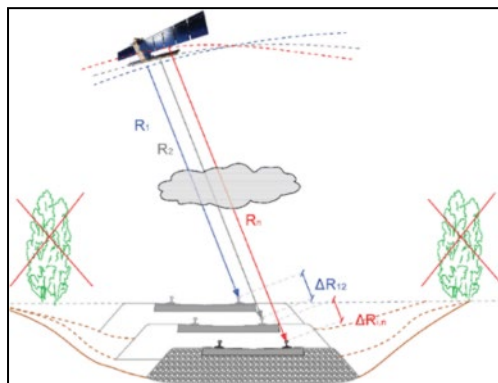


InSAR is a fruitful complement to earthworks surveillance, allowing predictive maintenance and :

- Large scale ground motion monitoring
- Historical deformation study

InSAR data interest for SNCF Réseau :

- Global coverage of the French railway network
- Large scale monitoring (regional deformation surrounding the railway)
- High measurement frequency (every 6 to 12 days) → Good time series



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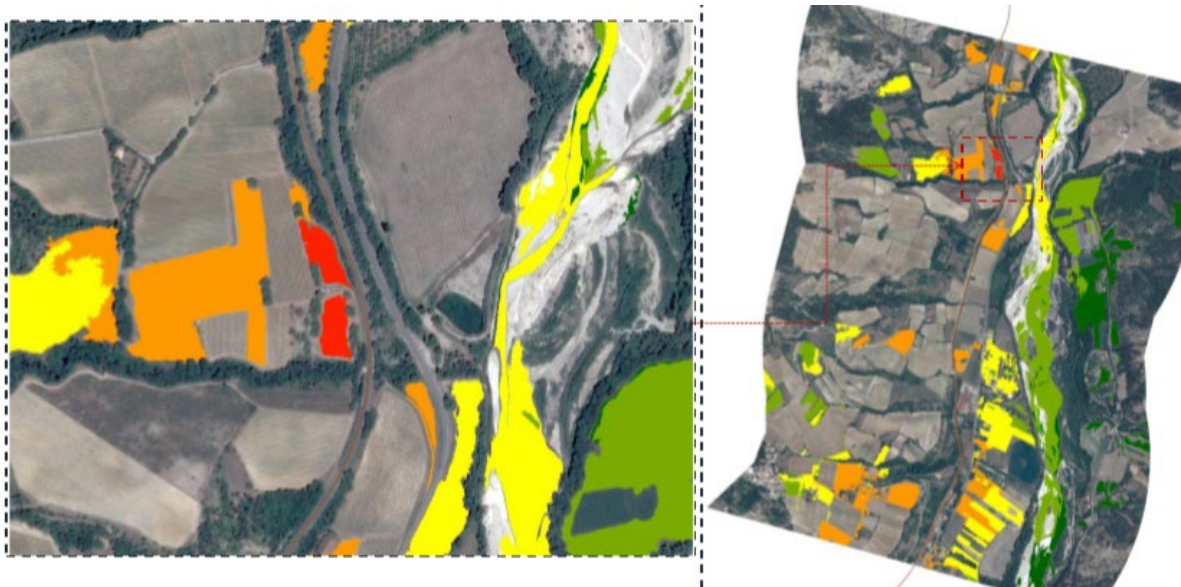
NEED



Understand how the land use changes have an impact on hazards such as flood, mudflow and landslide.

Data interest for SNCF Réseau :

- Automatic detection of land use change close to the tracks
- Improved the OSO database with seasonal time laps (to identify farming change)



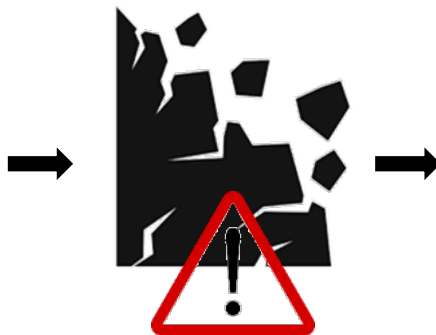
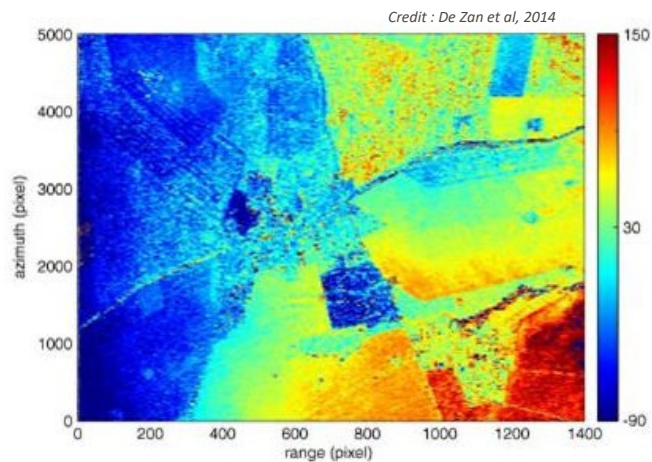
NEED



