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EU SPACE WEEK 2023

7 - 9 November - Sevilla, Spain

EU Space Programme Copernicus for Rail

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2023-11-07



European
Commission



Agenda – Copernicus for Rail

- Rail network infrastructure management needs
- Introduction to Copernicus
- Sentinel 1 and 2 - radar and optical satellites
- Copernicus services:
 - Land Monitoring service including European ground motion service
 - Emergency Management service
 - Climate Change Service
- Examples from private EO service providers
- Data access
- Future of Copernicus



Earth observation for Rail network infrastructure – a diverse set of needs



Infrastructure Planning

- Monitor surface ground motion
- Monitor soil moisture
- Assess weather and climate risk
- Terrain models, land use/cover

Reconstruction, decommissioning

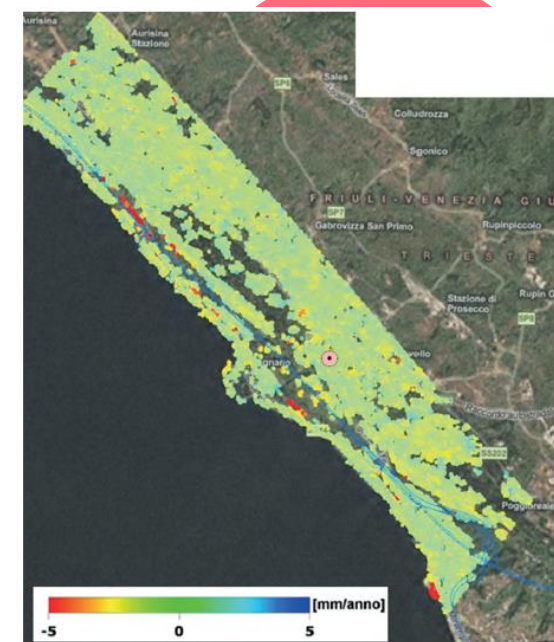
- Assessing weather impact and climate risk

Infrastructure Construction

- Geotechnical and structural monitoring during construction
- Monitor construction progress

Infrastructure maintenance

- Monitor ground motion
- Vegetation monitoring
- Flood monitoring
- Land use/cover change



Pre-planning investigation from Monfalcone to Trieste (Italy). Attribution: SatSense.



EU's Earth observation programme Copernicus



SPACE

sentinel-6
sentinel-1
sentinel-5
Copernicus
Europe's eyes on Earth
sentinel-2
sentinel-5p
sentinel-4
sentinel-3

IN SITU

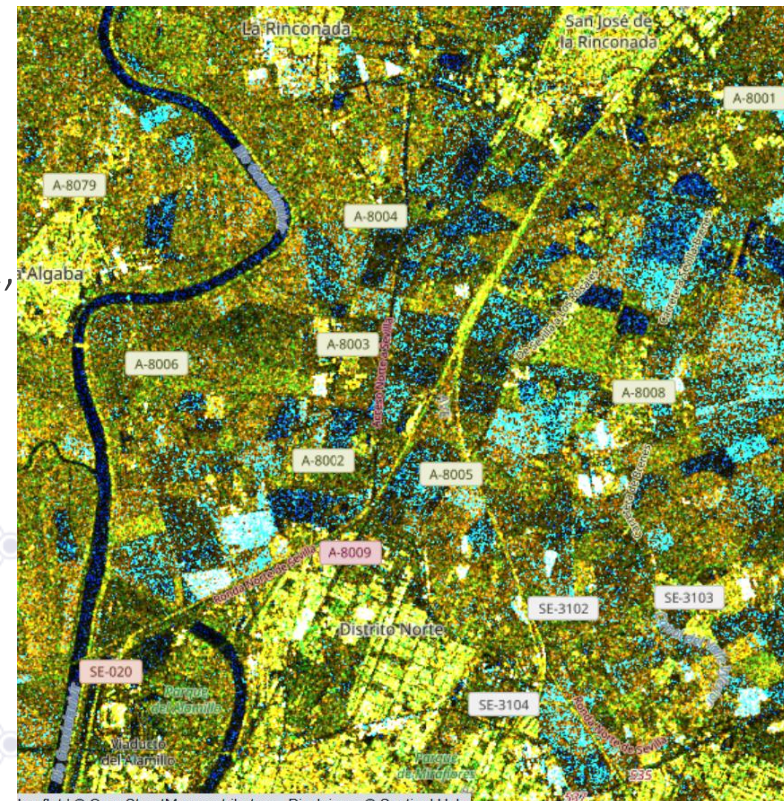
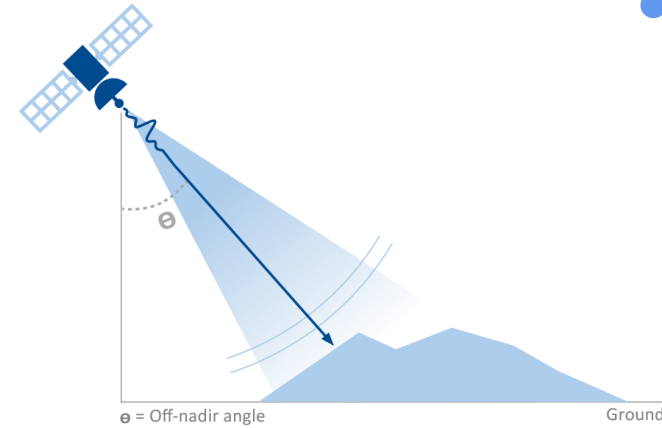
In Situ

SERVICES

Atmosphere Monitoring
Copernicus Marine Service
Land Monitoring
Climate Change
Security
Emergency Management

Copernicus Sentinel 1 radar

- Synthetic Aperture Radar (SAR) in C-band
- Several acquisition allow measure reflection phase, polarization.
- Spatial *resolution* 5x20m
- Global, persistent coverage
- Revisit time 6(12) days
- Nominal constellation: 2 satellites, currently operational: 1, one to be launched
- Free and open data since 2014
- Applications:
 - Marine, land monitoring, emergency response.
 - Ground motion analysis



