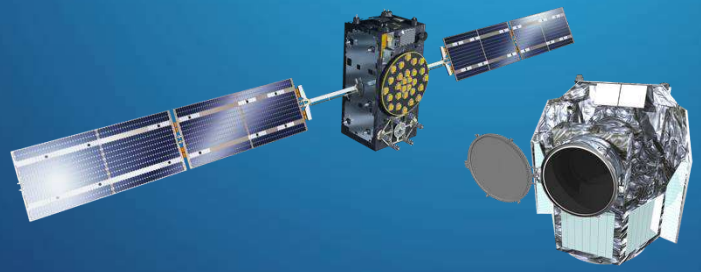
EO and Copernicus Sentinels for Transports Infrastructure Management

OECD 8th ITF TRANSPORT STATISTICS MEETING
20 September 2022

Alessandra Tassa

European Space Agency - Directorate of Earth Observation Programmes

What is the European Space Agency?



Make Space for Europe

5 500+

ESA Workforce

Pushing the limits of what is possible in space since 1975

22

Member States

2022 Budget

7.2 billion =

12 per European

Outline of presentation

- Two practical examples
  - The Norwegian roads authority
  - The Italian roads authority
- The context
  - Earth Observations: the view from above
  - The Copernicus Programme
- Other relevant examples

Satellite Earth Observations

➔ Know more: https://www.esa.int/Applications/Observing_the_Earth

Mapping terrain motion from satellites

Synthetic Aperture Radar (SAR): exploits sensor movements to obtain high-resolution radar signals

Interferometric SAR (InSAR): derive terrain deformation patterns by exploiting phase differences between two complex radar SAR observations of the same area.

Persistent Scatterer Interferometry (PSI) is a branch of interferometry that exploits point scatterers, with strong radar backscatter, over a long time period (years) to provide a phase history of the point target over time.

Applications of InSAR include:

- geophysical monitoring of natural hazards: earthquakes, volcanoes and landslides
- time-series analysis of surface deformation: subsidence and structural stability
- glacier motion analysis
- digital elevation mapping.

Link to ESA Guidelines for Interferometric Mapping

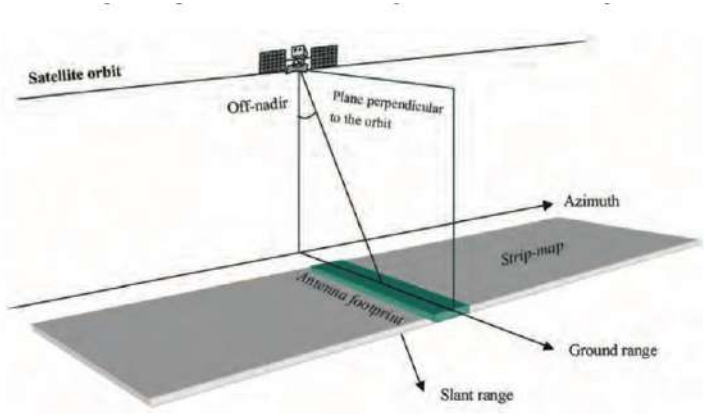
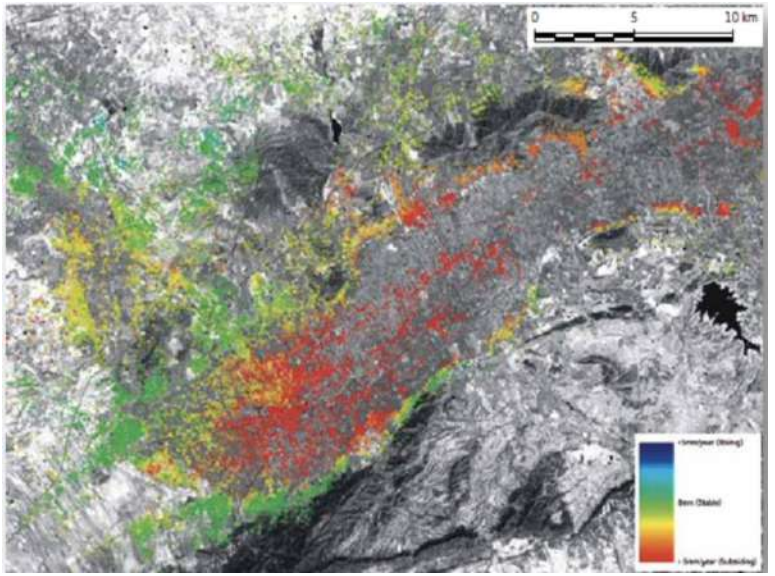


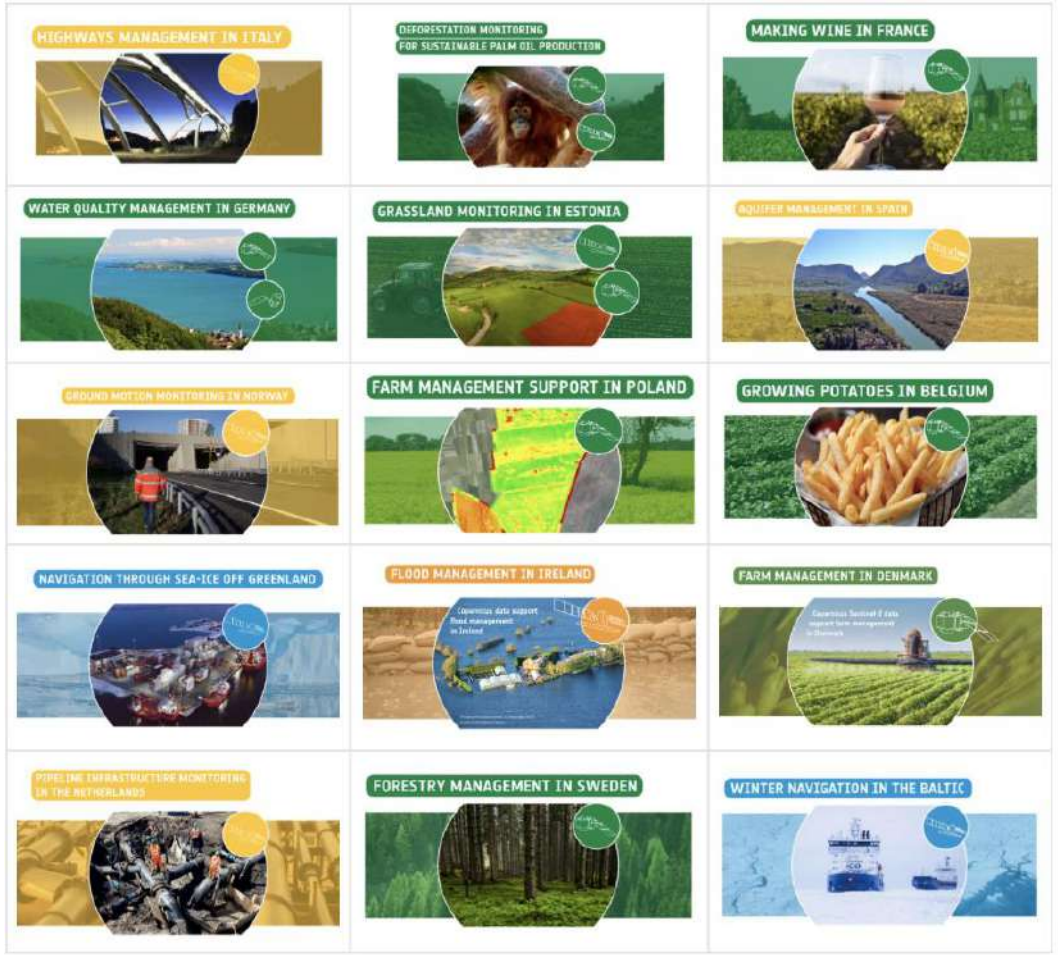
Figure 1-3: A SAR system from a satellite