Monitor the Soil moisture content on critical earthworks (especially during long rainy period) → be able to predict landslides.

Data interests for SNCF Réseau :

- Soil moisture content with a higher resolution than 1 km.



INPUT DATA FOR THE PROJECT

A satellite view of Earth at night, showing the curvature of the planet and the glow of city lights across the continents. The lights are concentrated in major urban centers and along coastlines, creating a pattern of yellow and orange spots against the dark blue and black of the night sky and oceans.

3

AREA OF INTEREST : EAST OF FRANCE

~ 300 km x 100 km

- + It includes railway lines of different categories: High Speed Lines, classic line...
- + It contains railway assets affected by motion of different types (subsidence, landslides..) and classified as sensitive (SNCF definition).
- + Some areas are under in-situ monitoring performed by ATT Division (internal control)

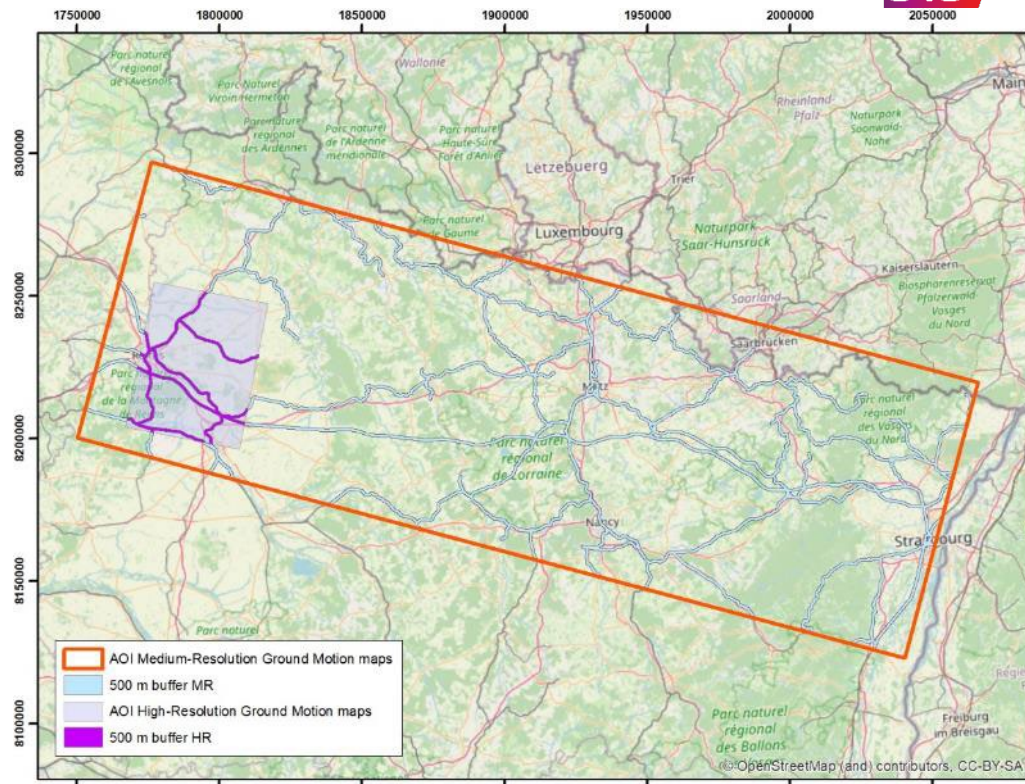
EO PRODUCTS DISTRIBUTED OVER 2 AREAS

Red AOI (all railway tracks)

- + Ground motion map: InSAR MR analysis

Purple AOI (all railway tracks)

- + Ground motion map: InSAR HR analysis
- + Land cover change detection
- + Soil moisture content



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SQUEESAR® SOLUTION (MEDIUM-RESOLUTION)

Ground motion map with InSAR medium-resolution analysis (East of France)