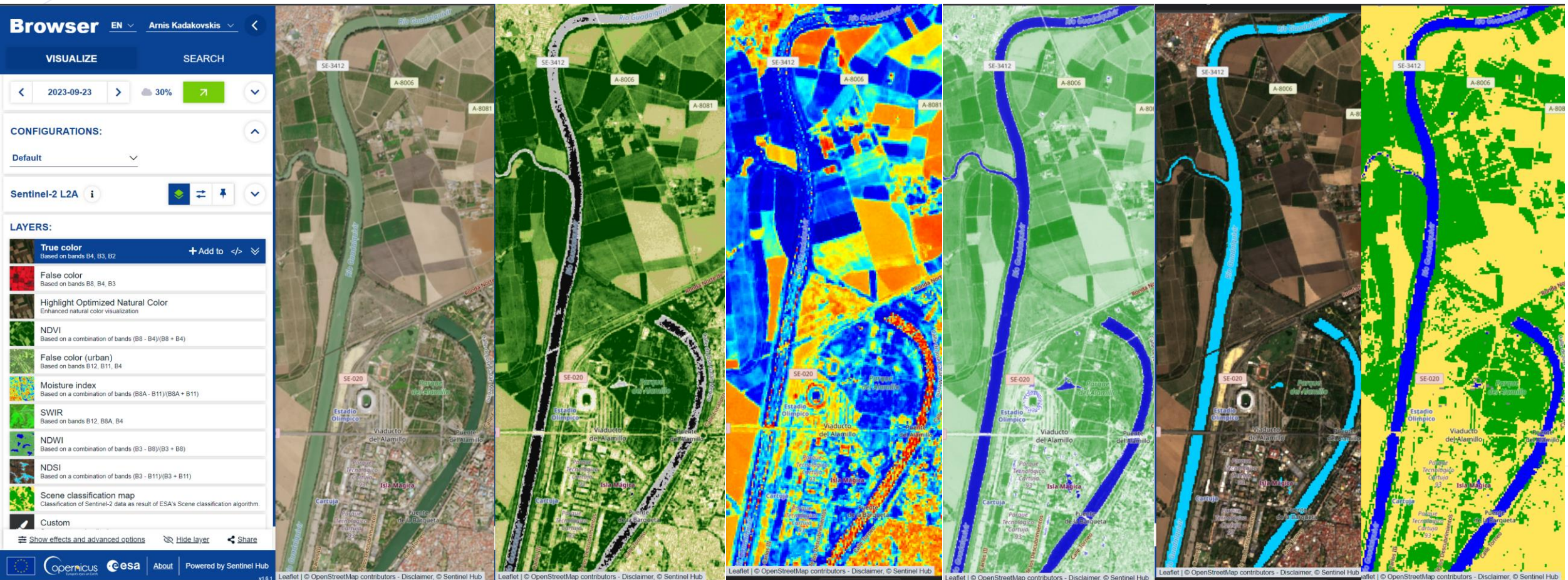
Copernicus Sentinel-2 multispectral imager

10-60m pixel, 13 bands, revisit every 5 days

Spectral and temporal domains contain most of the info at local scales



Dataspace.copernicus.eu



True color

Vegetation

Moisture index

Water index

Snow index

Classification

Copernicus services

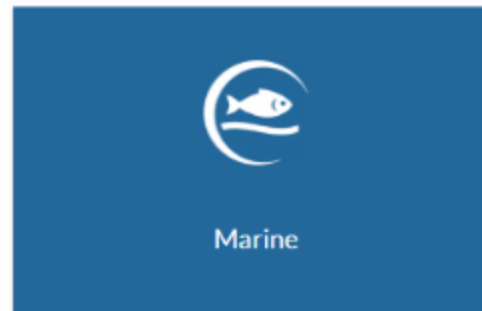
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<https://atmosphere.copernicus.eu/>



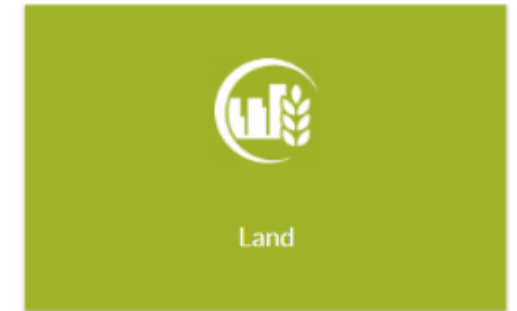
IMPLEMENTED BY
 ECMWF

<https://marine.copernicus.eu/>



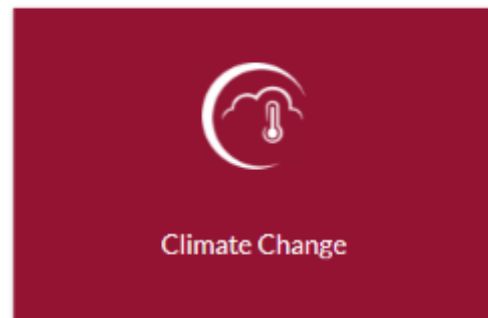
**MERCATOR
OCEAN**
INTERNATIONAL

<https://land.copernicus.eu/en>



**European
Environment
Agency**

<https://climate.copernicus.eu/>



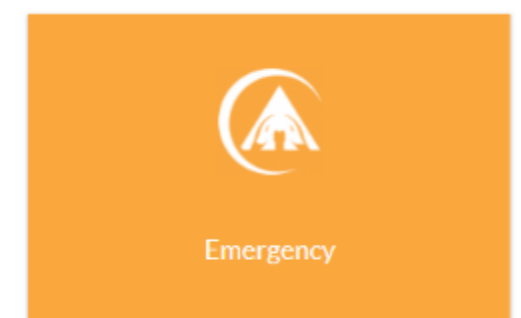
IMPLEMENTED BY
 ECMWF

<https://www.copernicus.eu/en/copernicus-services/security>



SatCen
European Union Satellite Centre **FRONTEX**
EUROPEAN BORDER AND
COAST GUARD AGENCY **EMSA**
European Maritime Safety Agency

<https://emergency.copernicus.eu/>



**Joint Research Centre
JRC**



Land

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Copernicus Land Monitoring Service

- Geographical information on **land cover and its changes, land use, vegetation state, water cycle** and Earth's **surface energy variables** on European and global levels for environmental applications
- **Harmonized** and **consistent** in time and space
- Products and manuals are free and open
- Implemented by JRC and EEA
- Website: <https://land.copernicus.eu/>

