EU Space Programme
Copernicus for Rail

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European Commission

EUSPA European Union Agency for the Space Programme

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Agenda – Copernicus for rail

- Why are we here
- Rail network infrastructure management needs
- Introduction to Copernicus
- Sentinel 1 and 2
- Copernicus services:
  - Land Monitoring service
  - Emergency Management service
  - Climate Change Service
- Data access
- Future of Copernicus

Rail network infrastructure management – a diverse set of needs

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Asset life cycle

- Site investigation
- Specification and planning
- Design
- Construction
- Operation
- Maintenance
- Decomissioning

Types of needs

- Hydrogeological stability
  - Ground motion
  - Soil moisture
- Vegetation management:
  - On or next to tracks
  - On adjacent slopes
- Third party activity next to tracks
  - Buildings
  - Quarries, earthworks etc
  - Land use/cover change
- Response to natural hazards
- Terrain/elevation models
- Climate forecasts

Underlined – needs with Copernicus solutions

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EU’s Earth observation programme Copernicus

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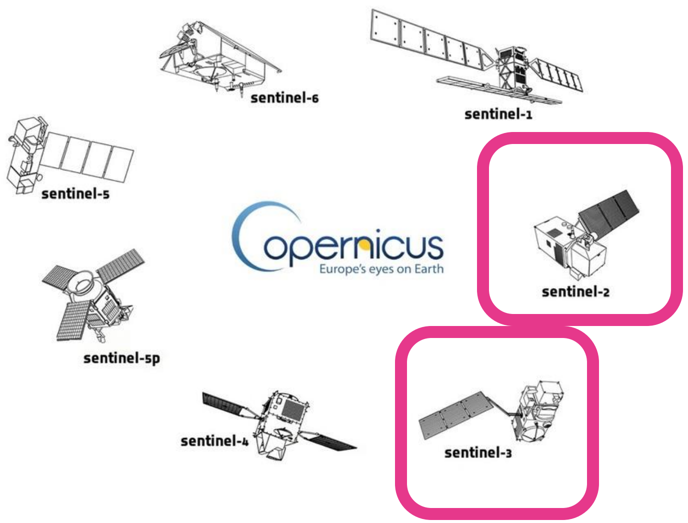
SPACE



IN SITU

In Situ

Copernicus contributing missions

SERVICES

Atmosphere Monitoring

Copernicus Marine Service

Land Monitoring

Climate Change

Security

Emergency Management

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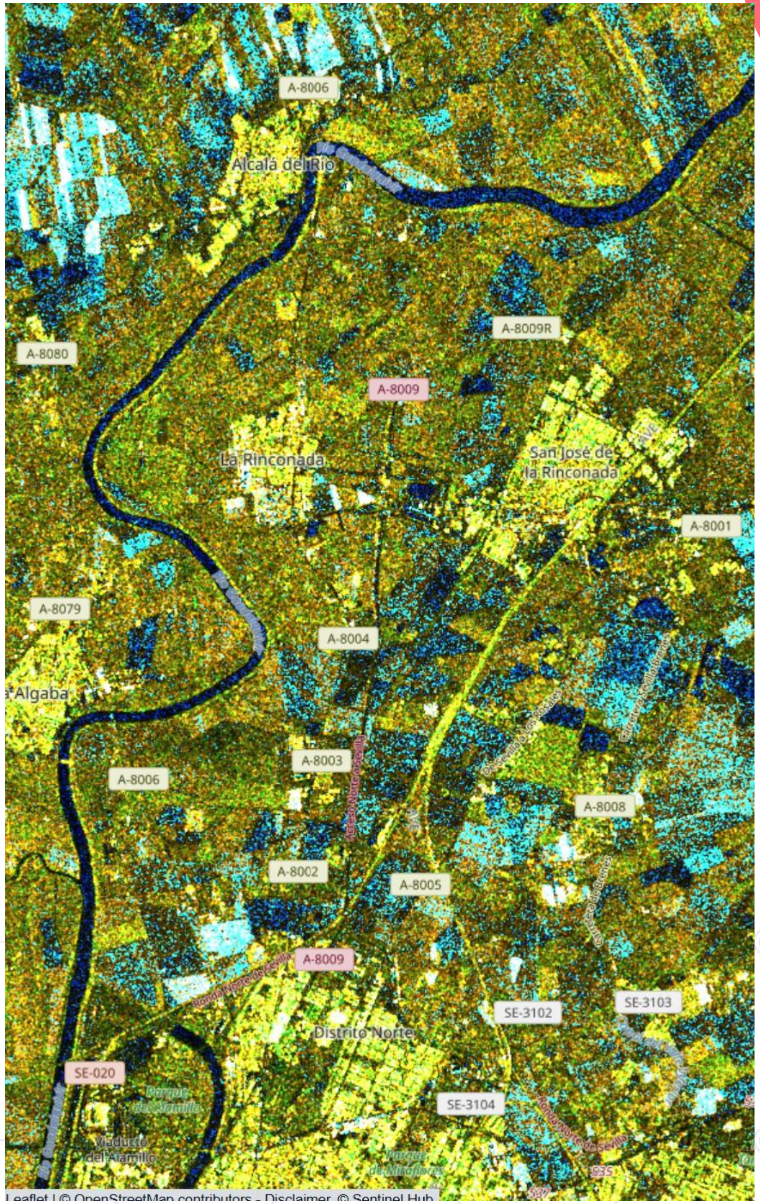
Copernicus Sentinel 1 radar

- Synthetic Apperture Radar (SAR) with:
  - Interferometric mode (inSAR) – used for ground motion analysis
  - Polarimetric mode – land cover, vegetation structure, soil moisture characterisation
- Spatial *resolution* 5x20m
- Revisit time 6(12) days*
- Global, persistent coverage
- Nominal constellation: 2 satellites, currently operational: 1
- Archive since 2015

*One of two satellites waits the launch of it’s replacement.