SeBS: the Sentinels Benefits Study

Showcasing the benefits derived from the use of Copernicus Sentinels through fully developed value chains

- Managed by the European Association of Remote Sensing companies (EARSC)
- Funded by the EU and ESA
- 15 long case + 8 short case reports
- Complementary cross-cutting analyses
- Fully fledged methodology available for practitioners



➔ *Know more:* https://earsc.org/sebs

SeBS case: ground motion monitoring in Norway

GROUND MOTION MONITORING IN NORWAY

What it is about

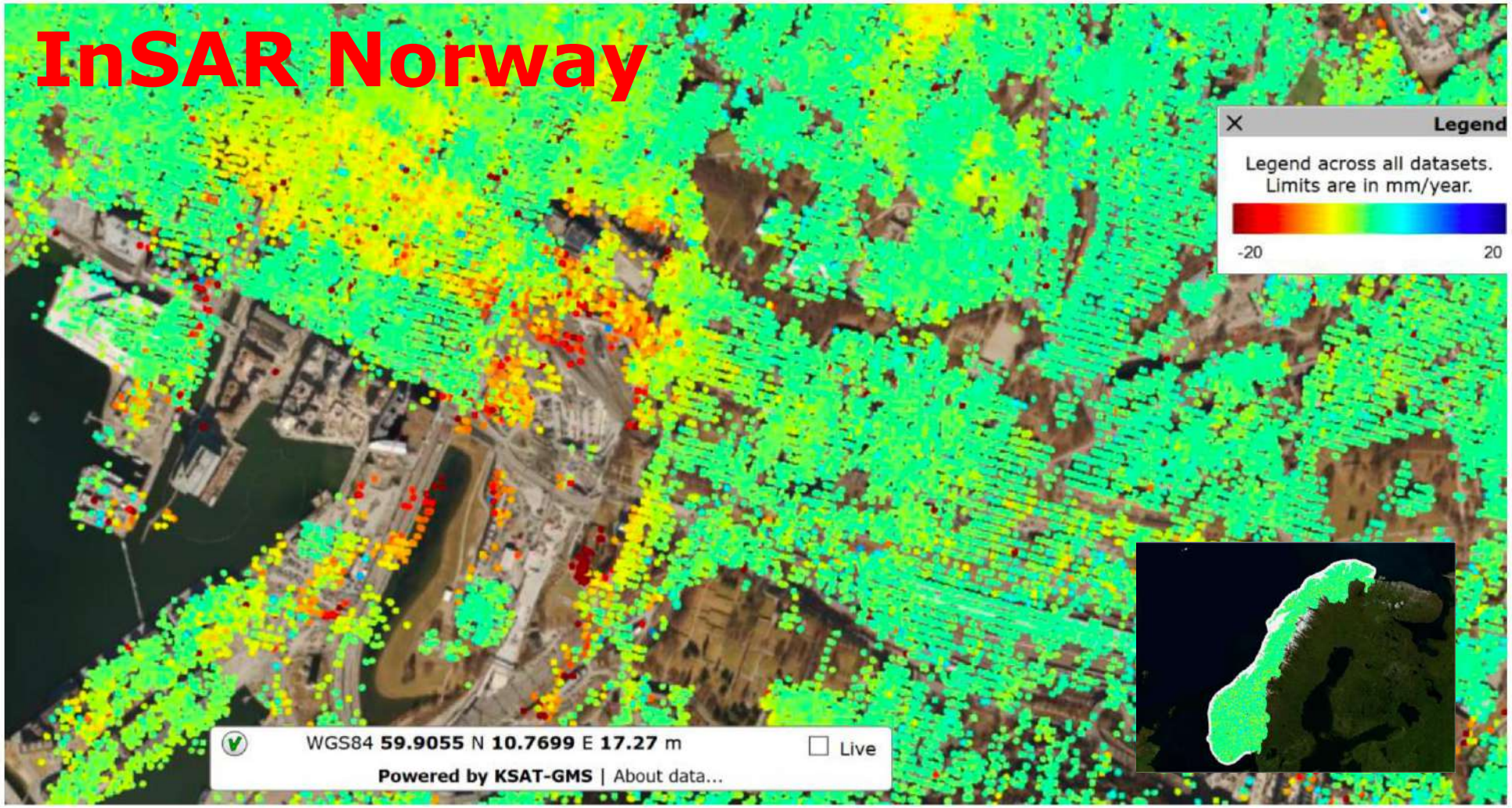
Norway is a country which has been formed by glaciers leaving steep mountainsides and deep valleys filled with moraines – especially near the coast. This landscape gives rise to rockslides (the cause of several disasters in Norwegian history) and slipping land. The Norwegian Geological Survey (NGU) has created a new service called InSAR Norway to help monitor the ground instability using satellite data. The Norwegian Public Roads Authority (NPRA) has started using this service to help identify and understand where ground motion can impact on road construction. Knowing the risk and causes of movement allows for more stable roads and tunnels leading to many benefits for Norway.

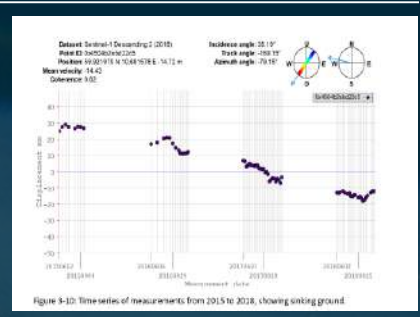
The Norwegian Public Roads Authority (NPRA) has started using a service based on Sentinel-1 satellite data (InSAR Norway) to help identify and understand where ground motion can impact on road construction.

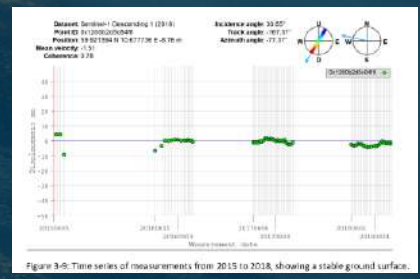
Highly precise (of mm accuracy), high resolution (metre- scale measurement grid) and large-scale measurements of ground or infrastructure movements are provided through the mapping service.