Ground motion monitoring

Land cover and land use mapping

Priority area monitoring

Bio-geophysical parameters

Satellite data

Reference and validation data

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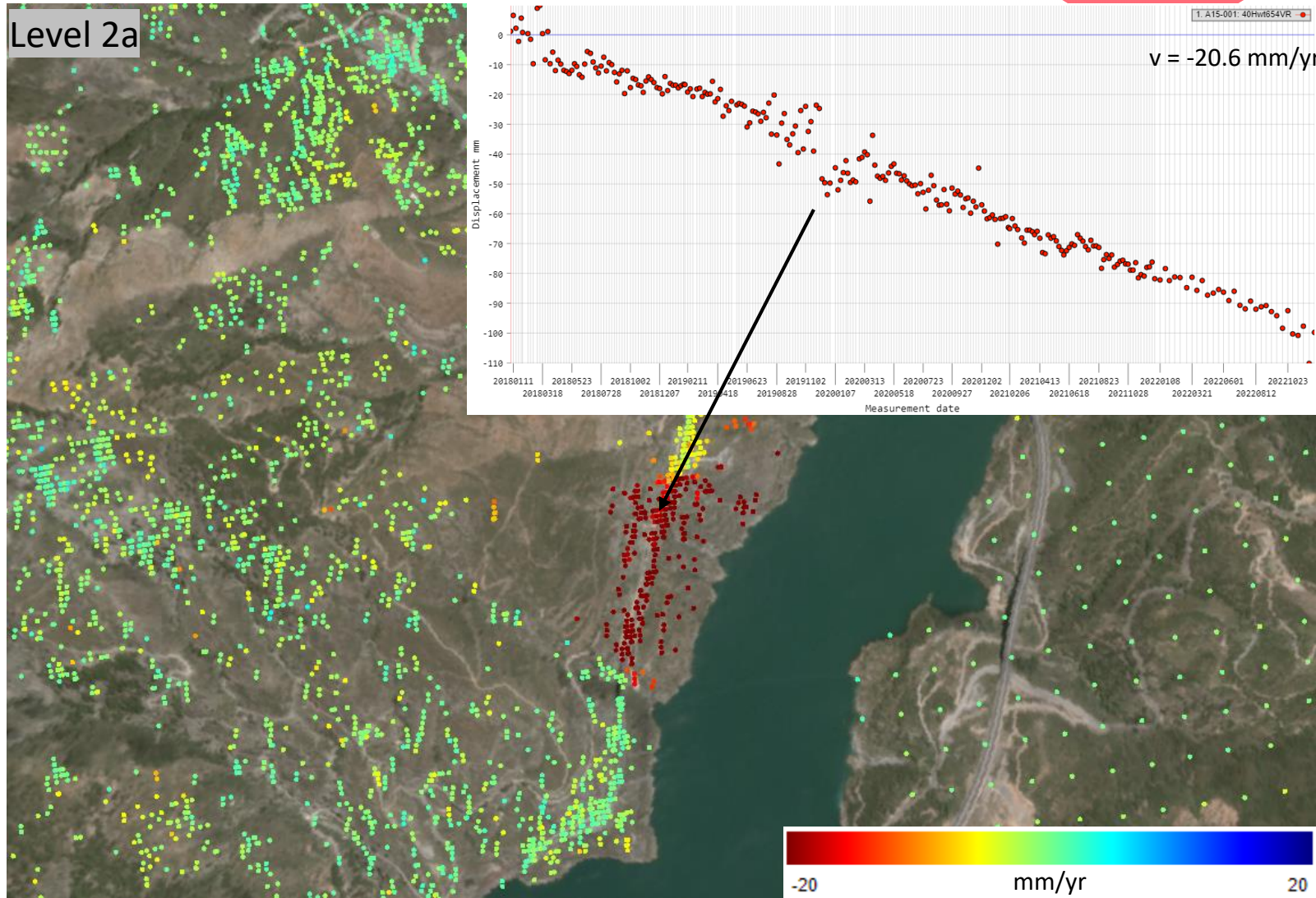
European Ground Motion Service

- Spatial resolution: 5x20/ 100x100 m
- Update frequency: Yearly, with time series
- Most recent reference layer: 2018 – 2022
- Example of applications:
 - Monitoring infrastructure and slope instabilities → asset management and impact assessment

Webinar:

https://land.copernicus.eu/en/products/european-ground-motion-service?tab=user_outreach

Level 2a

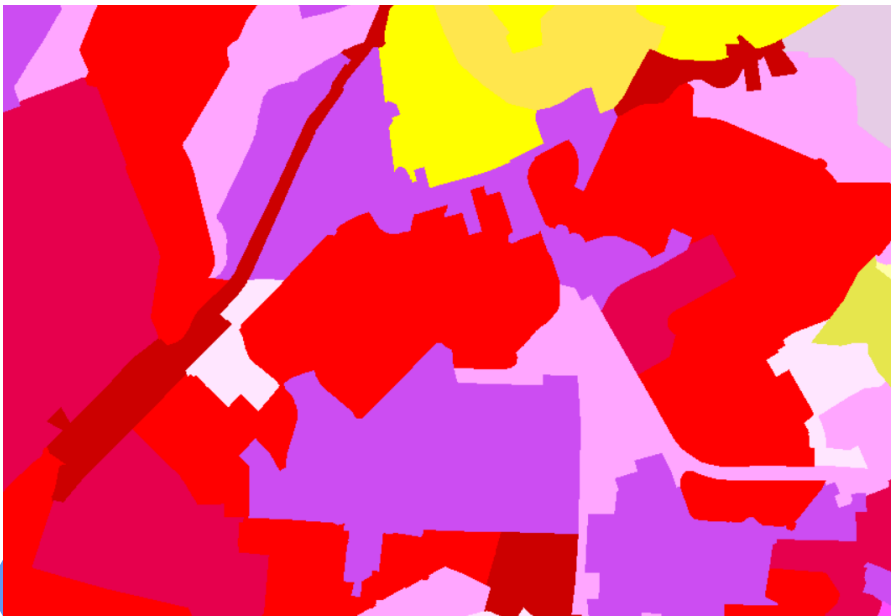




Land

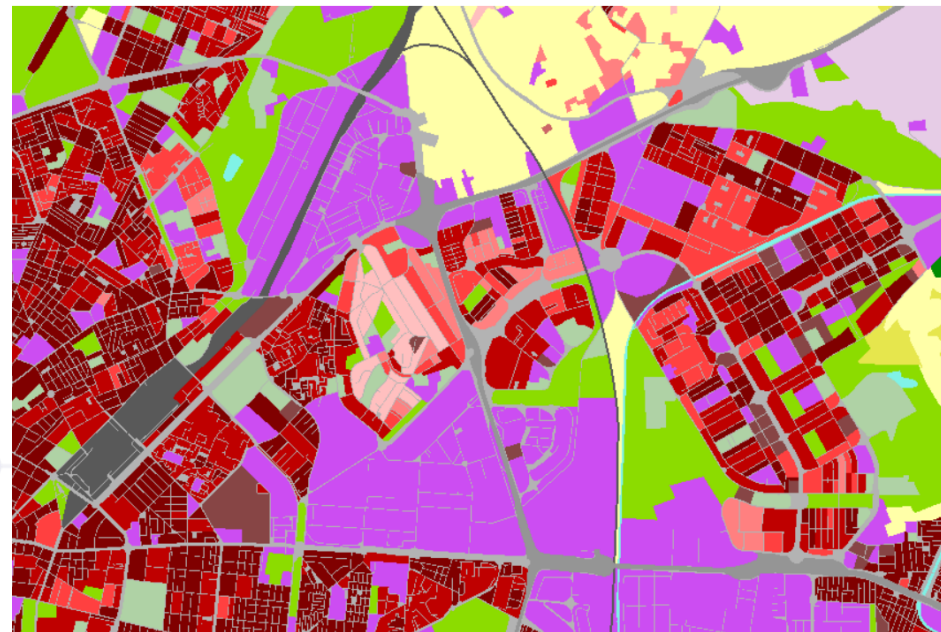
Corine Land Cover

- Spatial resolution: 25/5 ha MMU
- Update frequency: 6 years
- Most recent reference layer: 2018
- Example of application:
 - Planning location of new infrastructure: What kind of land cover, land use?