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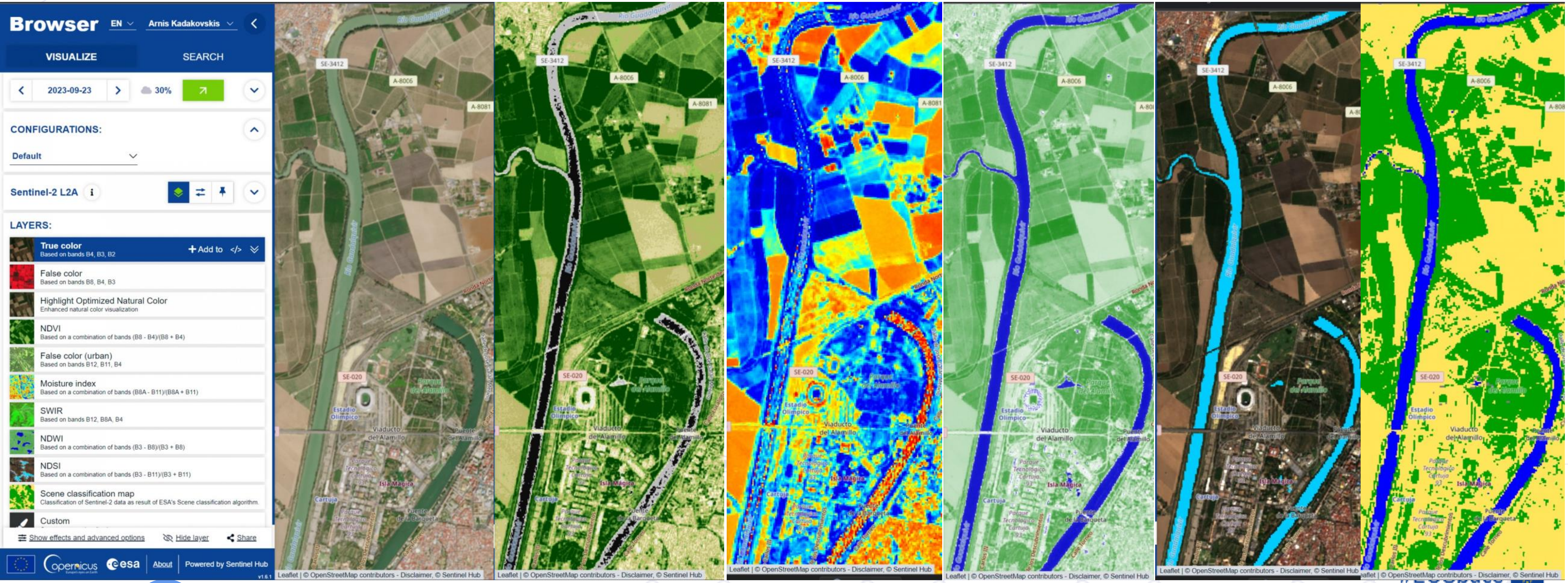
Copernicus Sentinel-2 multispectral imager

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 Moisture index Snow index Classification

Copernicus services

https://atmosphere.copernicus.eu/

Atmosphere

IMPLEMENTED BY ECMWF

https://marine.copernicus.eu/

Marine

MERCATOR OCEAN INTERNATIONAL

https://land.copernicus.eu/en

Land

European Environment Agency

Joint Research Centre JRC

https://climate.copernicus.eu/

Climate Change

IMPLEMENTED BY ECMWF

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

Security

SatCen European Union Satellite Centre

FRONTEX EUROPEAN BORDER AND COAST GUARD AGENCY

EMSA European Maritime Safety Agency

https://emergency.copernicus.eu/

Emergency

Joint Research Centre JRC

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

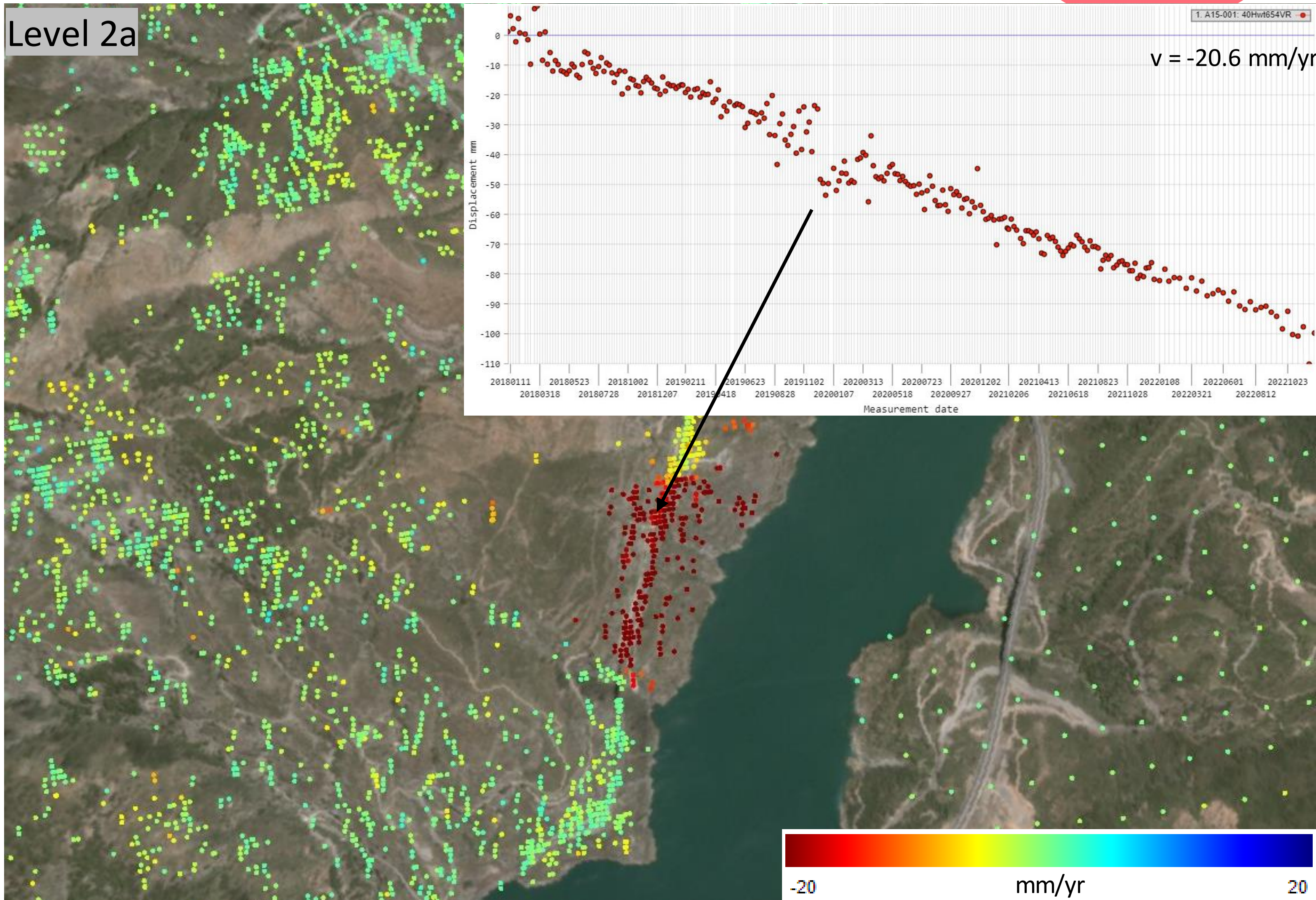
European Ground Motion Service

- Spatial resolution: 5x20/ 100x100 m
- Update frequency: Yearly, with time series
- Most recent reference layer: 2015 – 2022
- Example of applications:
  - Monitoring infrastructure and slope instabilities → asset management and impact assessment