The generation of a map that monitors precisely ground motion over the entire country is only possible through the use of satellite data.

SeBS case: the satellite-based service







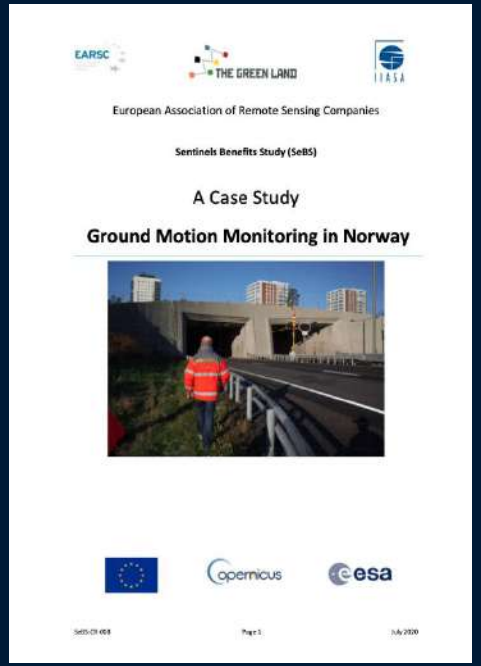
https://insar.ngu.no

Figure 3-8: Ground motion over the Bjørvika site in Oslo.

https://www.ngu.no/en/topic/insar-norway

SeBS: impacts for the roads authority in Norway

"In the case of Tønsberg, where a tunnel has experienced many years of problems, engineers were at a loss as to why subsidence was occurring. Now the mystery is solved – thanks to the new service – which shows that rather than being a local problem, it extends over the whole town. This scale of survey measurements would not be possible using traditional methods, and hence the service is providing unique information. Had the service been available when the tunnel was designed and built (in 2004-2008), considerable savings would have been made by avoiding costly remedial work in recent years. ***Knowing the extent, scale, and degree of ground motion during the planning and design phases of projects can lead to more appropriate designs and avoid costly repairs later.*** *"*



Finally, in the centre of Oslo, a major redevelopment along the waterfront and beside the main railway station is finding unusual ground settlements and subsidence which is affecting its construction. ***Gathering a wider view using the InSAR generated ground motion maps allows a synoptic view to be taken.***

A further service that is based on Sentinel-1 images is being used to detect ***snow avalanches****. Apart from the risk to vehicles and infrastructure, avalanches can block roads and cut communications between affected areas.*

Wider use of the maps is expected since ***NPRA produces handbooks of practices to be used by road agencies throughout Norway****.*

Summary of Tier 2 benefits	€/year in Norway
Improved surveying reducing project costs	€30,000/year - €100,000/year
Detecting areas of risk at the planning phase of projects	€1.7 million/year - €3.4 million/year
Reduction in road resurfacing costs due to a better planned road nework	€700,000/year - €1.4 million/year
Improved maintenance – reduced risk of road closures	Counted under Tier 4

SeBS case: highways management in Italy

The Italian Roads Authority (ANAS) has started using a commercial service based on Sentinel-1 satellite data (Rheticus) to understand where movement of the ground has taken, or is taking, place.

The national coverage allows ANAS planners and engineers to have a countrywide view of ground movement at considerably lower cost and superior performance compared to alternatives.

Regular, high-precision measurements also enable monitoring of roads infrastructure such as bridges and tunnels. In the future, enhanced measurements using **corner reflectors** offers the possibility of sustained monitoring of bridges and tunnels.

Increased risk of severe flooding caused by changing climatic conditions, places more demands on designs and constructions which can be mitigated through ground motion measurements.

SeBS case: the satellite-based service

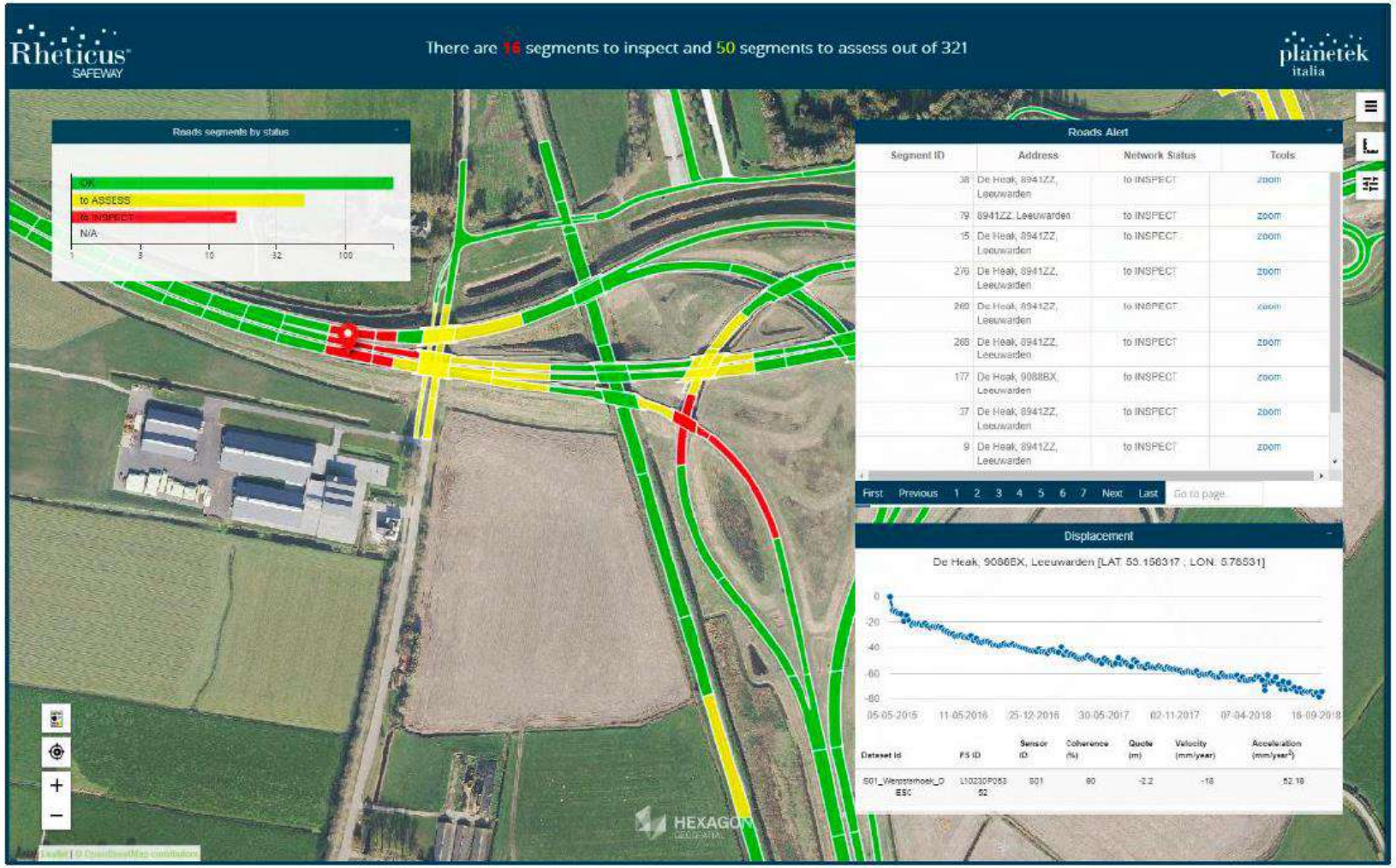
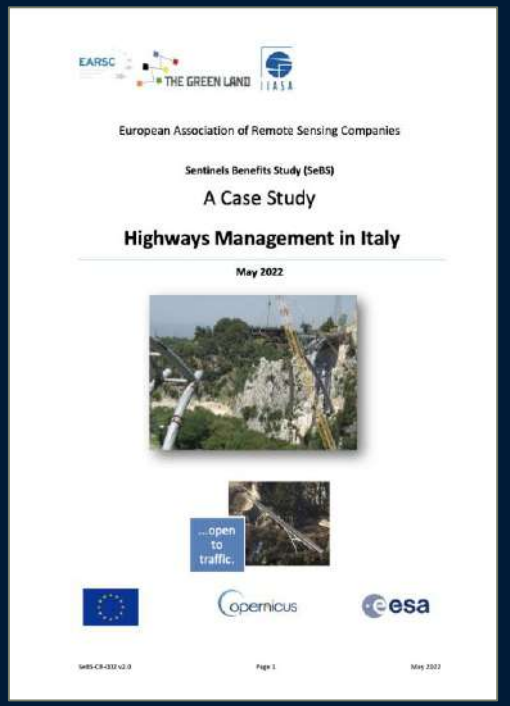