Urban Atlas

- Spatial resolution: 0,25/1 ha MMU
- Update frequency: 6 years
- Most recent reference layer: 2018
- Examples of applications:
 - Planning location of new infrastructure: What kind of land cover?
 - Monitoring evolution → asset management and impact assessment



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Corine Land Cover+ Backbone

- Spatial resolution: 10 m
- Update frequency: 3 (soon 2) years
- Most recent reference layer: 2018
- Examples of applications:
 - Planning location of new infrastructure: What kind of land cover, land use?
 - Monitoring evolution → asset management and impact assessment



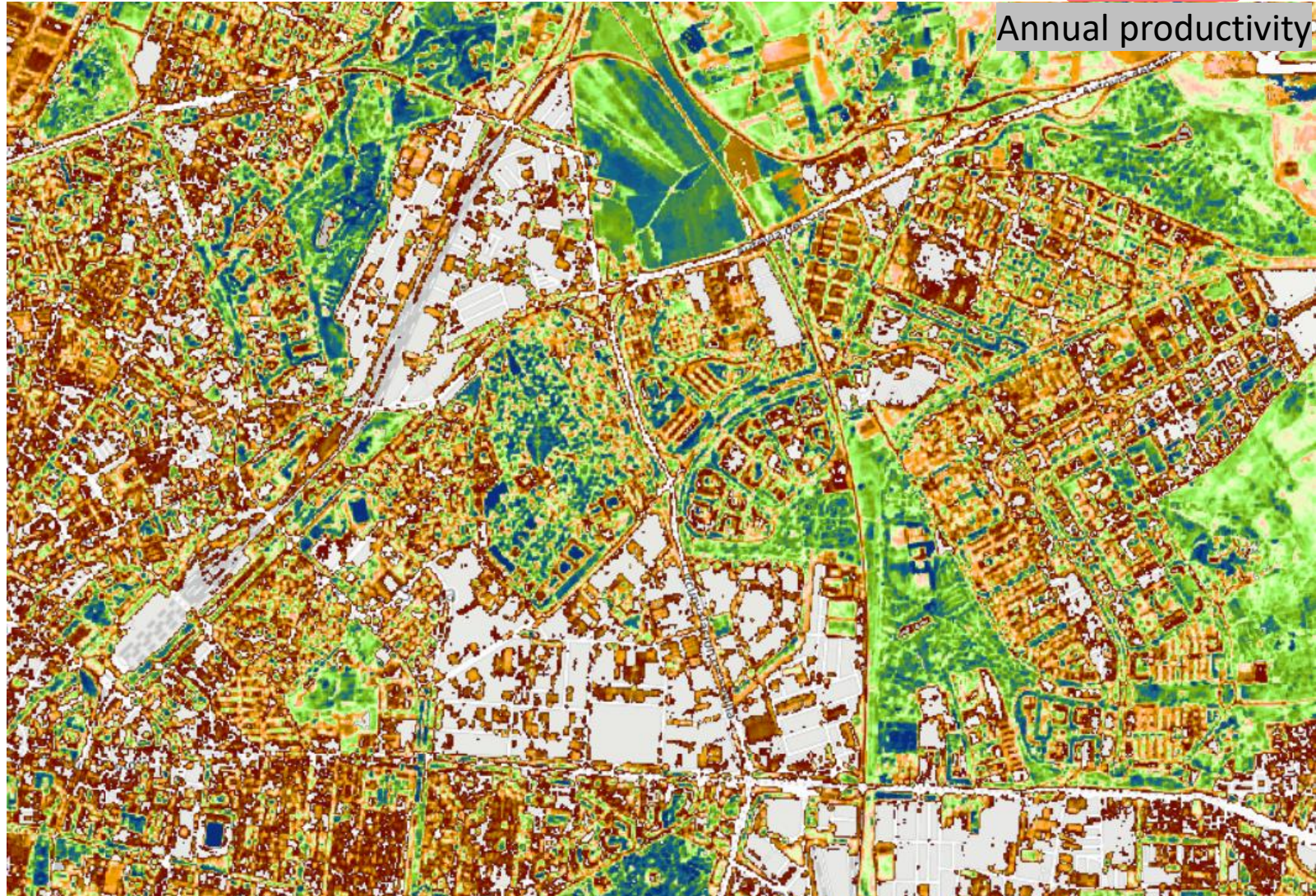


Land

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HR Vegetation Parameters

- Spatial resolution: 10 m
- Update frequency: Daily/10-daily/Yearly
- Most recent reference layer: 2022/2023
- Example of applications:
 - Assessing evolution in vegetation → asset management





