Exploring the potential of Copernicus Sentinel missions in environmental research through open access and knowledge sharing

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Impact a better future

Introduction

- Forest ecosystems facing rapid climate change impacts; urgent need for timely monitoring.
- Earth Observation satellites provides a possibility to observe forests and not only, constantly and at a global scale 24/7
- Earth observation can be defined as a process of acquiring observations of the Earth's surface and atmosphere via remote sensing methods.
- EO data can be used to identify forest boundaries, distinguish tree species, estimate biomass, and quantify forest health.
- Integral to monitoring forest governance through identification of illegal activities, forest harvests, forest fires, the state of secondary growth, and settlements and agriculture.

Credits: contains modified Copernicus Sentinel data (2023), processed by ESA

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The Copernicus Programme

Europe's eyes on Earth – flagship programme of the European Union

- Monitors the Earth, its environments and ecosystems
- Prepares for emergency situations (security risks, natural or man-made disasters)
- **All data provided under full, free and open policy**
- **16 TB of data collected everyday**
- Tool for economic development and a driver for digital economy

Families of satellites
dedicated to Copernicus **"The Sentinels"**

~30

Contributing missions
from National, European or International organisations

European Commission
esa European Space Agency
FRONTEX EUROPEAN BORDER AND COAST GUARD AGENCY
EMSA
ECMWF
EUMETSAT
European Environment Agency
Mercator Ocean Ocean Forecasters
SatCen European Union Satellite Centre

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Copernicus Sentinels

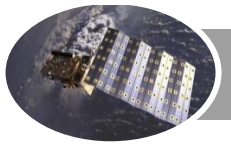
Sentinel-1A/B/C/D: Radar Mission — 3 Apr. 2014/ 22 Apr. 2016-23 Dec. 2021/2024/TBD

Sentinel-2A/B/C/D: High Res. Optical Mission — 23 Jun. 2015/ 7 Mar. 2017/2024/TBD

Sentinel-3A/B: Medium Res. Imaging and Altimetry Mission — 16 Feb. 2016/ 25 Apr. 2018/TBD/TBD

Sentinel-4A/B: Geostationary Atmospheric Chemistry Mission — 2024/2027

Sentinel-5P: Low Earth Orbit Atmospheric Chemistry Mission — 13 October 2017



Sentinel-5A/B: Low Earth Orbit Atmospheric Chemistry Mission — 2024

Sentinel-6A/B: Altimetry Mission — 21 Nov. 2020/2025

Sentinel-1 | Radar Mission

Payload: C-band synthetic aperture radar (SAR) at 5.405 GHz

Constellation: Twin satellites - same orbit (180° apart) - 12-day orbit

Orbit: Polar, Sun-synchronous at an **altitude of 693 km**

Revisit frequency: max. 12 days at equator (ENVISAT– 35 days)

Coverage: Global (provides an all-weather, day-and-night acquisitions)

Life: Minimum of 7 years of mission life.

Four operational modes

Mode	Swath	Resolution
Interferometric wide-swath (IW)	250 km	5×20 m
Wave-mode (WV)	20×20 km (at 100 km intervals)	5×5 m
Strip map (SM)	80 km	5×5 m
Extra wide-swath (EW)	400 km	20×40 m