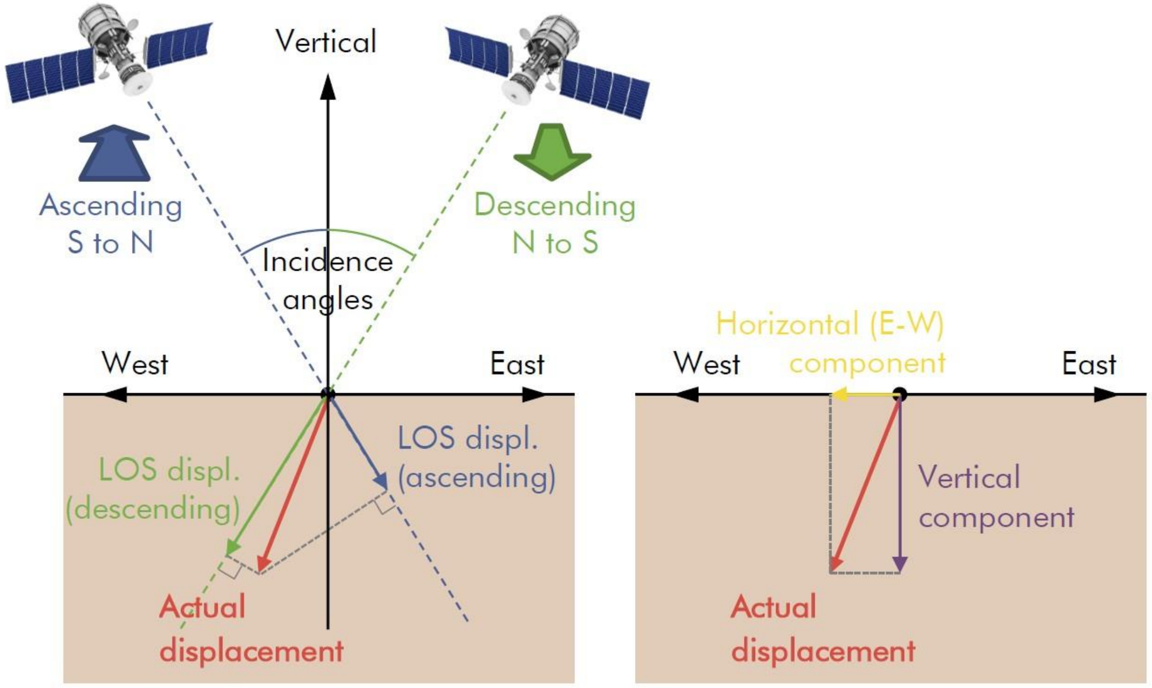
Service:

https://egms.land.copernicus.eu/

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



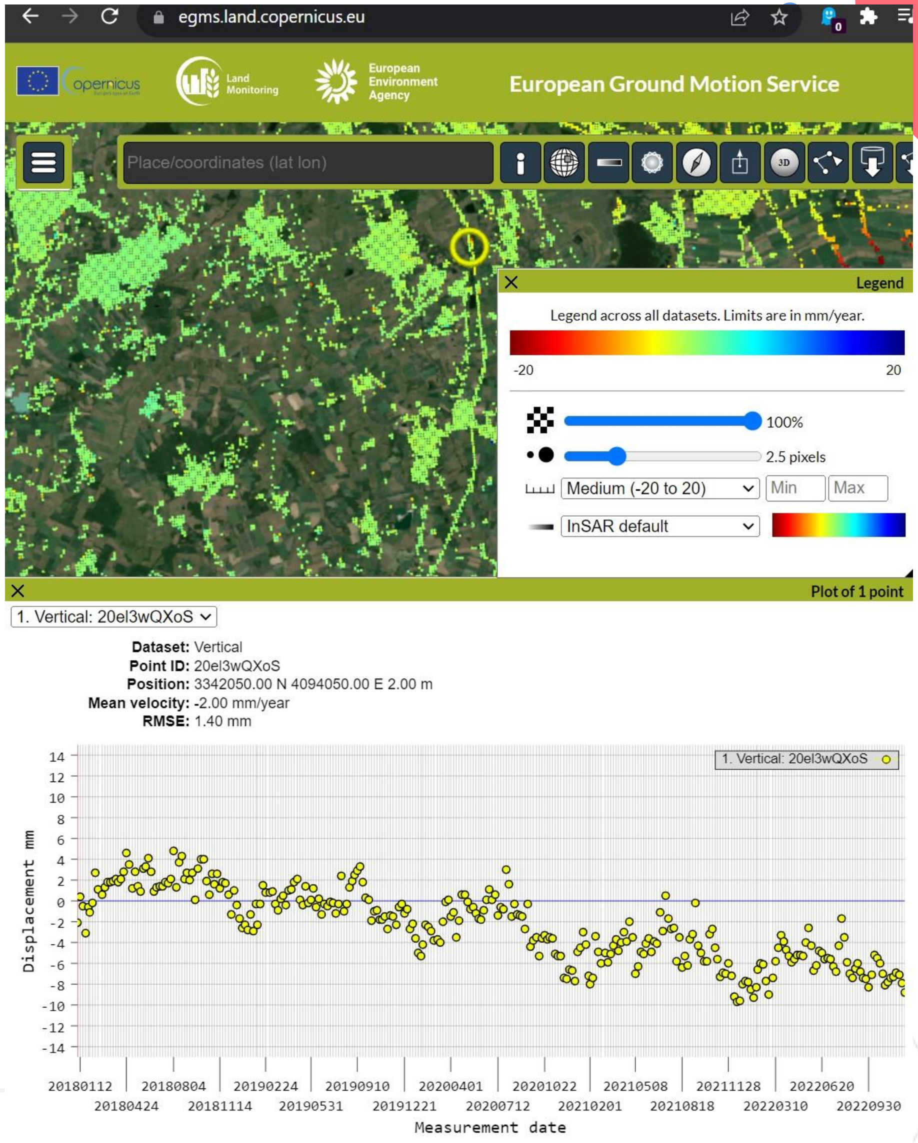
SAR interferometry



Line-of-sight (LOS) displacements from satellites

Resolved into true vertical and horizontal (E-W) displacements

Attribution: illustration by Geofem



Attribution: Copernicus EGMS, Sentinel-1 data

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Sentinel 1 – 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