Emergency

Copernicus Emergency Management System

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RAPID MAPPING

- On demand
- Standardised
- Hours-days

REFERENCE MAPS
 DELINEATION MAPS
 GRADING MAPS

VALIDATION



RISK AND RECOVERY MAPPING

- On demand
- Tailored to user needs
- Weeks-months

REFERENCE MAPS
 PRE-DISASTER SITUATION MAPS
 REFERENCE MAPS
 POST-DISASTER SITUATION MAPS

VALIDATION

EARLY WARNING

- Floods: EFAS
- Forest Fires: EFFIS

CONTINUOUS ALERTS



Landslide



Flood



Storm



Volcanic eruption



Technical Accident



Fire



Earthquake



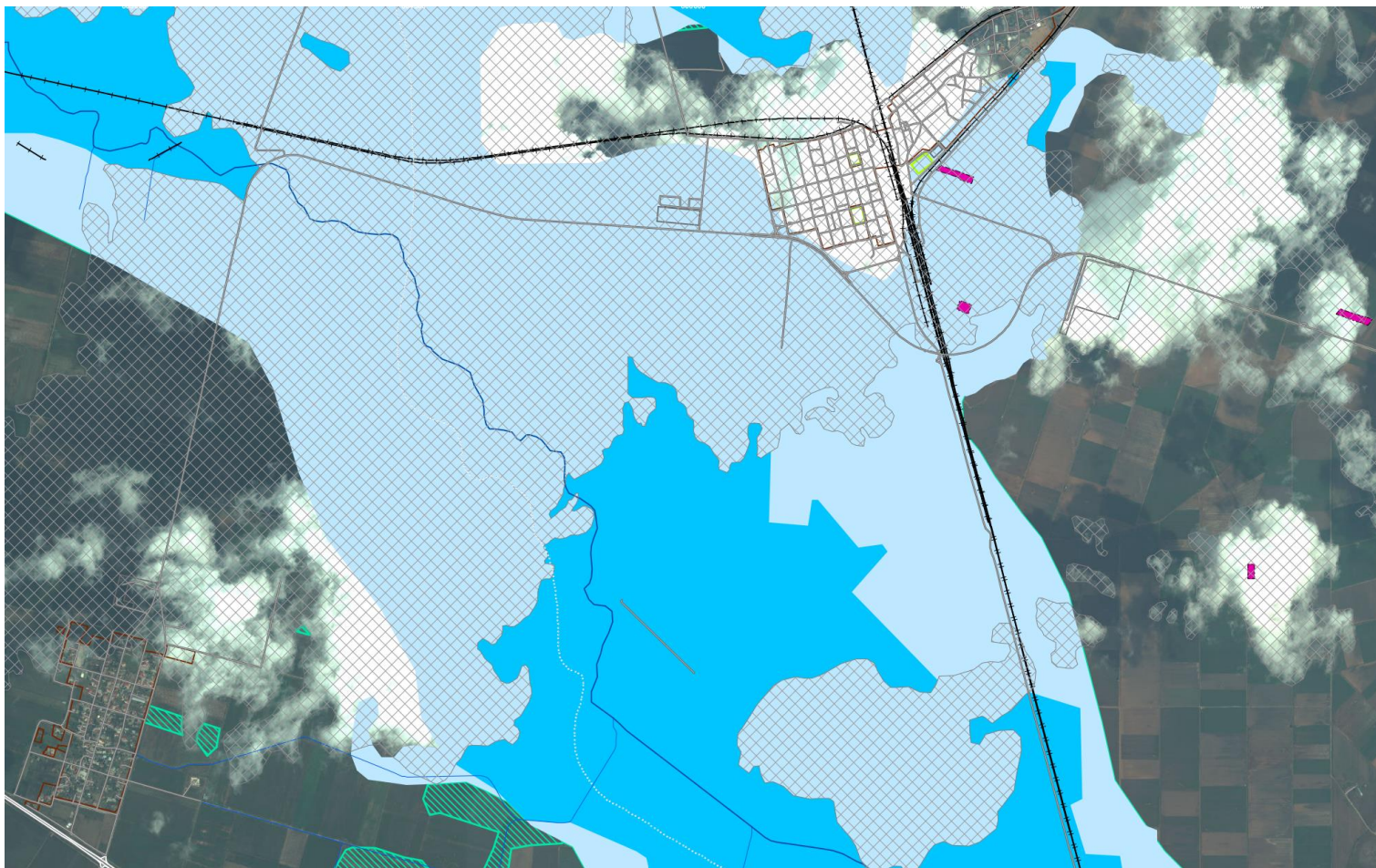
Other



Emergency

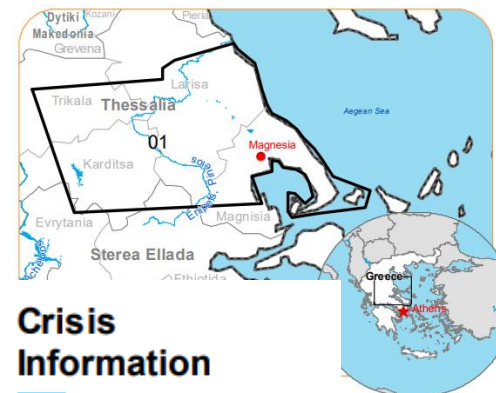
Copernicus Emergency Management system - example, floods in Greece

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EMSR692 - AOI01
Flood in Greece
MAGNESIA

Situation as of 09/09/2023 09:31 UTC
Delineation MONIT03 - Overview map 01



Crisis Information

-  Flooded Area
-  Previous Flooded Area (07/09/2023 16:24 UTC)
-  Flood trace



Climate Change

Road & Rail – Copernicus Climate Data to Support Critical Infrastructure

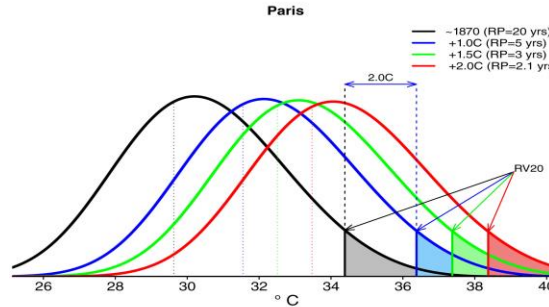


‘Building and infrastructure are designed using **standards that rely on historical climate information**. The underlying assumption that ‘climate is a stationary thing is not valid.’

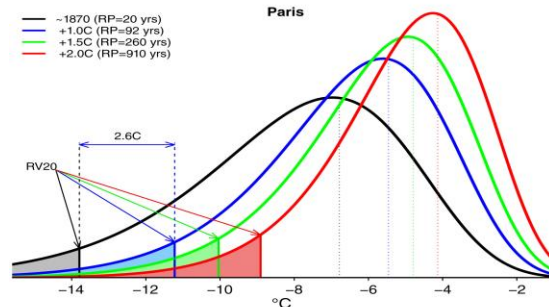
C3S developed demonstrators, based on Climate Data in the Climate Data Store and **user requirements**, to help introduce **climate information** to support infrastructure design

1. Extreme values – 1975 – 2100
2. Design years – 1975 – 2100

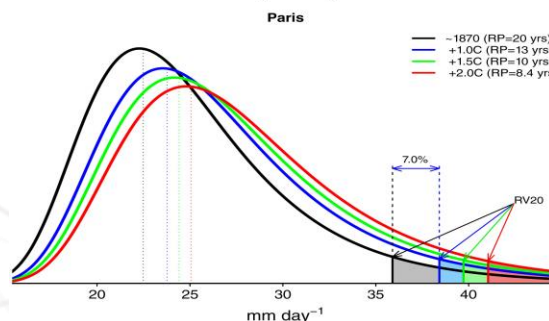
Median PDFs of warm extremes



Median PDFs of cold extremes



Median PDFs of precipitation extremes



Earth's Future, Volume: 6, Issue: 5, Pages: 704-715, First published: 20 April 2018,

Prototype catalogue entry in the Climate Data Store – Data used to support the infrastructure sector in C3S demonstrator activities

Statistic ?

At least one selection must be made

Extreme value

1 in 5 year 1 in 10 year

1 in 100 year

Percentile

Days above/below threshold

Other

Generalized Pareto distribution parameter

Experiment ?

At least one selection must be made

Design summer year Design summer

Design year average case - time Maximum design

Minimum design year case Minimum design

Experiment ?

Reanalysis Historical

Model ?


At least one selection must be made

HadGEM2-CC (UK Met Office, UK) ACCESS1-0 (BoM)

CNRM-CM5 (Météo-France) CSIRO-Mk3.5r (CSIRO)

A red circular logo with the text "EU SPACE WEEK" in a stylized font, underlined, and "2023" below it. A small blue dot is positioned to the left of the circle.