Figure 3-3: Rheticus® Safeway User Interface

https://www.planetek.it/eng/products/all_products/rheticus

SeBS case: impacts for the roads authority in Italy

We have identified 4 projects managed by ANAS which either have or could have benefited from the use of InSAR should it have been available in the early stages. In 2 cases, the planning and design would have been easier had existing ground movements been known. In one project, severe problems showed up when the project was well into its construction phase which are leading to very high additional costs, and which could have been largely avoided if InSAR measurements had been available for the design. One further project had problems triggered by the construction work which could have been detected and resolved earlier if InSAR measurements had been used.
As a result, ANAS has introduced the requirement to use InSAR monitoring into a number of new projects.



The information derived from SAR data are useful, and the benefit of their usage is very high, with respect to the possible costs. In this specific case the data have shown the absence of critical phenomena.

The ability to measure movement can lead to a better understanding of vulnerable areas and to change regulations linked to construction as a result. Planners can avoid authorizing construction in these areas. Knowing when a movement took place can go a long way to helping understand the cause and, if necessary, attribute liability. Knowing the speed at which a point on the ground is sinking or rising can even help engineering works as well as improve the understanding of risk.

	Minimum	Maximum
Reduced Survey costs	€0.9m	€1.8m
Savings on Remedial works	€2.4m	€5.8m
Savings on avoiding project delays	€0.5m	€1.0m
Total Economic Benefits	€3.8m	€8.6m

Table 5-4: Summary of ANAS economic benefits

SeBS: extrapolation of findings?

On-going analysis:

- To analyse commonalities and differences among different actors and potential uses of Sentinels data in different countries/regions
- To establish a benchmark of cases that can allow to improve the current understanding related to the use of Sentinels data.
- To establish a set of best practices which can inform road agencies on the benefits of using Sentinel data in other countries.

➔ *Know more:* https://earsc.org/sebs/sector-workshop-1-road-infrastructure-management/

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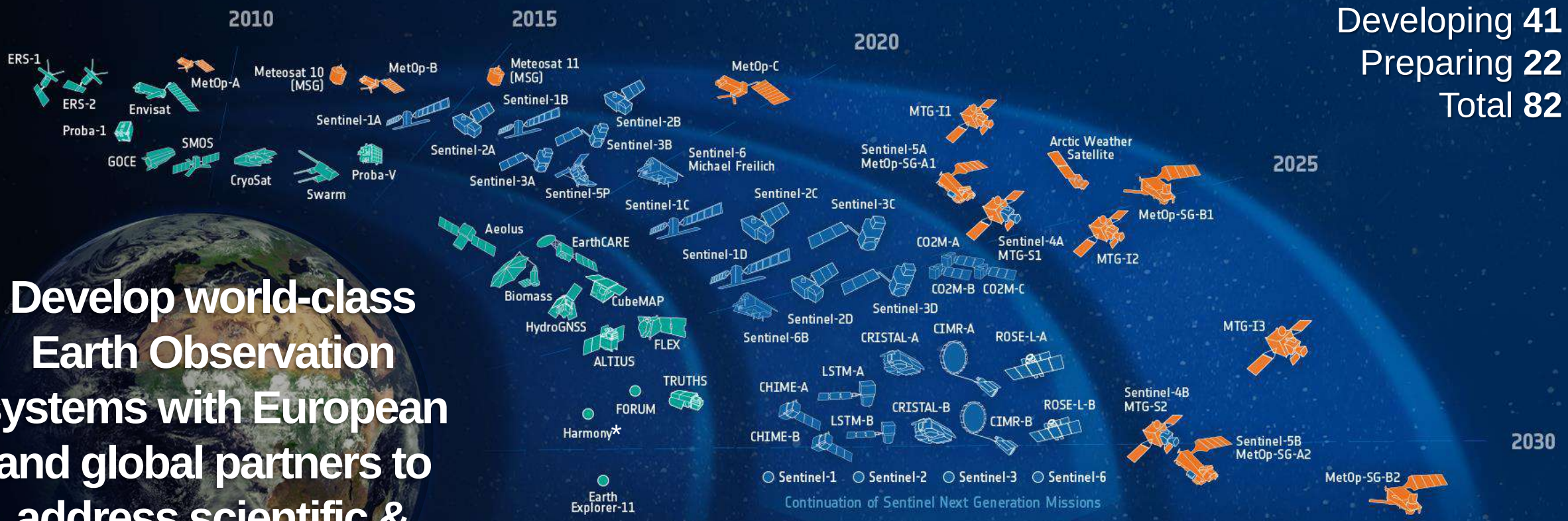
- Other relevant examples

ESA's Earth Observation Mission

Satellites

Heritage **04**
Operational **15**
Developing **41**
Preparing **22**
Total **82**



Develop world-class Earth Observation systems with European and global partners to address scientific & societal challenges

