EU Space Programme
Copernicus for Rail

Arnis Kadakovskis, EUSPA
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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

Asset life cycle
- Site investigation
- Specification and planning
- Design
- Construction
- Operation
- Maintenance
- Decommissioning

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
EU’s Earth observation programme
Copernicus

SPACE

IN SITU

SERVICES

Copernicus contributing missions
Copernicus Sentinel 1 radar

- Synthetic Aperture 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.
Copernicus Sentinel-2 multispectral imager

Dataspace.copernicus.eu

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

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

https://atmosphere.copernicus.eu/

https://marine.copernicus.eu/


https://climate.copernicus.eu/


https://emergency.copernicus.eu/
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/](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:
SAR interferometry

Attribution: illustration by Geofem

Attribution: Copernicus EGMS, Sentinel-1 data
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
Copernicus Sentinel-1 based landslide monitoring

Attribution: Satsense, Network Rail
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)


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).
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 Réseau, 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
Copernicus Emergency Management System

RESILIENCE

RISK AND RECOVERY MAPPING
- On demand
- Tailored to user needs
- Weeks-months

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

VALIDATION

EARLY WARNING
- Floods: EFAS
- Forest Fires: EFFIS

CONTINUOUS ALERTS

Rapid Mapping
- On demand
- Standardised
- Hours-days

Reference Maps
- Delineation Maps
- Grading Maps

Preparedness

Emergency

Response

Recovery

Copernicus Emergency Management system - example, floods in Greece

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
Copernicus data access – a few quick links

- [https://copernicus.eu](https://copernicus.eu) – main website, links to the 6 Copernicus services
- Bring processing to the data, not data to processing.
- [https://dataspace.copernicus.eu](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](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](https://aws.amazon.com) registry
- [Google Earth Engine](https://earthengine.google.com) – 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