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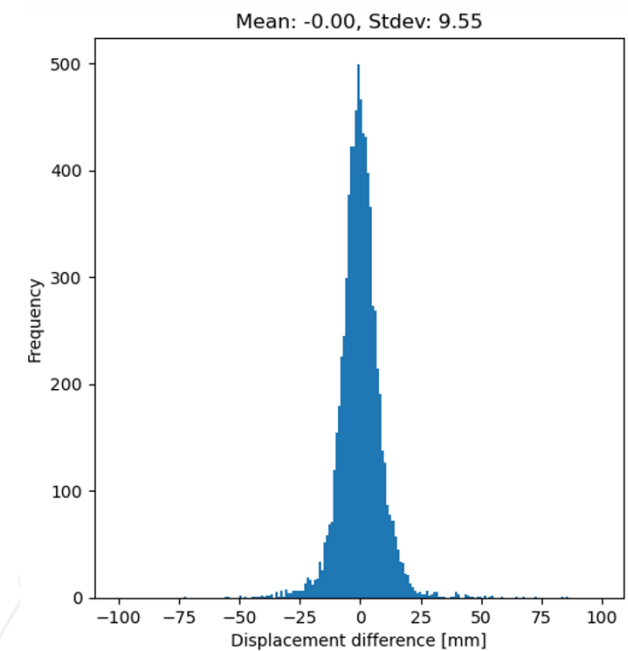
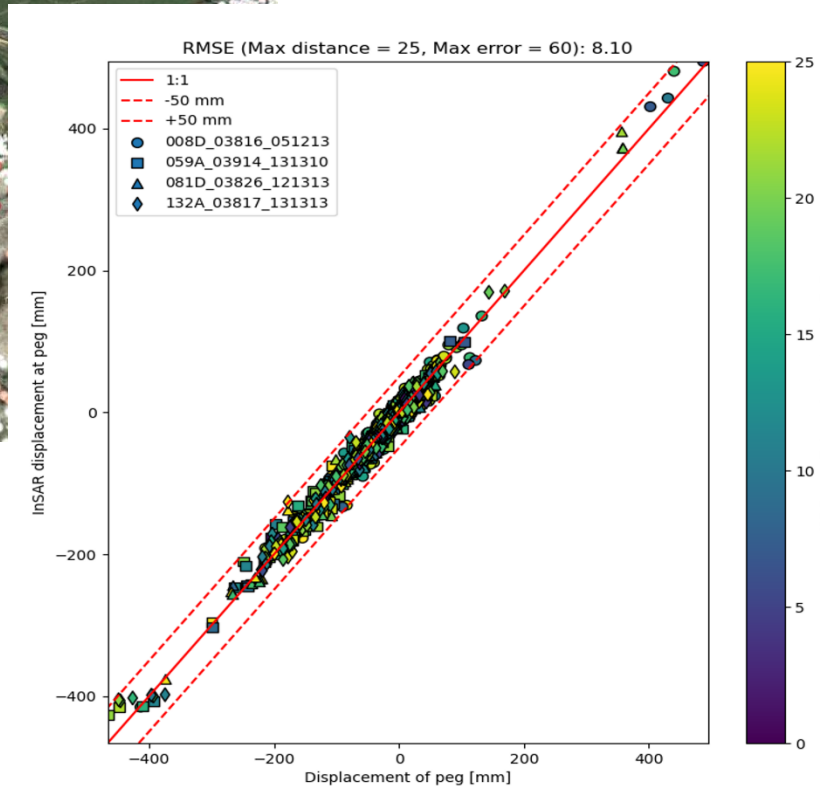
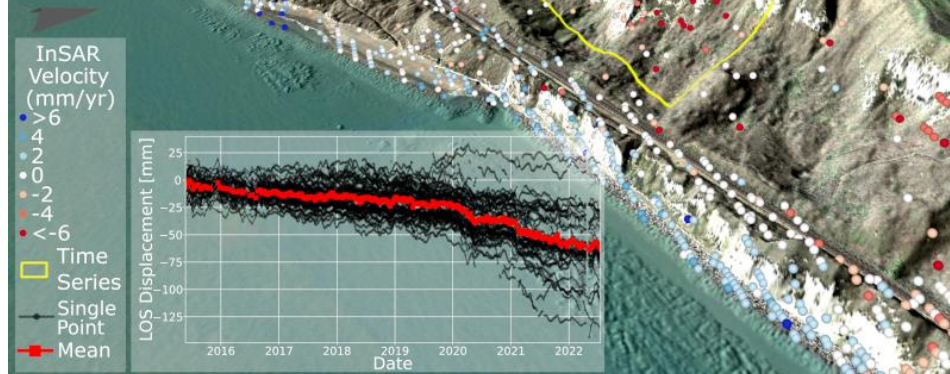
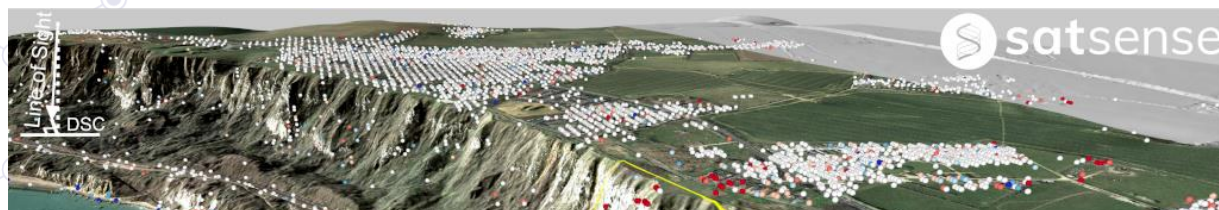
A decorative network diagram in the top-left corner consisting of several nodes connected by lines, forming a partial grid-like structure.

Copernicus used by private EO service providers. Examples

A decorative network diagram at the bottom of the slide, featuring a series of interconnected nodes and lines, with a small blue circle on the left side.

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Sentinel-1 inSAR landslide monitoring



Attribution: Satsense, Network Rail
<https://satsense.com/case-studies/comparing-insar-date-and-peg-monitoring-data>

Sentinel 1 inSAR ground motion monitoring impact of earth works

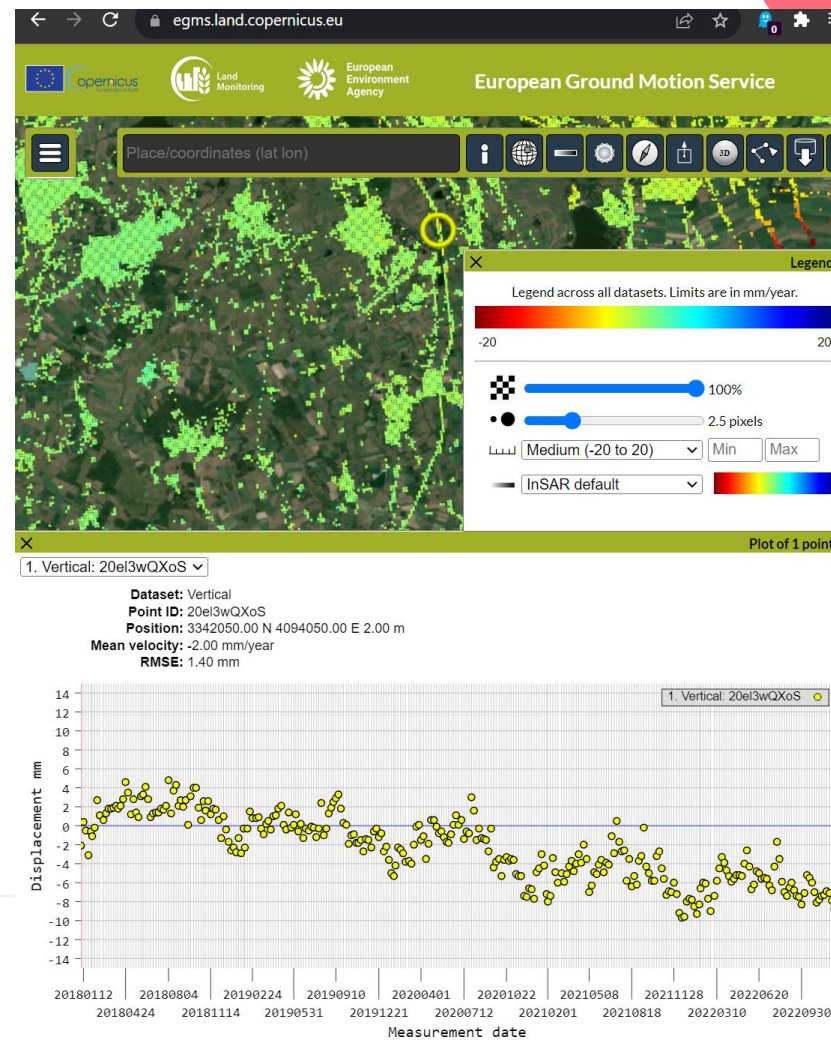


Earthworks correlated to ground motion identified with InSAR S-1 results along the railroad network between Reims and Strasbourg