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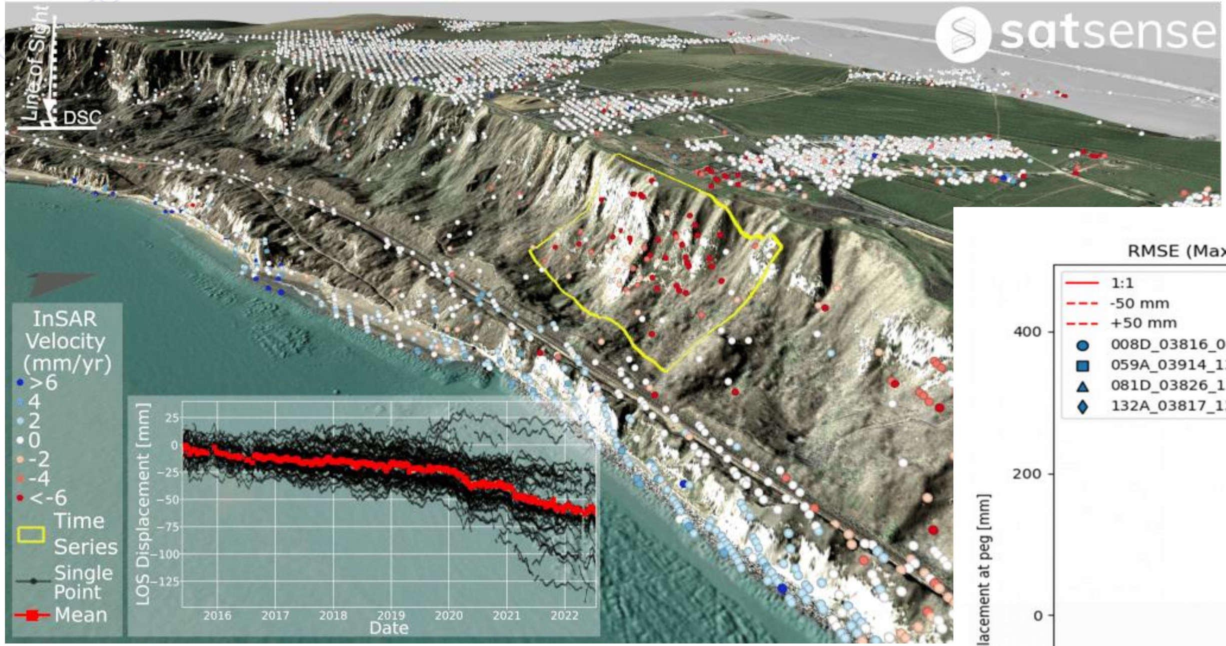
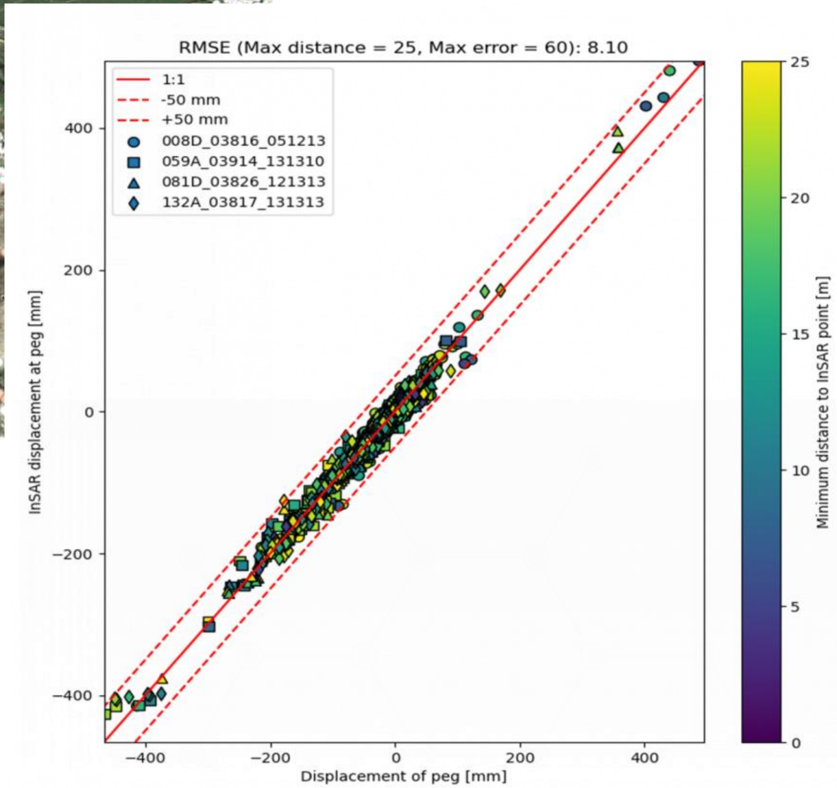
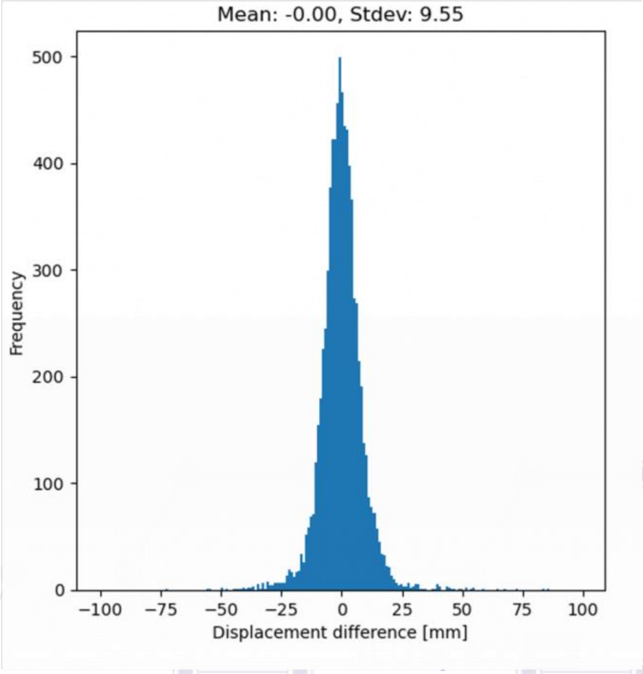
Copernicus Sentinel-1 based landslide monitoring



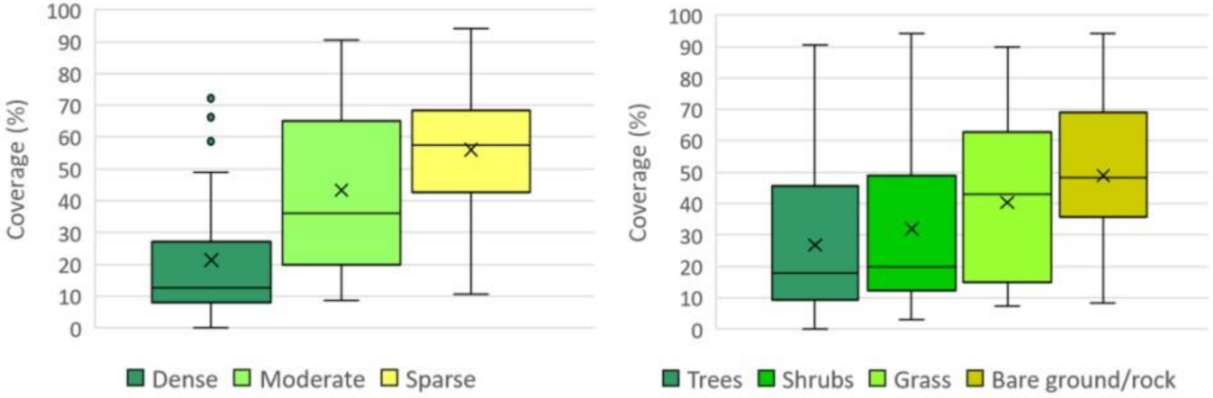




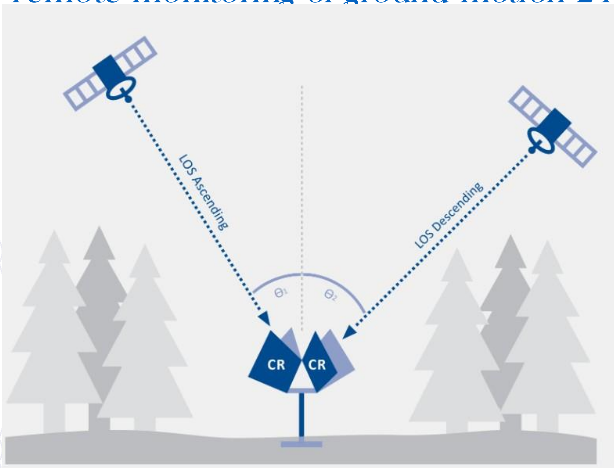
Attribution: Satsense, Network Rail
https://satsense.com/case-studies/comparing-insar-date-and-peg-monitoring-data