Sentinel-1 data

< 1000 images (4 Tracks) from 2016.06 to 2021.06

Temporal resolution: 6 days

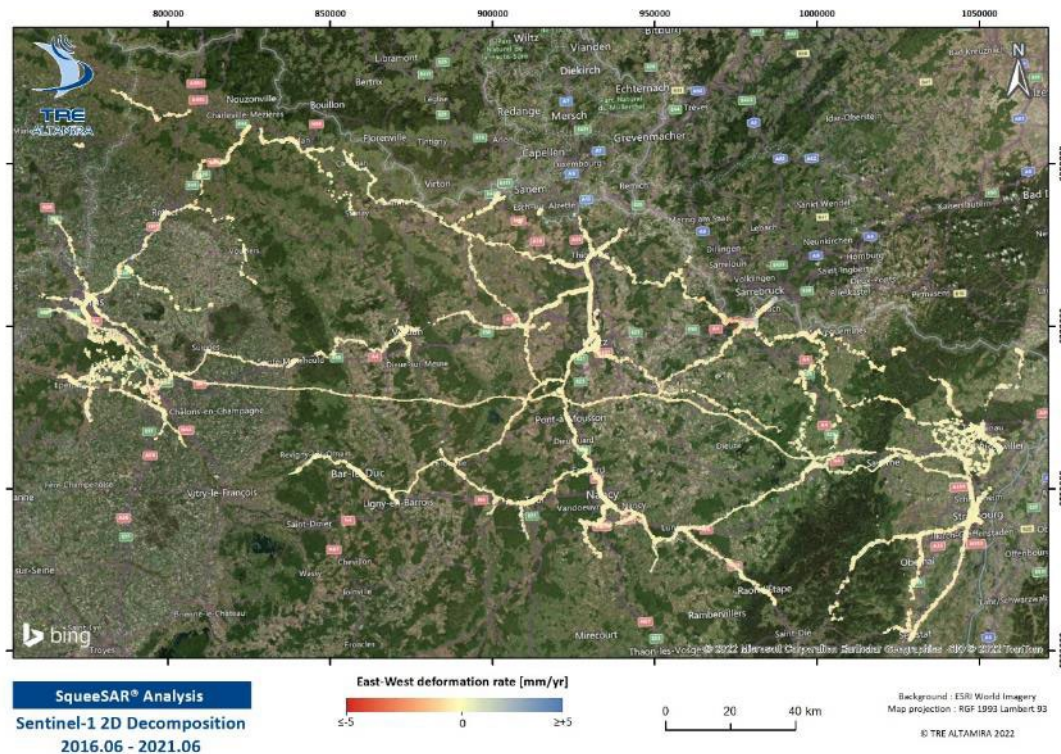
Spatial resolution: 20 m x 5 m

Suited for regional-scale analysis and large ground motion movement

2D decomposition

Vertical component

East-West component



SQUEESAR® SOLUTION (HIGH-RESOLUTION)

Ground motion map with InSAR high-resolution analysis (Reims)