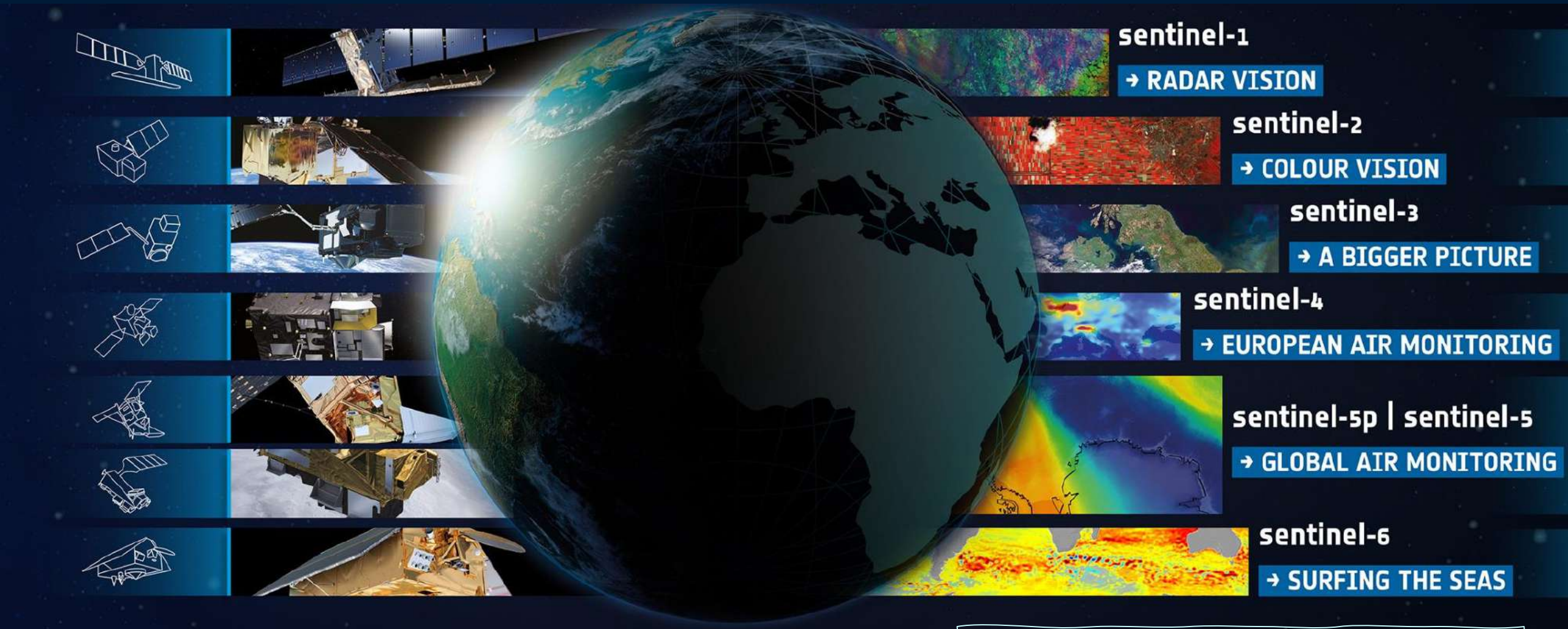
Science | Copernicus | Meteorology

*Pending final mission selection

The Copernicus Programme

➔ *Know more: https://copernicus.eu*

Copernicus Sentinels



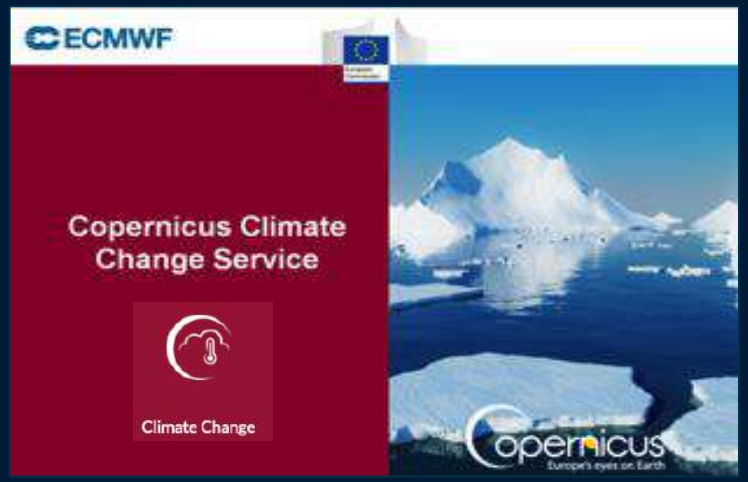
➔ *Know more: https://sentinels.copernicus.eu*

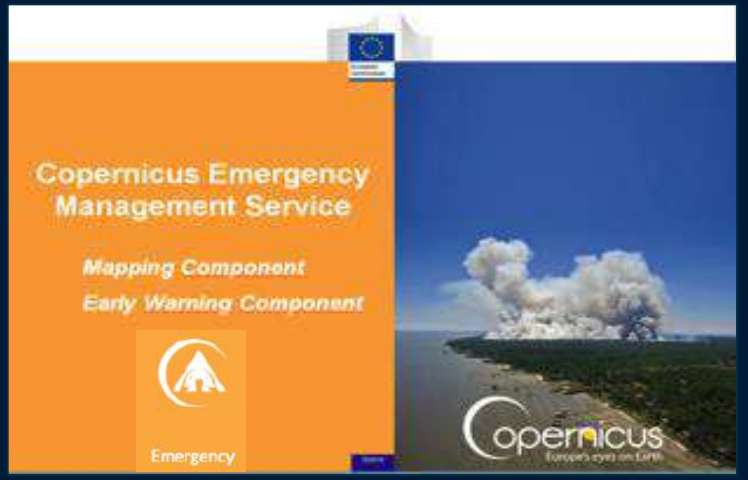
→ THE EUROPEAN SPACE AGENCY

Copernicus Contributing Missions

➔ *Know more: https://spacedata.copernicus.eu*

Copernicus Services



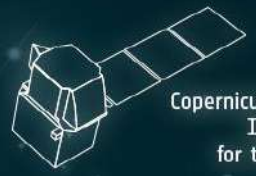


➔ *Know more: https://copernicus.eu/services*

PROGRAMME OF THE EUROPEAN UNION

Copernicus
Europe's eyes on Earth

co-funded with esa



CHIME
Copernicus Hyperspectral Imaging Mission for the Environment

soil properties
crop health
biodiversity
water quality

ROSE-L
L-band Radar Observing System

geohazards
polar ice
forest management
food security
maritime surveillance

LSTM
Land Surface Temperature Monitoring

sustainable agriculture
water resources management
drought
urban heat islands

CIMR
Copernicus Imaging Microwave Radiometer

sea-ice concentration/extent
global ocean and cryosphere
soil moisture and vegetation

CO2M
Copernicus Anthropogenic Carbon Dioxide Monitoring

carbon dioxide and methane from human activity

CRISTAL
Copernicus Polar Ice and Snow Topography Altimeter

sea-ice thickness
ice sheets and glaciers
snow
polar oceanography
coastal and inland waters