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-ground-motion-24-11-2022/



Corner reflectors – a solution to vegetation, changing texture

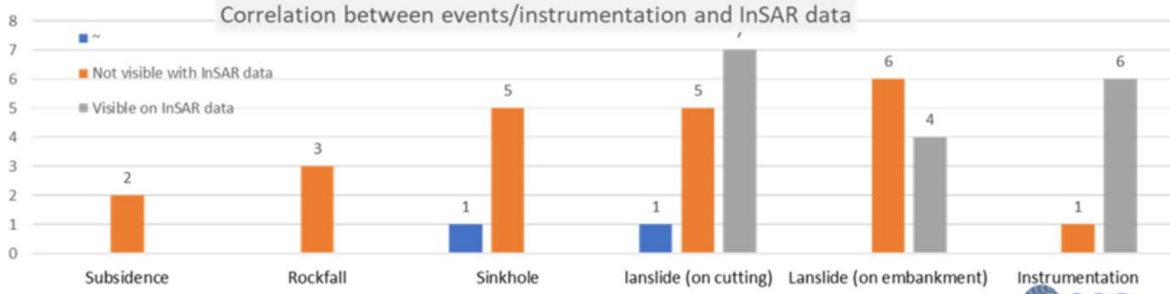
Image attribution: Tre Altamira

Validation and limitations of InSAR

Test cases over France – Earthworks monitoring

UN12: Critical analysis over the validation phase for InSAR data

- Main objective: Earthwork deformation monitoring over a large scale
- 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, rock fall, too small spatial wavelength subsidence)
  - Critical events happening in 2016
- Small wavelength phenomena 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).



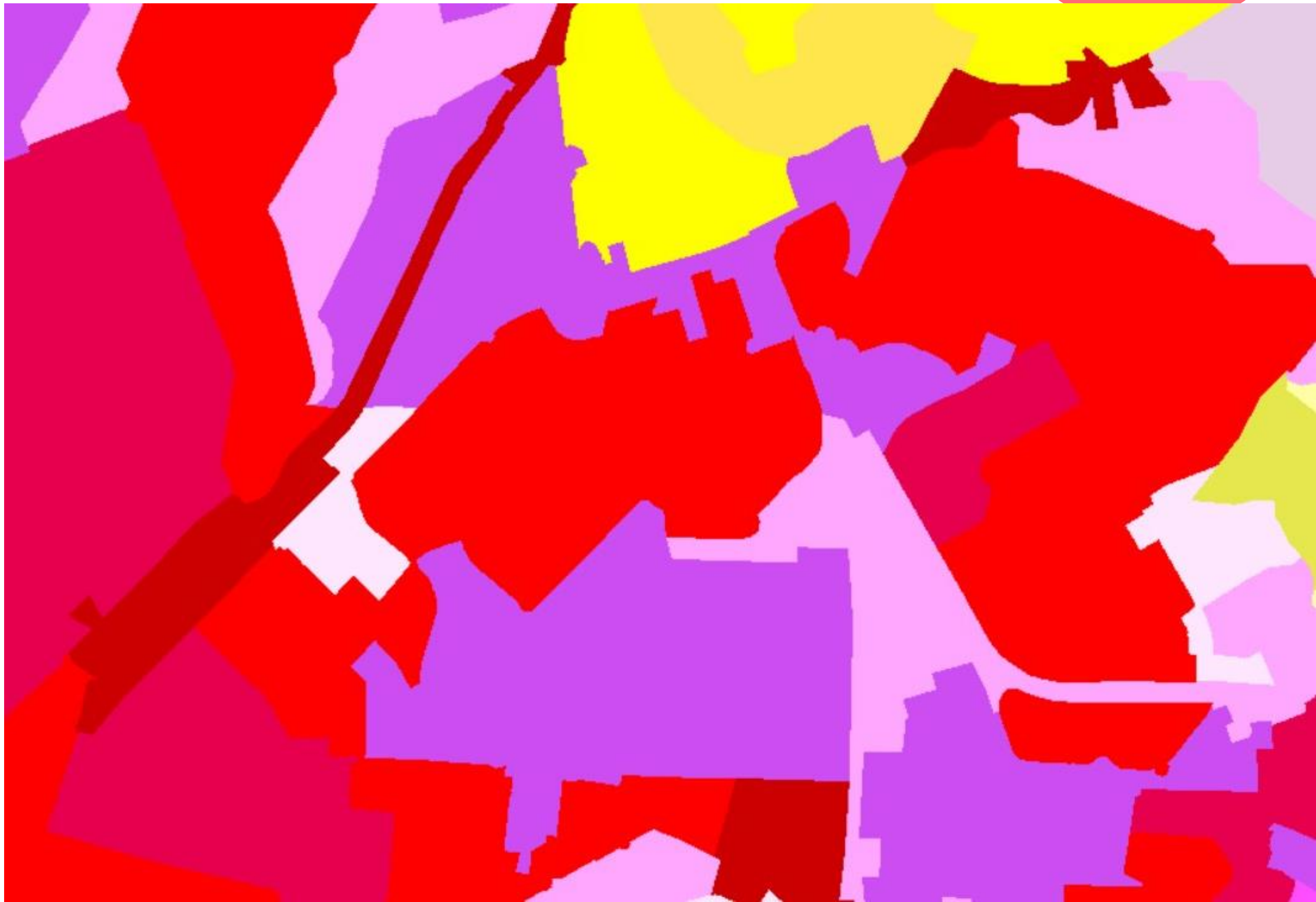
Funded by ESA

Follow-up links

- InSAR and Earth Observation techniques for infrastructure, a guide by CIRIA, 2022
- Infrastructure Mapping and Planning (EO4Infrastructures) project – a consortium of SNCF Reseau, RFI, DB Netz, GAF AG and financed by ESA. One report published.
- Sumo4Rail project – application of EGMS to Rail. Nothing published yet
- Guidance material by some of the private service operators
- Soon to be published EUSPA's report on user needs for rail infrastructure management

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?