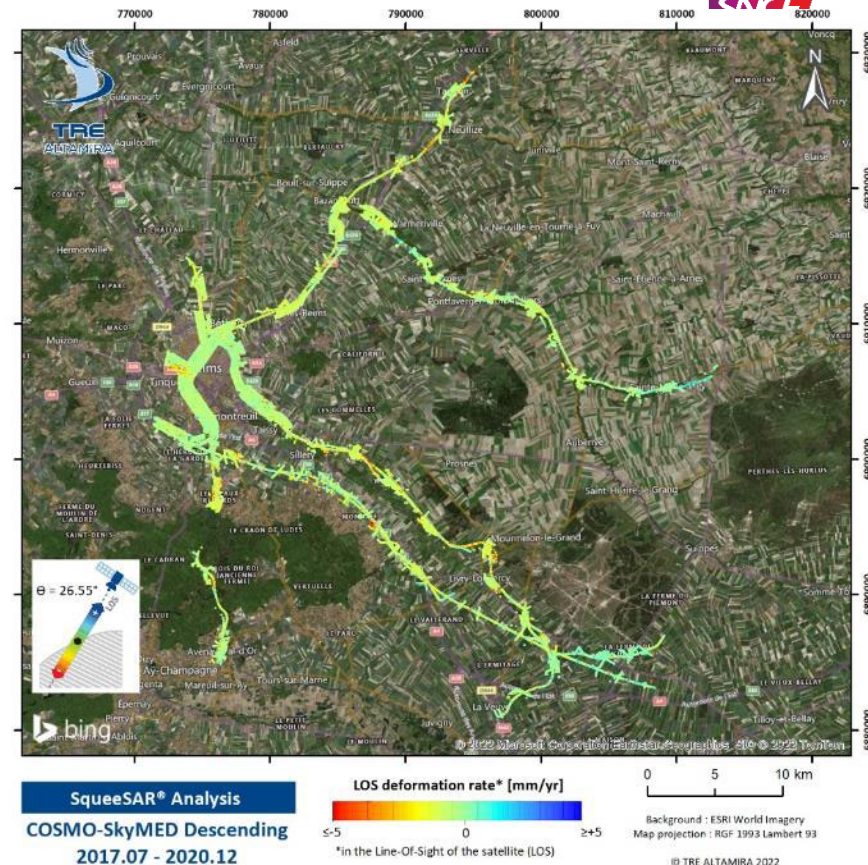
COSMO-SkyMED data

51 images (desc. geometry) from 2017.07 to 2020.12

Temporal resolution: 16 days

Spatial resolution: 3 m x 3 m

Suited for city-scale and earthwork analysis

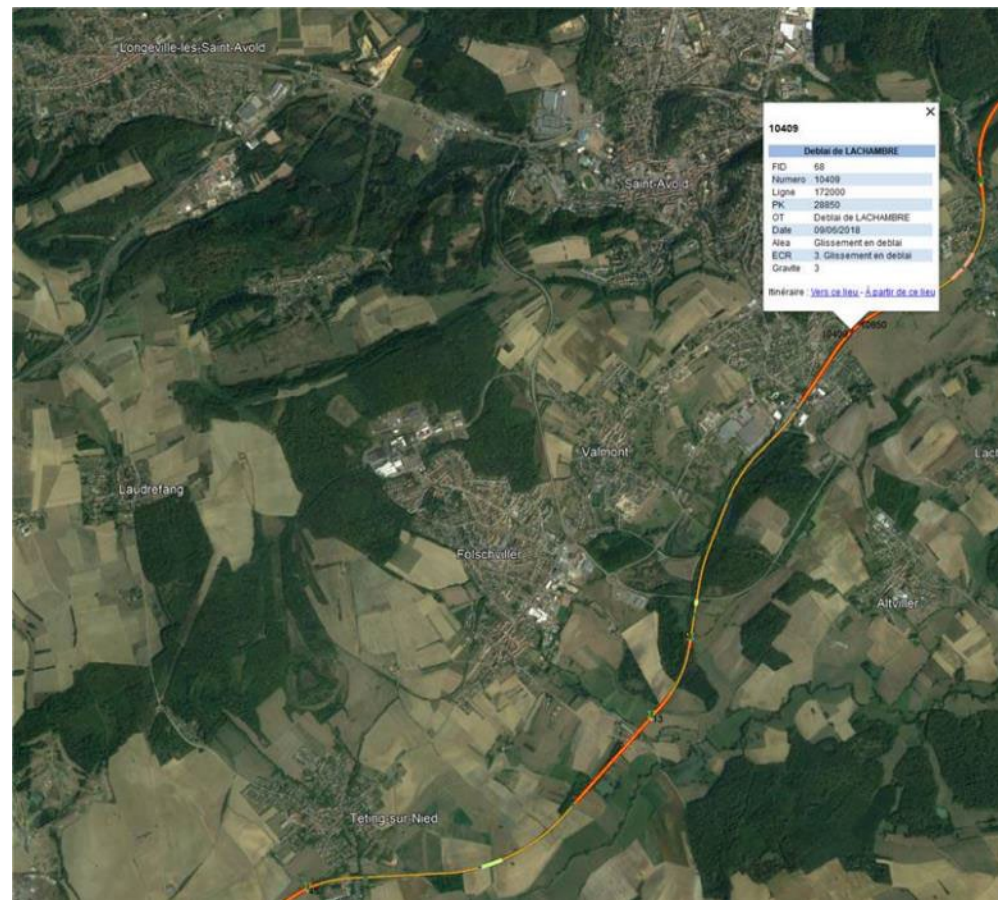


SNCF RESEAU INPUT DATA

- ❖ Past critical events
 - Earthwork critical event database over the entire railroad network from 2016 to 2021 - between Reims and Strasbourg 34 earthworks critical events

- ❖ Database of sensitive structures with different levels of risk
 - 329 sensitive earthworks are identified on the studied area