Source: EO4Infrastructures, final report, 2022, e-GEOS, GAF, SNCF, RFI, DB Netz, funded by ESA

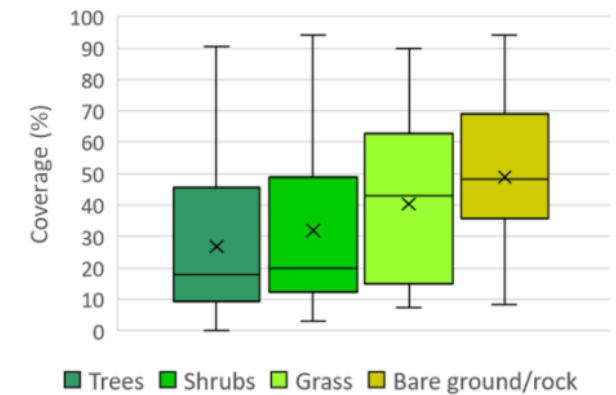
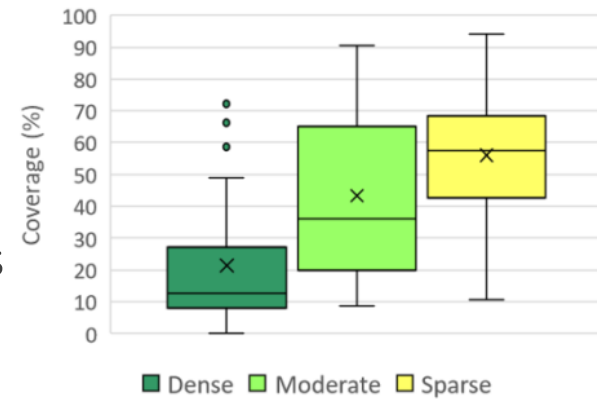
Benefits of inSAR for infrastructure management

- Monitor assets at network scale
- Prioritize the use of other, insitu methods
- Monitor at regular intervals
- Alerts for slow moving phenomena
- See the past - historical displacements

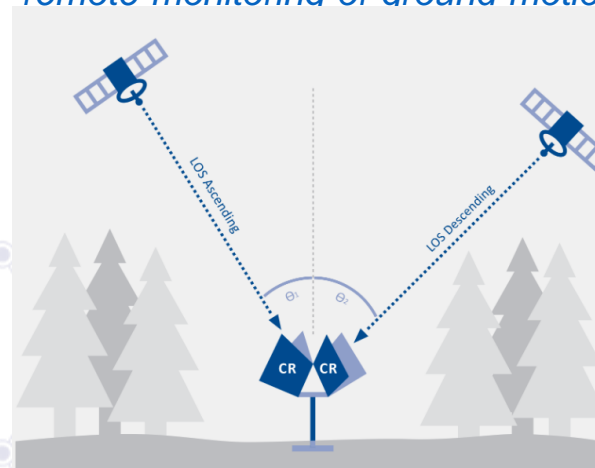


Limitations of InSAR

- More vegetation -> less measurement points
- Can't measure at specific, predetermined locations unless corner reflectors are used
- Low sensitivity to North-South displacement
- Can't measure continuously (S1 – currently every ~8 days in Europe)
- Can't measure fast displacement
- Can't measure displacement and soil moisture accurately if surface texture is changing (e.g. earthworks, snow)



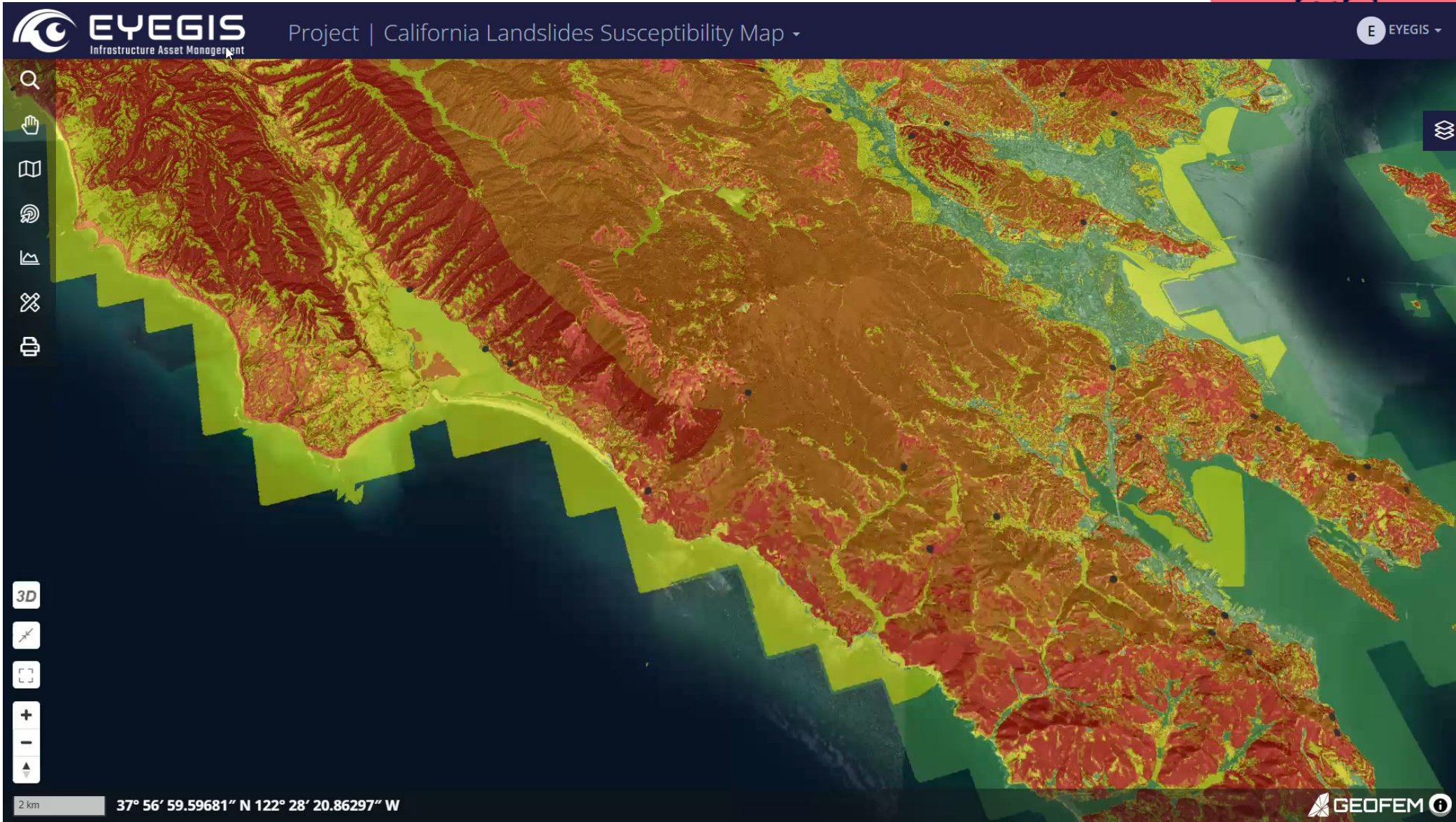
Attribution: Satsense, Network Rail, <https://www.geplus.co.uk/opinion/rail-remote-monitoring-of-around-motion-24-11-2022/>