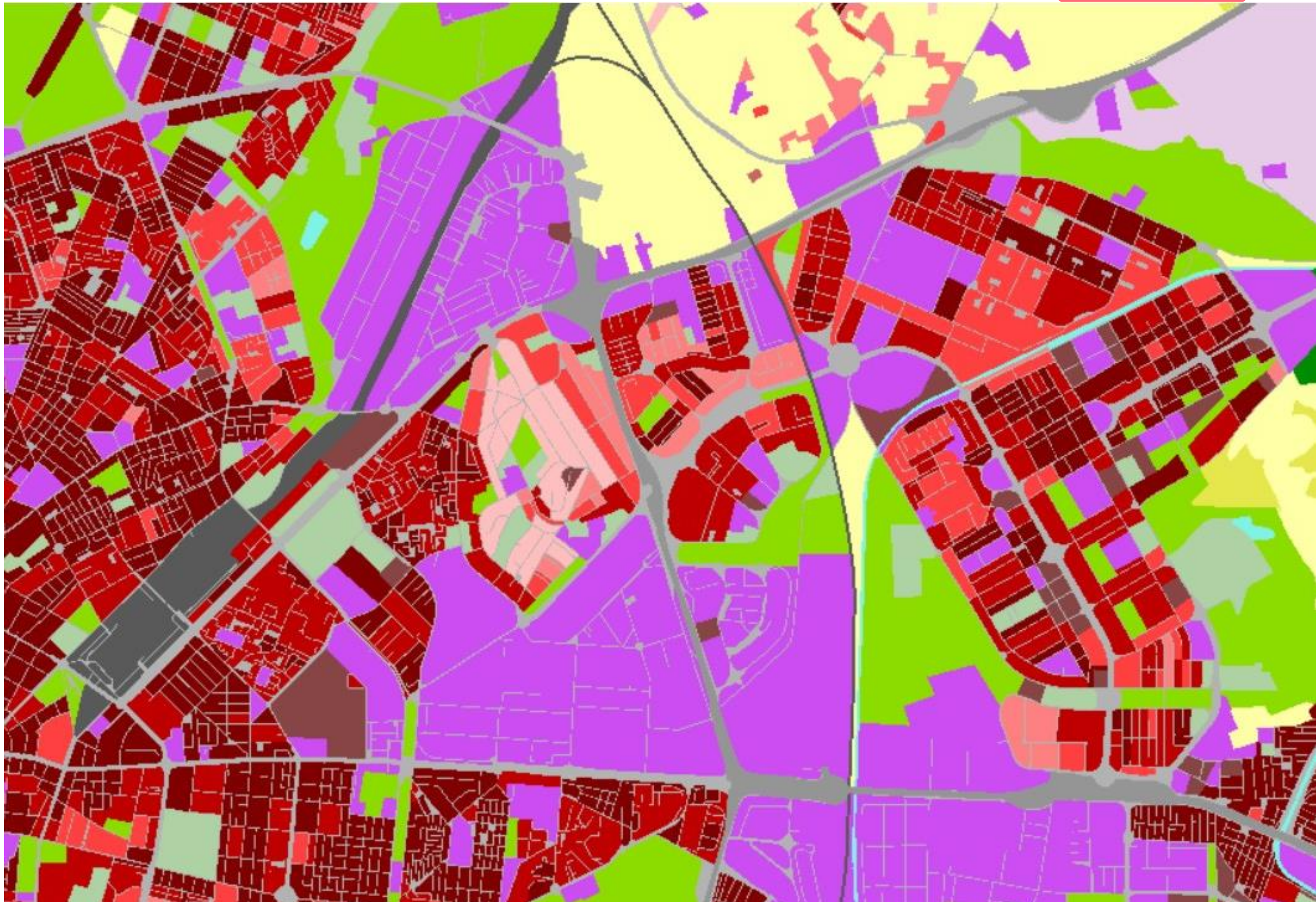


Corine Land Cover+ Backbone

- 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

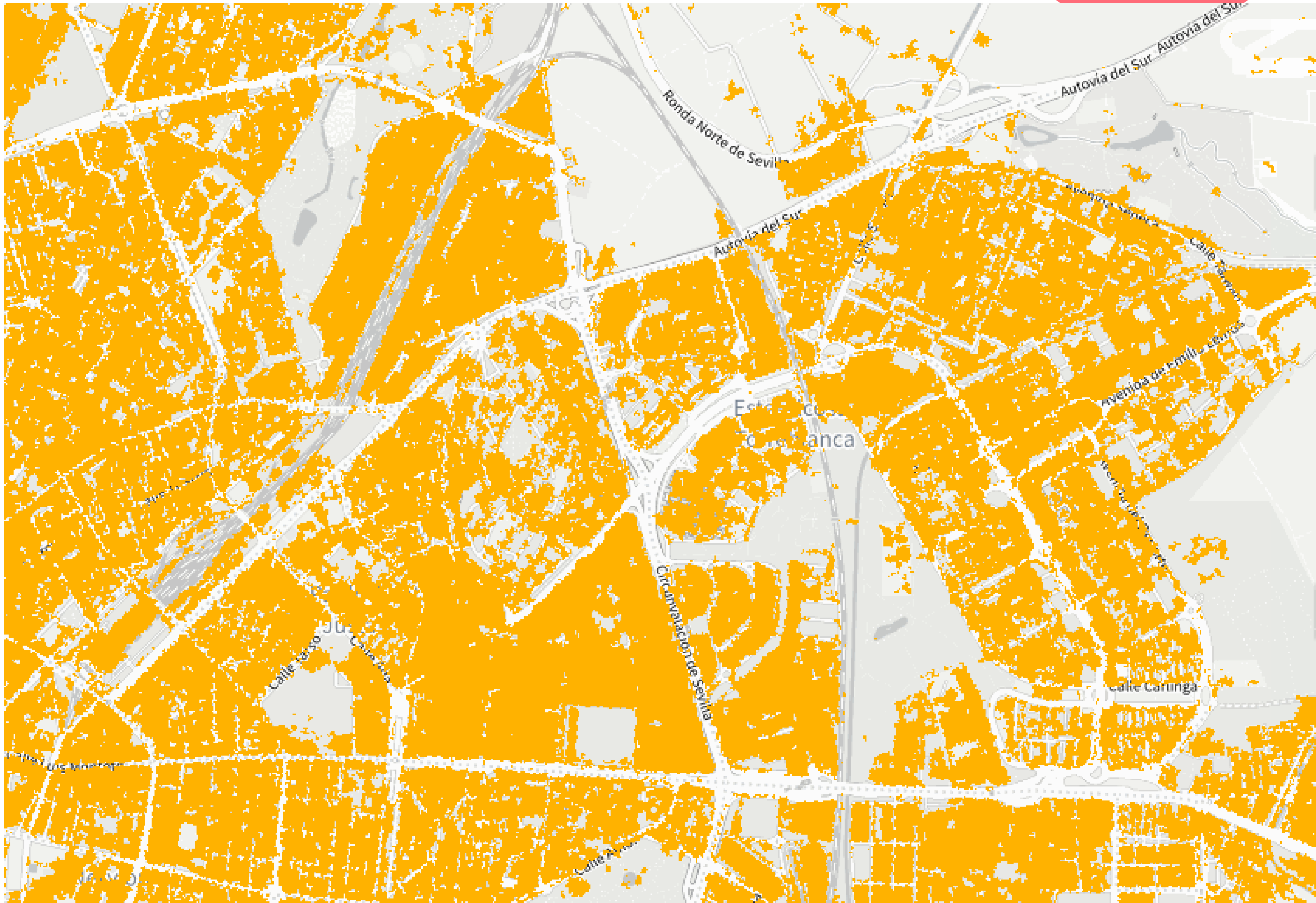
Urban Atlas

- 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



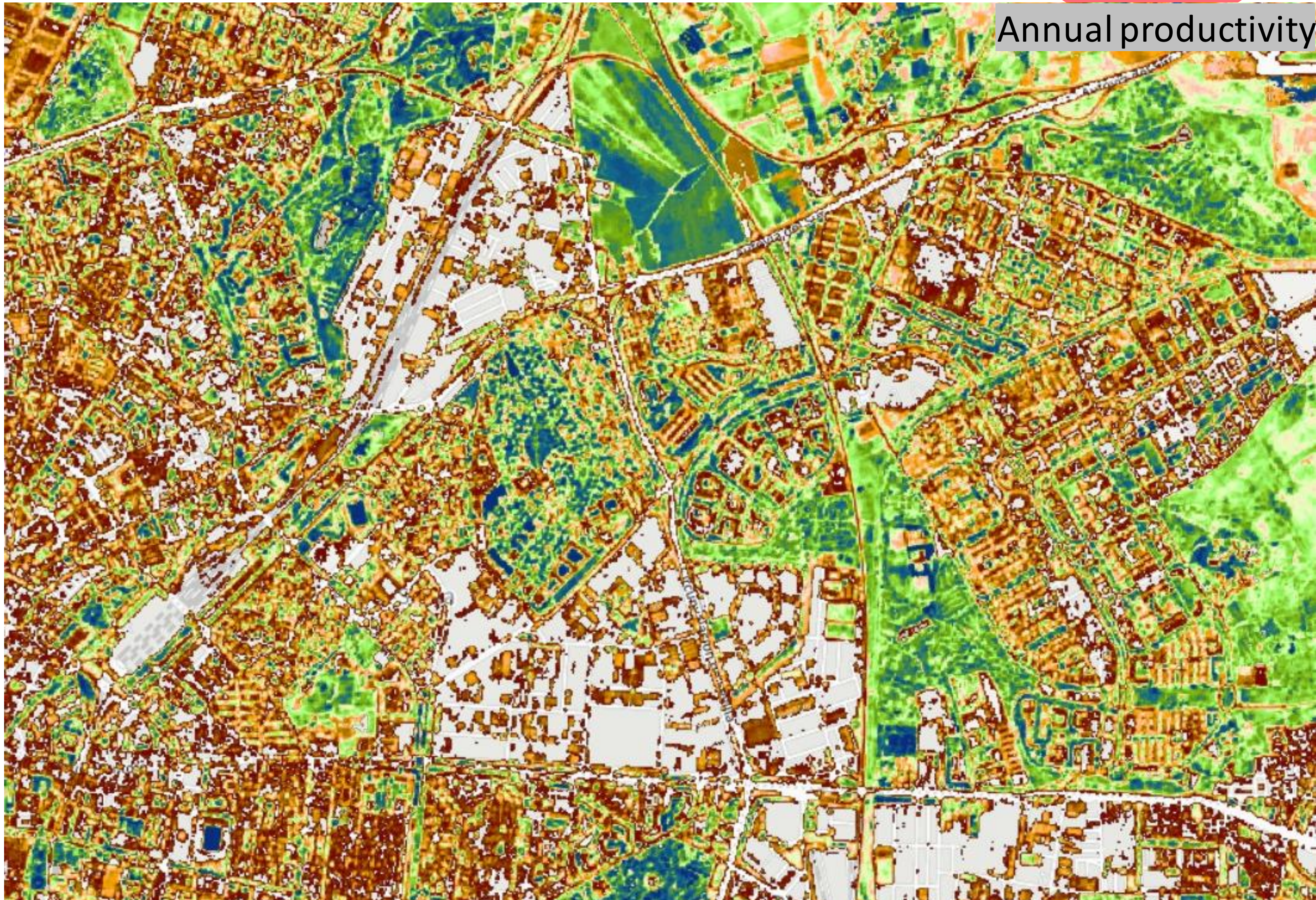
HR Impervious Built-up

- Spatial resolution: 10/100 m
- Update frequency: 3 years
- Most recent reference layer: 2018
- Examples of applications:
  - Models of run-off/ flood scenarios



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