- ❖ In-situ measurements (topographic and inclinometric survey).
 - 7 instrumented earthworks



LAND COVER CHANGE DETECTION 2016-2021

Satellite data used

Sentinel-2 optical data

Temporal resolution: 6 days

Spatial resolution: 10 m x 10 m

Land cover map for each millisecond between 2016 and 2021

Pixel based change detection for the period 2016-2021



Land cover change (stripped red)

Over VHR imagery (Google)

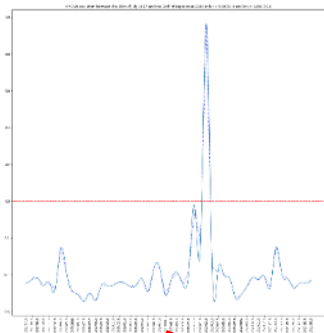
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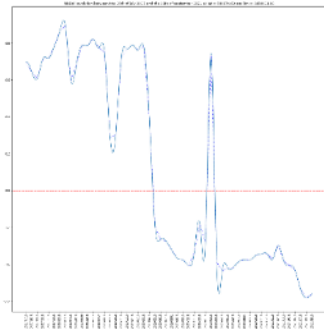
WATER INDEX (MNDWI) EVOLUTION FROM 2016 TO 2021

Based on Sentinel-2 time series from 2016 to 2021

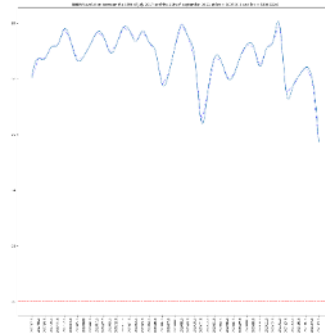
Flood event (beg. 2020)



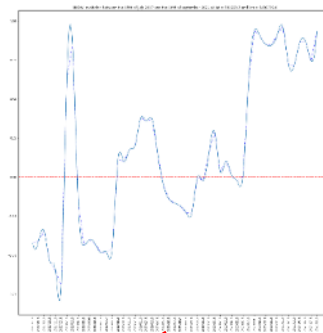
Loss of water



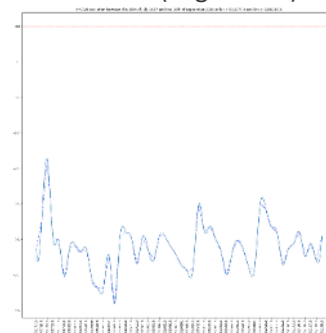
water



Gain of water



No water (vegetation)



Water occurrence map (blue shade)
Over VHR imagery (Google)



VALIDATION PHASE

3



MEDIUM-RESOLUTION / HIGH-RESOLUTION

Spatial resolution

Pixel size: C-band: 20 m x 5 m X-band: 3 m x 3 m

Density: 1202 MP/km² 2113 MP/km²

Atmospheric correction

Higher spatial density -> better atmospheric correction

Displacement accuracy

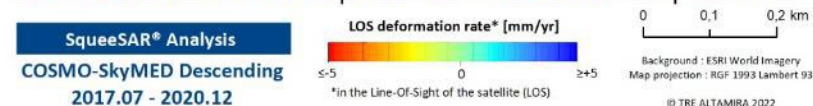
Phase variance proportional to the acquisition wavelength

Wavelength: $\lambda_{\text{C-band}}$: 5.66 cm $\lambda_{\text{X-band}}$: 3.55 cm

Comprehension of the results

LOS angle: $\theta_{\text{C-band}}$: ~41° $\theta_{\text{X-band}}$: ~27°

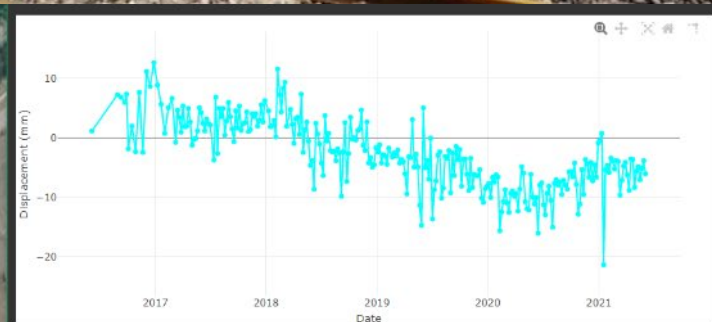
Easier comparison with levelling when the LOS angle is smaller