➔ *Know more:* https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

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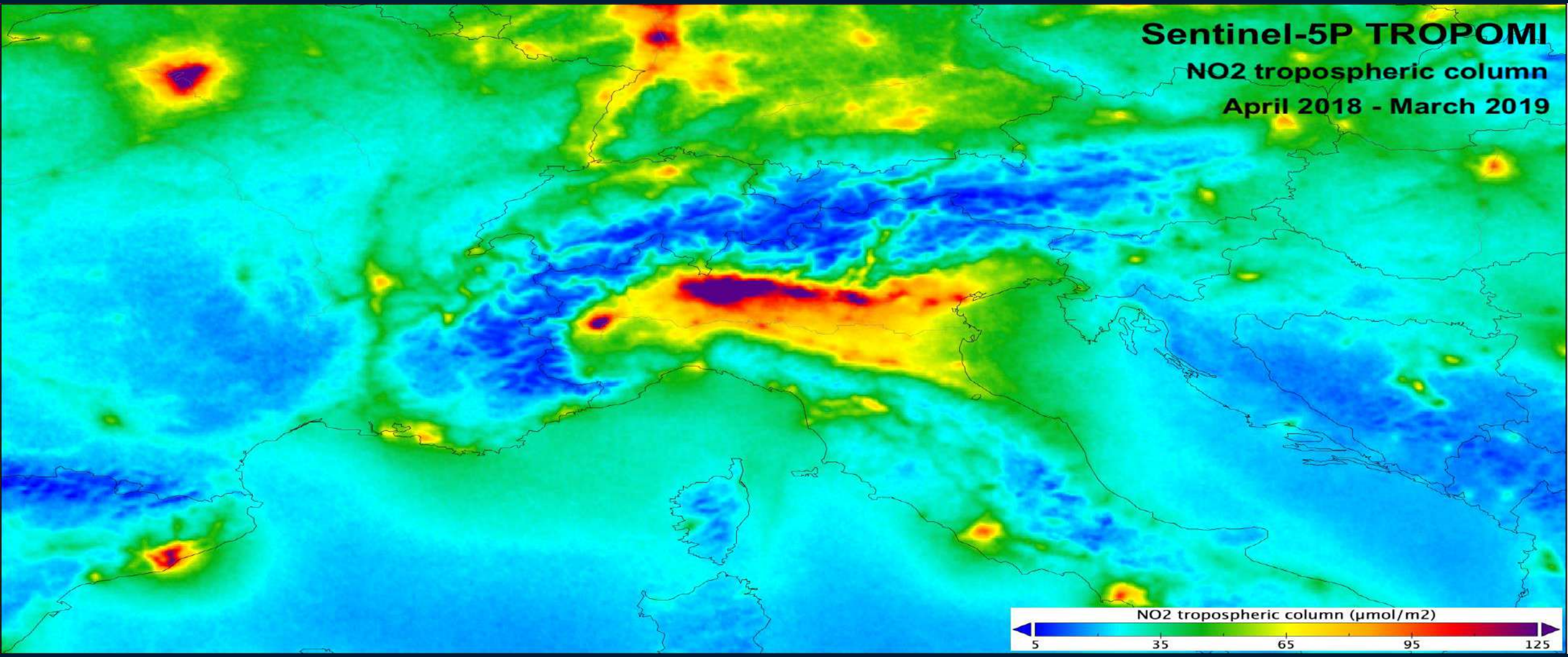
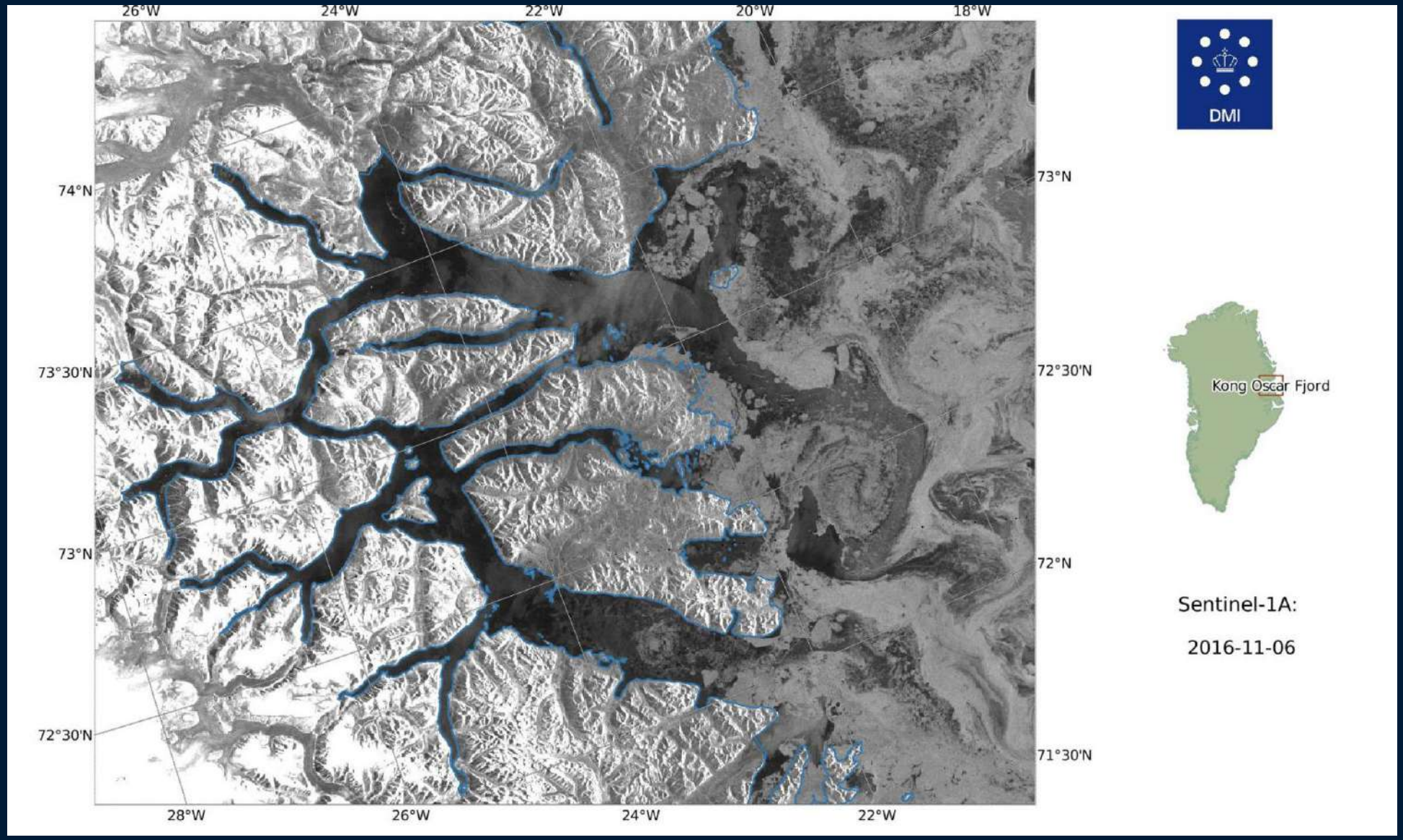
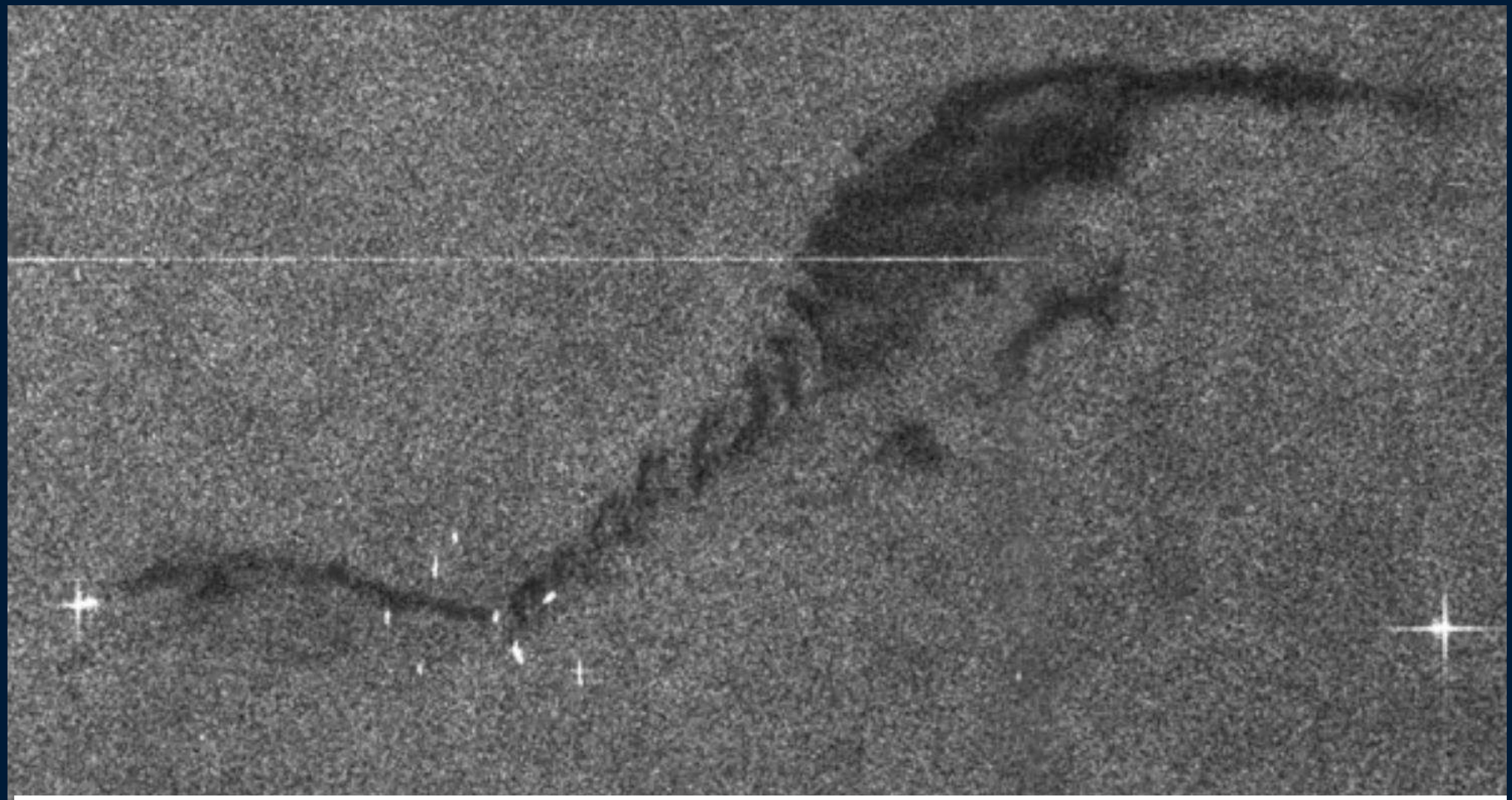
Other examples: air quality