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Copernicus Emergency Management System

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

CONTINOUS ALERTS

Copernicus Emergency Management Service. *Directorate Space, Security and Migration, European Commission Joint Research Centre (EC JRC)*. https://emergency.copernicus.eu/

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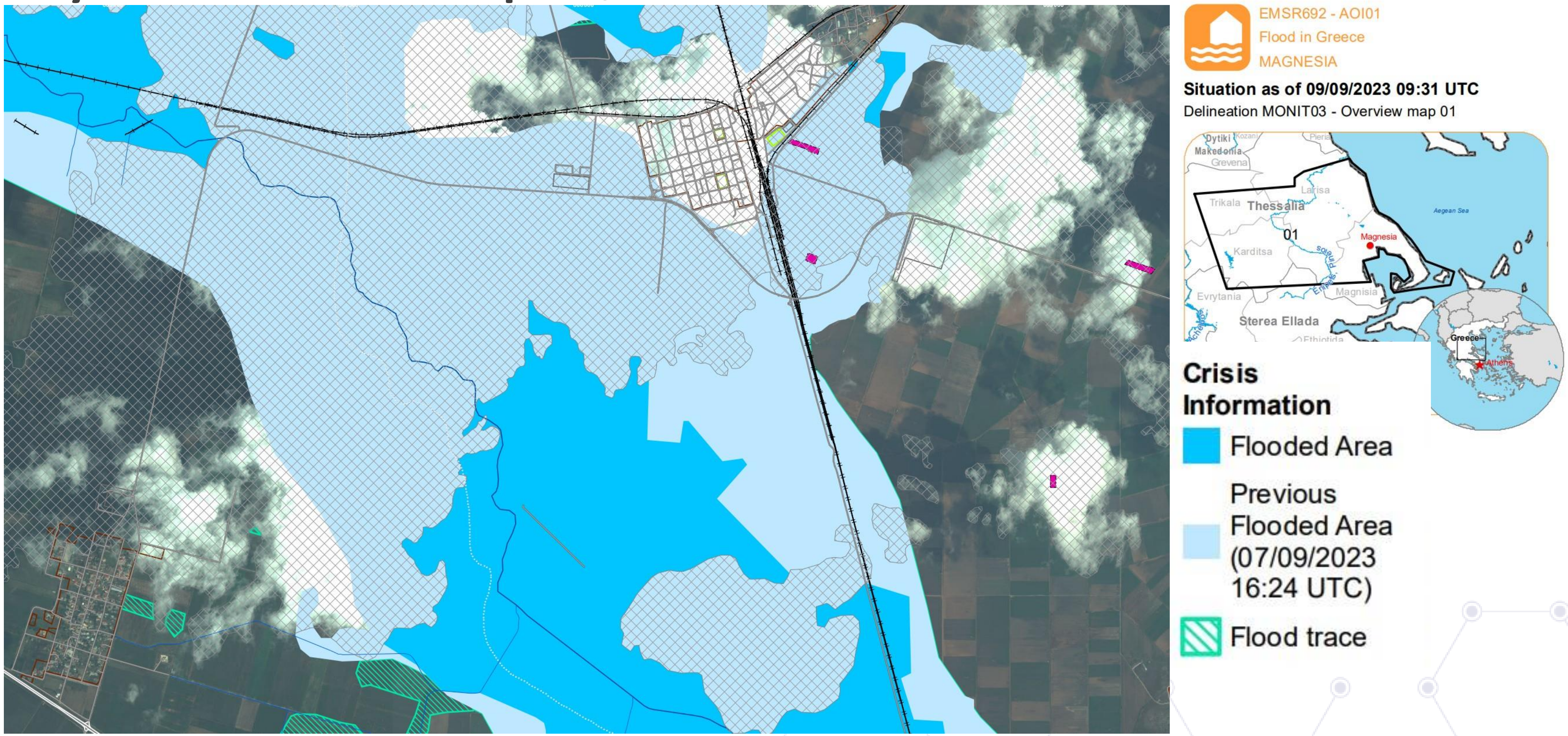
Copernicus Emergency Management system - example, floods in Greece