CRITICAL EVENTS– VALIDATION PHASE

❖ Example of a critical event EW 1

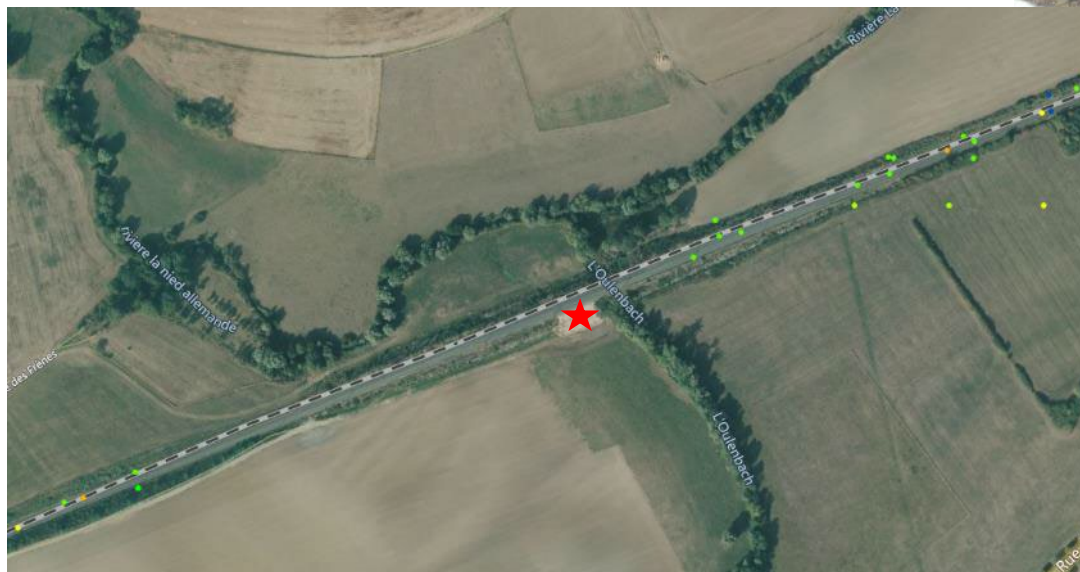
- Landslide 2018-06-09



Name	Area	Direction	Sensor	From	To
E04INFRA_GDM_S1_T139_D_2_ES2502C4S	REIMS_STRASBOURG	DESC	S1	2016-06-05	2021-06-04

CRITICAL EVENTS– VALIDATION PHASE

- ❖ Example of a critical event EW 2
 - Landslide 2020-02-12



On the area of interest

Critical events → 11 out of 34 validated

No data

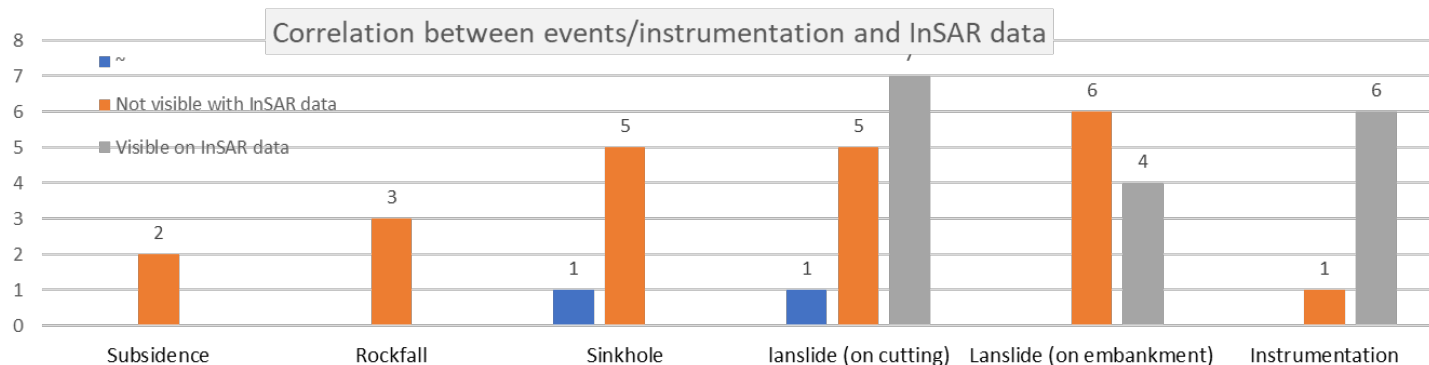
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CRITICAL ANALYSIS OVER THE VALIDATION PASE FOR INSAR DATA

❖ The 11 critical events that have been detected by InSAR correspond to landslide events.