Corner reflectors – a solution to vegetation, changing texture
Image attribution: Tre Altamira #EUSpace

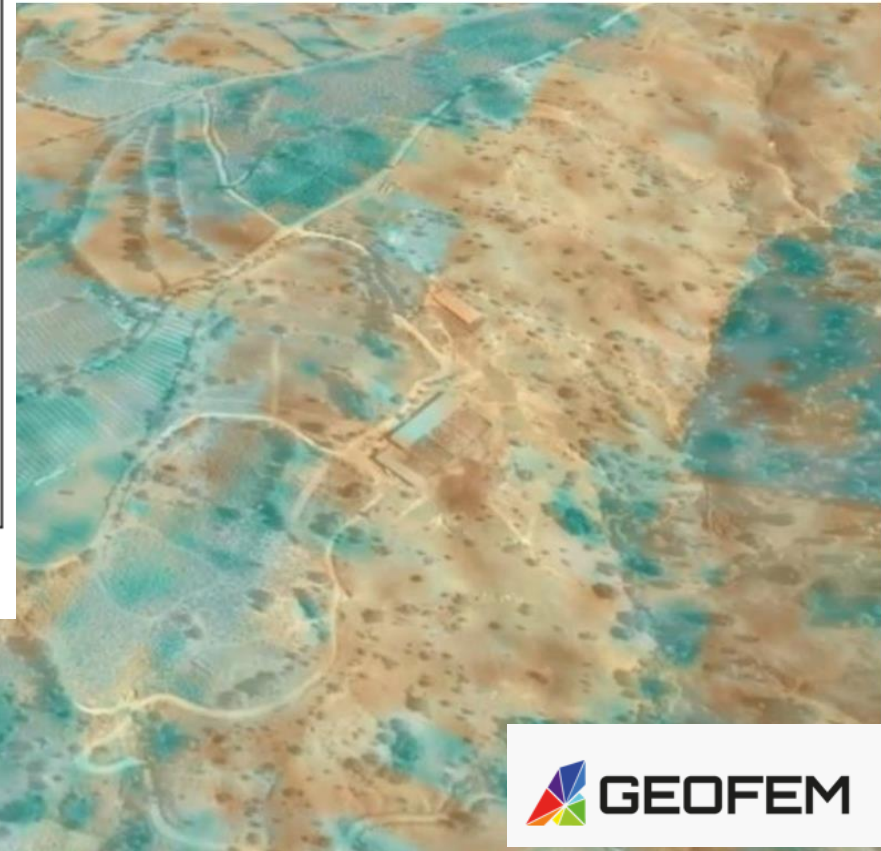
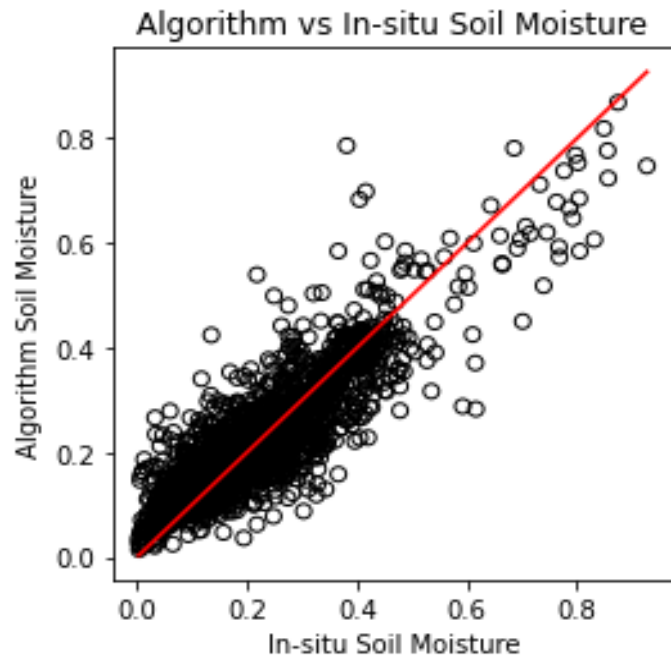
Landslide susceptibility assessment

Regularly updated to reflect climate change and the triggered landslides of each season.



Volumetric Soil moisture with Sentinel-1

- Based on Sentinel 1 radar backscatter and other data
- Absolute moisture estimate requires in-situ calibration data
- Top layer only
- Dense vegetation occludes measurements



Calibrated Sentinel-1 SAR soil moisture
Geofem, Sentinel-1

Copernicus data – how to access. Many options.

- <https://copernicus.eu> – main website, links to the 6 Copernicus service
- <https://dataspace.copernicus.eu> – most complete set of Sentinel data, cloud processing, Copernicus browser for quick and easy viewing. Free with limited usage.
- <https://wekeo.eu> - EU's Copernicus data access and processing platform, run by managers of several Copernicus Services. Free with limited usage.
- [AWS Open data](#) registry
- [Google Earth Engine](#) – most popular EO computation cloud platform
- Dozens of local mirrors, platforms, access hubs, web map mosaic services
- Not all access points are created equal. Pay attention to what sensors, acquisition modes, product levels, length of historical archive are available.

Rail infrastructure needs to Copernicus mapping

- Hydrogeological stability
 - **Ground motion** – Sentinel 1, EGMS
 - **Soil moisture** – Sentinel 1, Sentinel 2, CLMS Land Cover and soil moisture products
- Vegetation management:
 - On or next to tracks – Copernicus not sufficient
 - On adjacent slopes – Sentinel 1,2, CLMS high resolution phenology layers
- Third party activity next to tracks
 - Buildings, S1,S2, CEMS GHSL Built up layer, CLMS CLC+
 - Quarries, earthworks etc. – S2, Imperviousness layer, CLMS CLC
 - Land use/cover change – CLMS Corine Land cover, Urban Atlas, CLC+, Imperviousness layer
- Flood and forest fire hazards - CMEMS
- Terrain/elevation models – Copernicus DEM
- Climate forecasts – Copernicus Climate Change Service
- Others

Copernicus Space segment evolution



Of specific interest to Rail usecases:

- ROSE-L – L-band radar, better vegetation penetration, soil moisture retrieval
- LSTM – land surface temperature, will contribute to soil moisture retrieval



Thank you!

Arnis Kadakovskis, EUSPA

With contributions from:
Joana Balasis, EEA, CLMS

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Stijn Vermote, ECMWF

Demo sessions Nov. 8th:

10:30 – 11:00: EGMS

11:15 – 11:45: CLC and CLC+



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