Copernicus Emergency Management Service." *Directorate Space, Security and Migration, European Commission Joint Research Centre (EC JRC)*. https://emergency.copernicus.eu/

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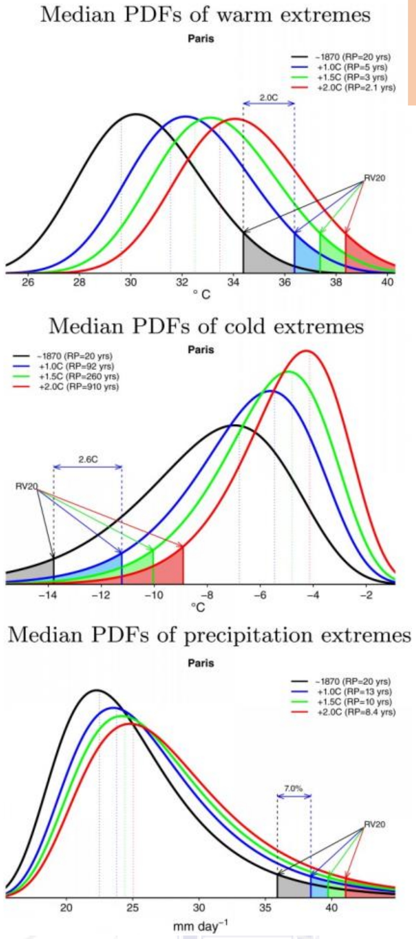
Road & Rail – Copernicus Climate Data to Support Critical Infrastructure

'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.'

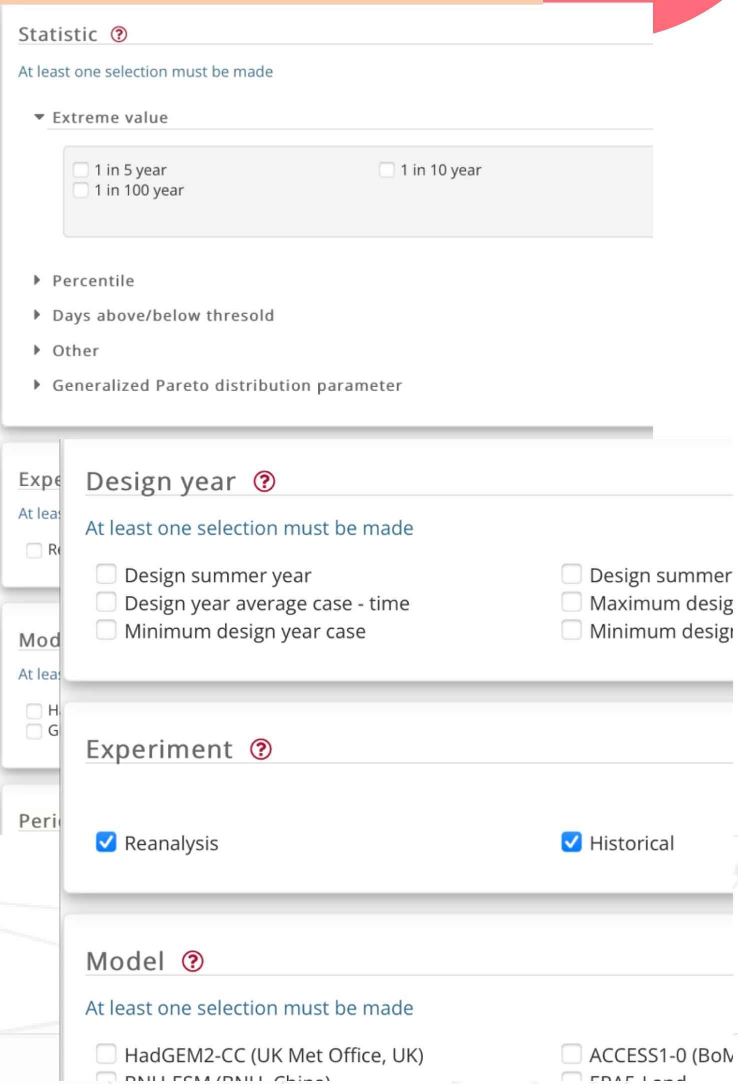
C3S developed demonstrators, based on Climate Data in the Climate Data Store and **user requirements,** to help introduce **climate information** to support infrastructure design

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



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



Copernicus data access – a few quick links

- https://copernicus.eu – main website, links to the 6 Copernicus services
- Bring processing to the data, not data to processing.
- https://dataspace.copernicus.eu – most complete set of Sentinel data, in-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, acces hubs
- Not all access points are created equal. Pay attention to what sensors, acquisition modes, product levels, length of historical archive are available.

Key takeaways

- Copernicus Sentinel-1 DinSAR has proven value on several operational scenarios of ground motion monitoring around rail network
- DinSAR technology is mature, decades of experience for some geotechnical/EO service providers
- Copernicus Land Monitoring System's European Ground Motion Service – a first step before deeper analysis
- Copernicus Emergency Management System for flood, geohazard, fire risk assessment, extent mapping, post event analysis
- Copernicus Climate Change Service climate forecasts for infrastructure design and planning
- Private EO service providers add significant value in processing and analysing the Copernicus data

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

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