For the 23 events that have not been detected, the reasons are:

- Lack of PS in the area
 - Thick vegetation
 - Other hazards (sinkhole, rockfal, too small spatial wavelength subsidence)
 - Critical events happening in 2016
- ❖ Small wavelength phenomén are not detected by InSAR technique because of the spatial resolution of Sentinel-1 sensor (i.e. sinkhole over the railway track).
- ❖ Surface displacements from InSAR technique are not sensitive enough for events monitored by in-situ surveys (levelling).



CRITICAL ANALYSIS OVER THE VALIDATION PHASE FOR SOIL MOISTURE AND LAND COVERAGE MAPS

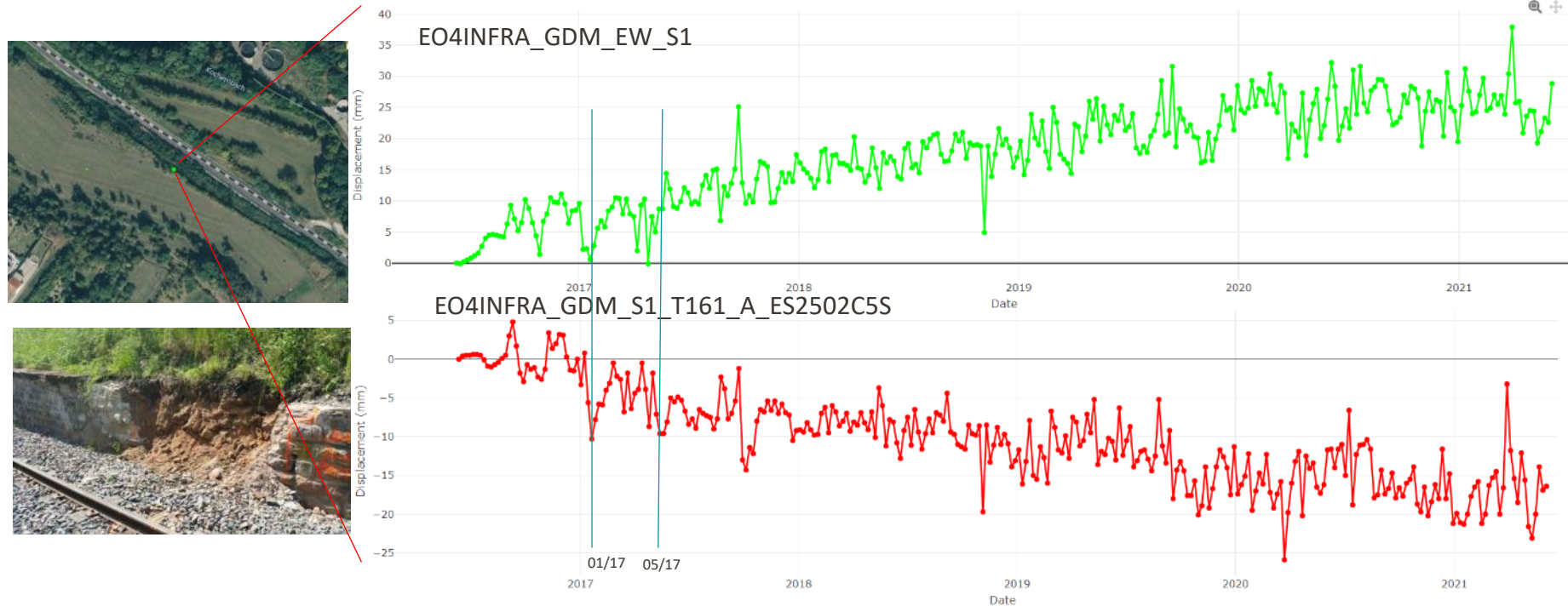
- ❖ Land coverage changes identified on past critical events
 - 6 critical events with hazards such as sinkhole, flood and scourf
- ❖ Map of soil moisture index (NDWI) over the city of Reims (France) in TIF format
 - Validation over the index over lakes and rivers
 - The platform was not able to show the time series

PERSPECTIVES

A satellite view of Earth at night, showing the curvature of the planet and the glow of city lights across the continents. The image is dark blue with yellow and white lights representing urban areas. A large, semi-transparent number '3' is overlaid in the bottom left corner.