Other examples: sea ice charting



Other examples: oil spills detection



Oil spill observed off the Belgian coast near Zeebrugge on 08/10/2015 after a collision between two vessels. Contains modified Copernicus Sentinel data [2015].

Other examples: vessels detection

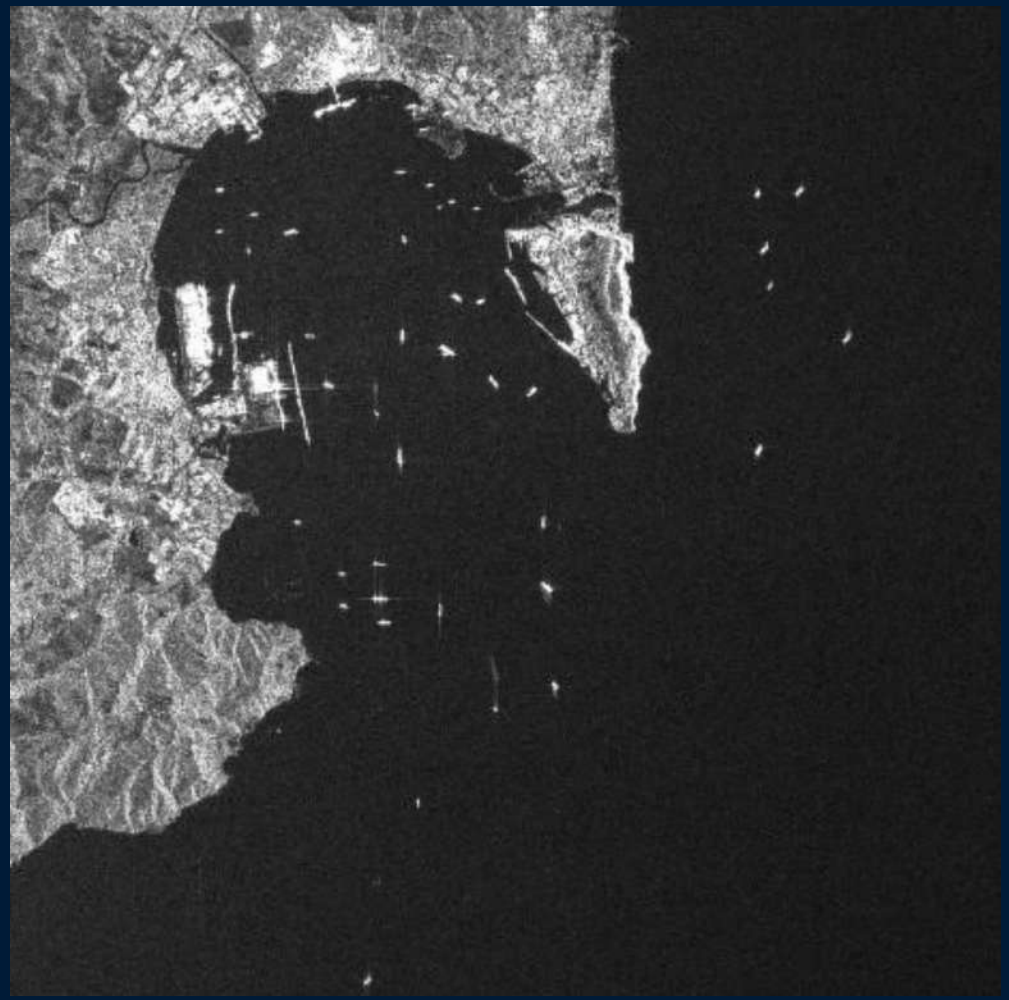
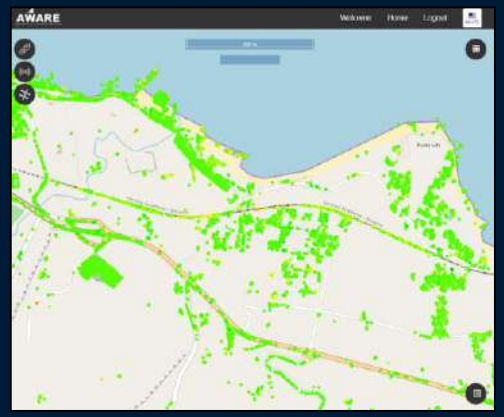
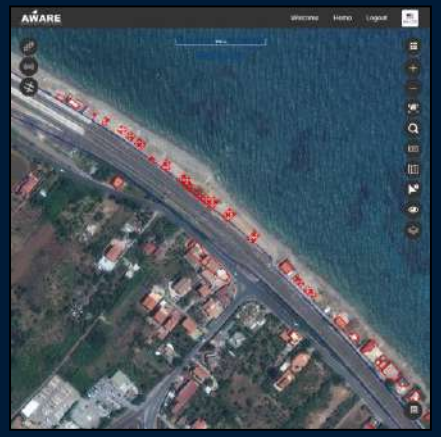