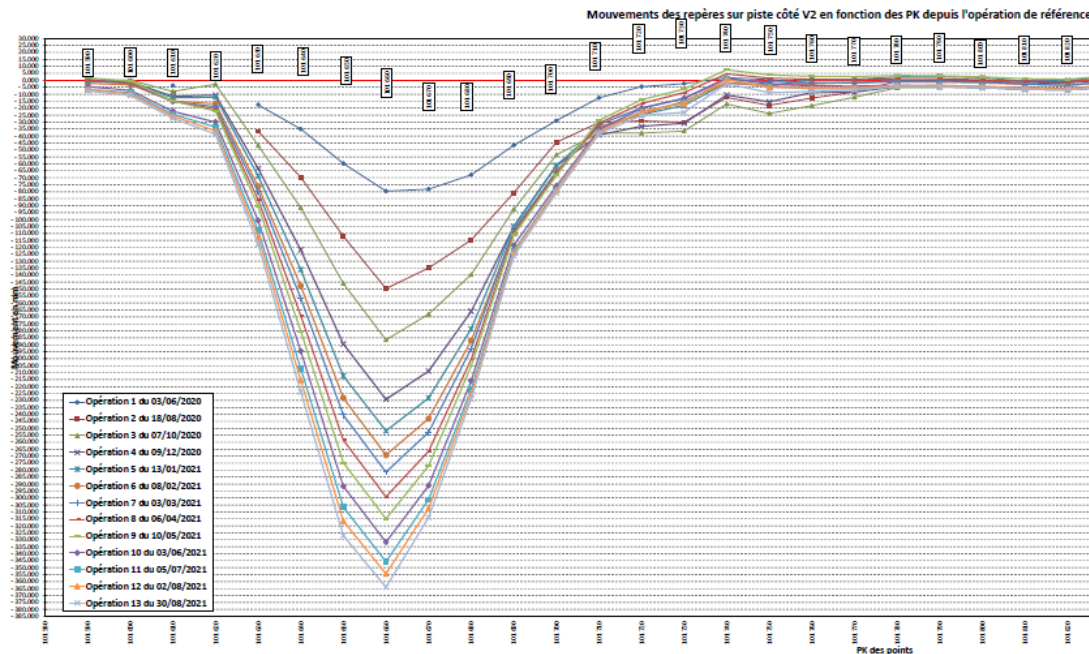
3

GROUND MOTION EXAMPLE “EW N°4” LANDSLIDE 31/05/2017



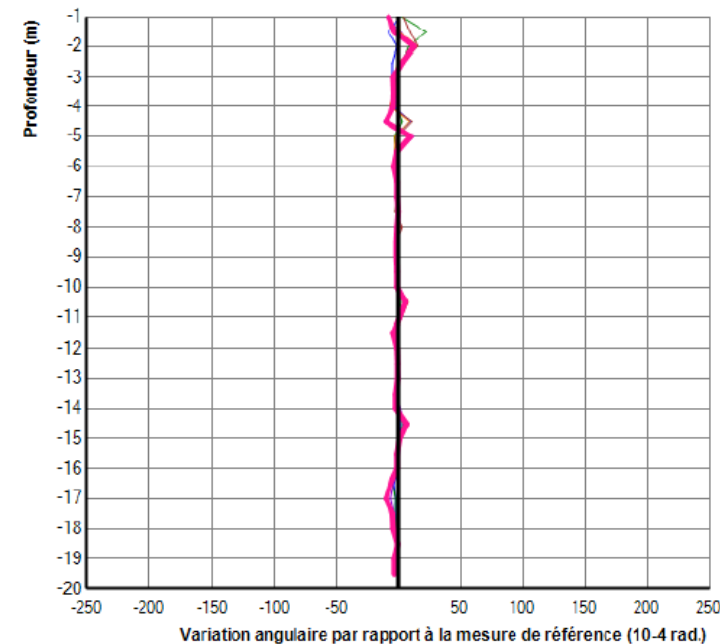
GROUND MOTION EXAMPLE “EW N°4”

❖ Topographic survey



Survey from 06/20 to 08/21 – mouvement detected 2.3 cm/month

▪ Inclinometric survey



New survey 2018 – no rupture detected



PERSPECTIVES

- ❖ New topographic instrumentation on ground movement to correlate InSAR data + topographic data (SNCF R. ATT and IGN) → from LOS, EW and Z component to **3D movement**.



- ❖ Flood : use rainfall warning tool to correlate past earthwork alert with water index time series

- ❖ Land change : correlate past landslide with land change use map





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THANK YOU

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