Illustration of vessels observed between Gibraltar and Algesiras on September 2017, Copernicus Sentinel Data [2017]

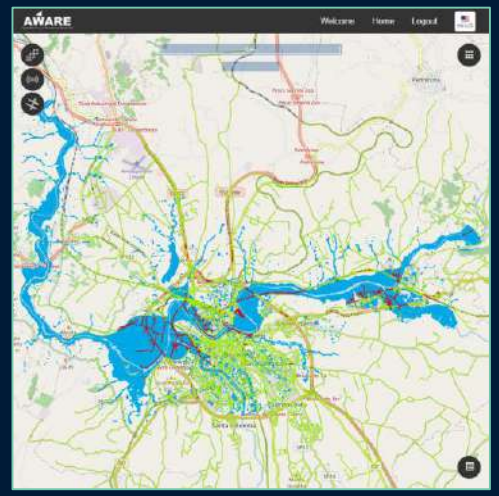
Other research areas examples



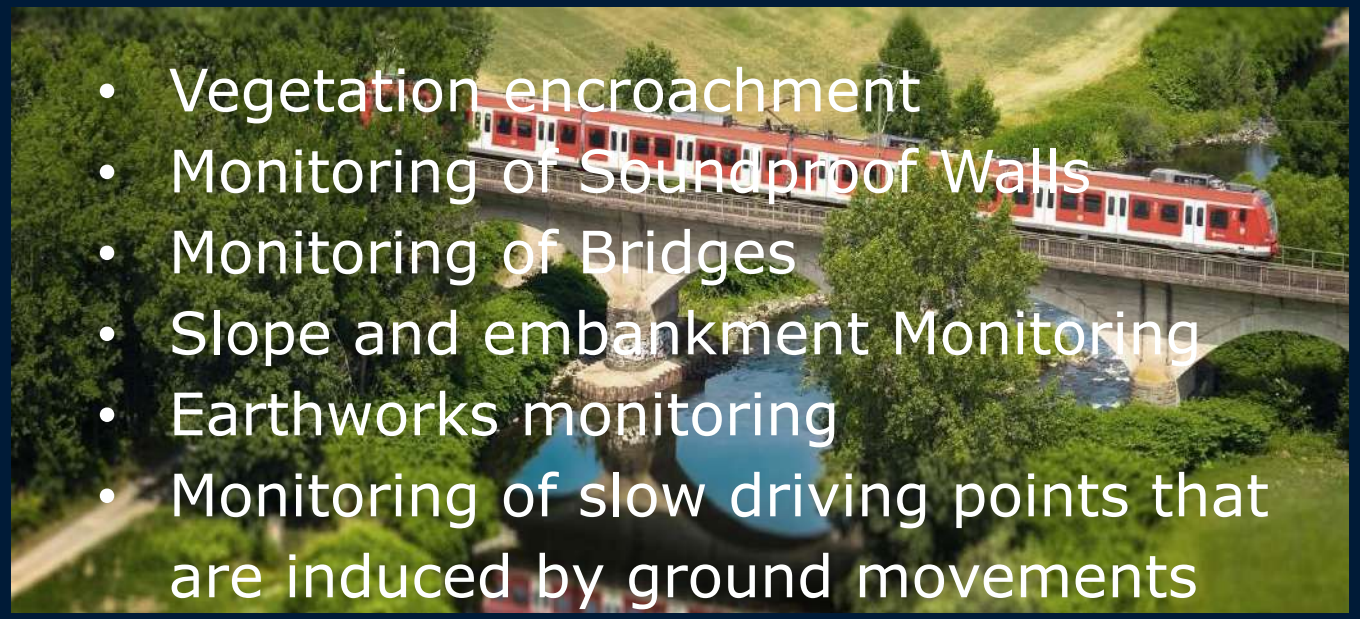
VHR hydrogeological stability monitoring



Buildings monitoring: VHR change detection along railways



Enhanced flood footprint



- Vegetation encroachment
- Monitoring of Soundproof Walls
- Monitoring of Bridges
- Slope and embankment Monitoring
- Earthworks monitoring
- Monitoring of slow driving points that are induced by ground movements
- .....

➔ *Know more:* EO4infrastructures

DESTINATION EARTH

UNLOCKING THE POTENTIAL OF DIGITAL MODELLING

Utilising high-performance computing, machine learning and satellite data, the digital twins of **Destination Earth** will provide us with an accurate representation of the past, present and future changes of our world.

European Union

ECMWF esa EUMETSAT

Conclusions

- Earth Observations and the Copernicus Programme provide information that can support transport management and related policies
- Existing use cases provide practical examples for interested newcomers
- Research ongoing in ESA in cooperation with transport authorities to develop further products tailored for the sector

Thank you!

Questions? Email Alessandra.Tassa@esa.int