Builds on heritage SAR systems on ERS-1, ERS-2, Envisat and Radarsat

Single or dual polarization: VV, HH, VV+VH, HH+HV

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-1

Sentinel-2 | High resolution optical mission

Payload: Multispectral instrument - 13 spectral bands

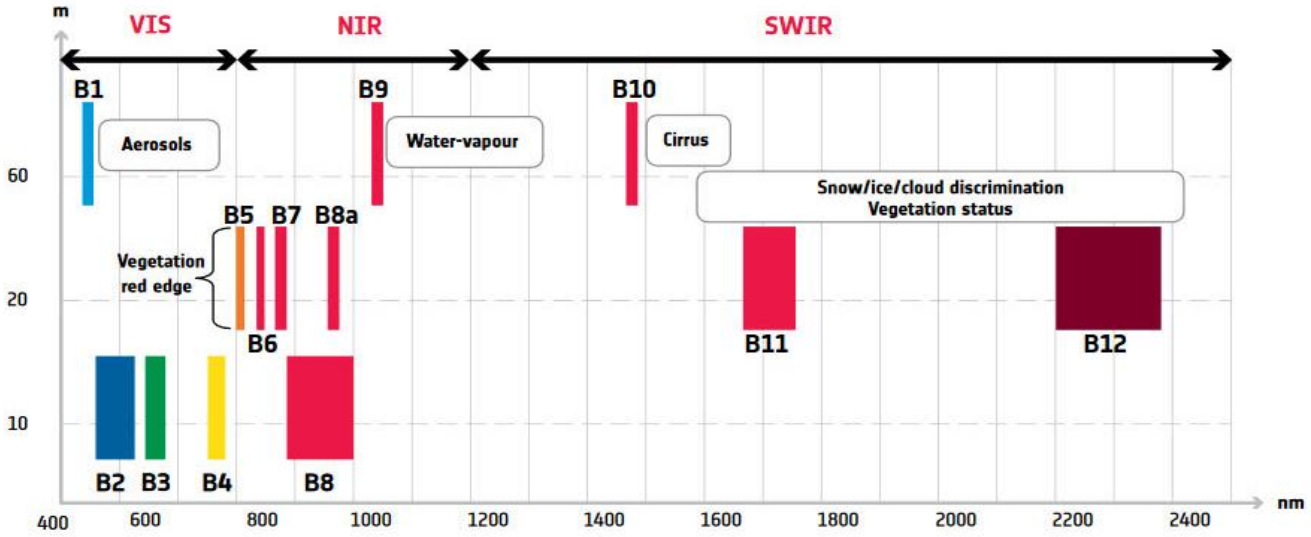
Constellation: Twin polar-orbiting satellites in the same orbit

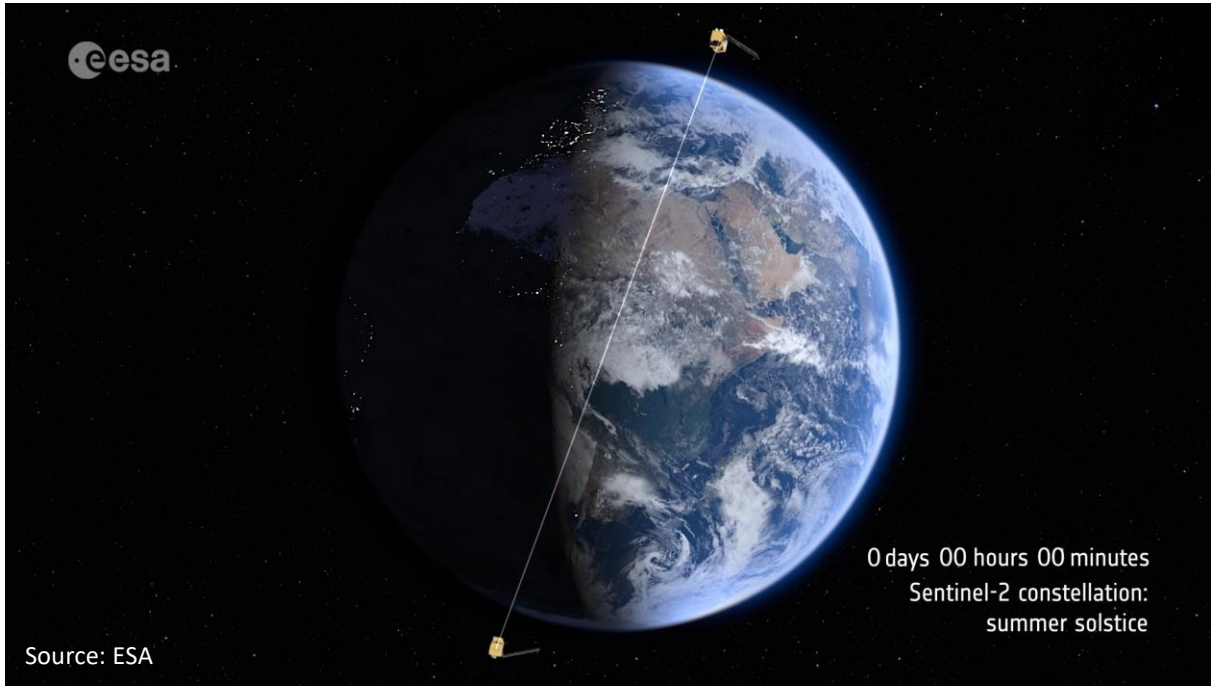
Orbit: Polar, Sun-synchronous at altitude of 786 km

Revisit frequency: 5 days at equator

Coverage frequency: 5 days at equator to < 1 day at high latitudes

Life: Minimum of 7.25 years





Products available to users:

- **Level-1C** - Top-of-atmosphere reflectance in cartographic geometry
- **Level-2A** - Bottom-of-atm. reflectance in cartographic geometry (systematically generated over Europe, globally by the end of 2018)

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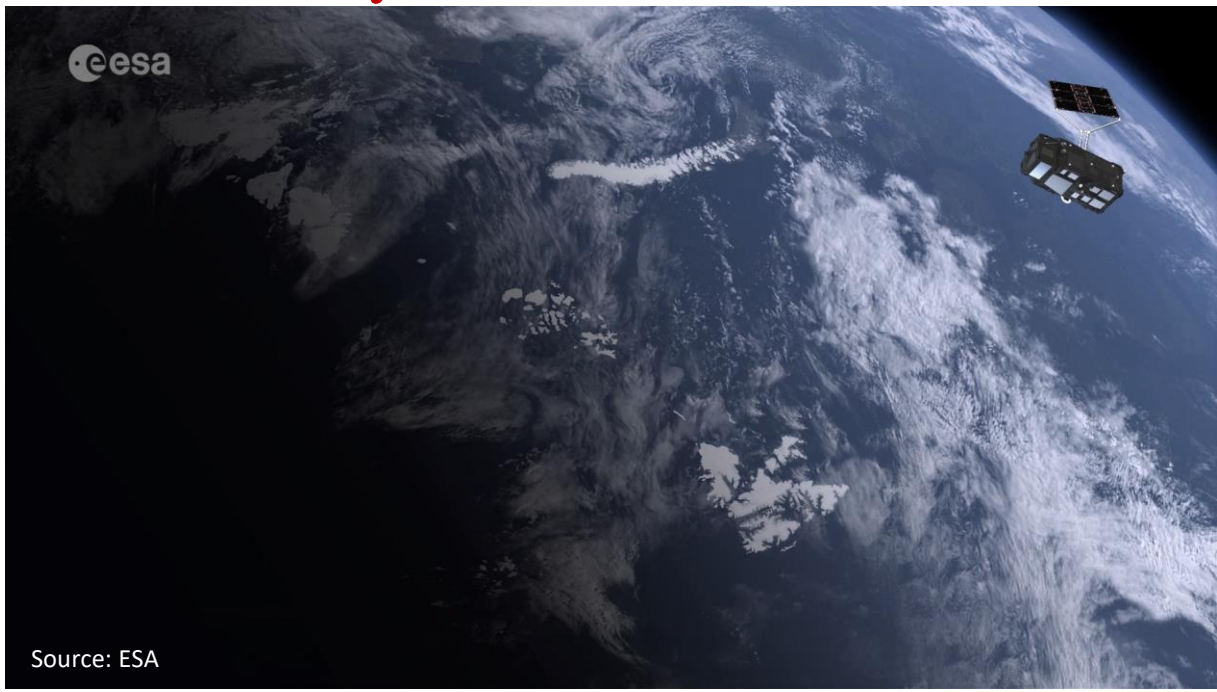
Sentinel-3 | Medium Resolution Imaging and Altimetry Mission

- **Payload: 4 instruments:**
  - Ocean and Land Colour Instrument **(OLCI)**
  - Sea and Land Surface Temperature Radiometer **(SLSTR)**
  - Synthetic Aperture Radar Altimeter **(SRAL)**
  - MicroWave Radiometer (**MWR)**
- **Constellation:** Twin satellites - same orbit (180° apart)
- **Orbit:** Polar, Sun-synchronous at altitude of 815 km
- **Revisit frequency:** < 1 day repeat cycle for OLCI/SLSTR with 2 satellites, 27 days for the topography package
- **Coverage:** Global (day-and-night acquisitions)
- **Life:** Minimum of 7 years (consumables for 12 years)



Source: ESA

Instruments used for land monitoring applications:

- **OLCI:** Land product - global vegetation index or Fraction of Absorbed Photosynthetically Active Radiation in plant canopy.
- **SLSTR:** biomass burning (wildfire detection) surface temperature monitoring (LST

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Copernicus Sentinels

Sentinel-4

- **Payload: UVN (Ultraviolet Visible Near-Infrared) -** passive imaging spectrometer hosted on the MTG satellites
- Trace gases and aerosols in the atmosphere and pollutants: nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), formaldehyde (HCHO)
- **Orbit: geostationary orbit** at altitude of about 35786 km
- **Revisit frequency:** 60 min
- **Life:** Minimum of 8.5 years

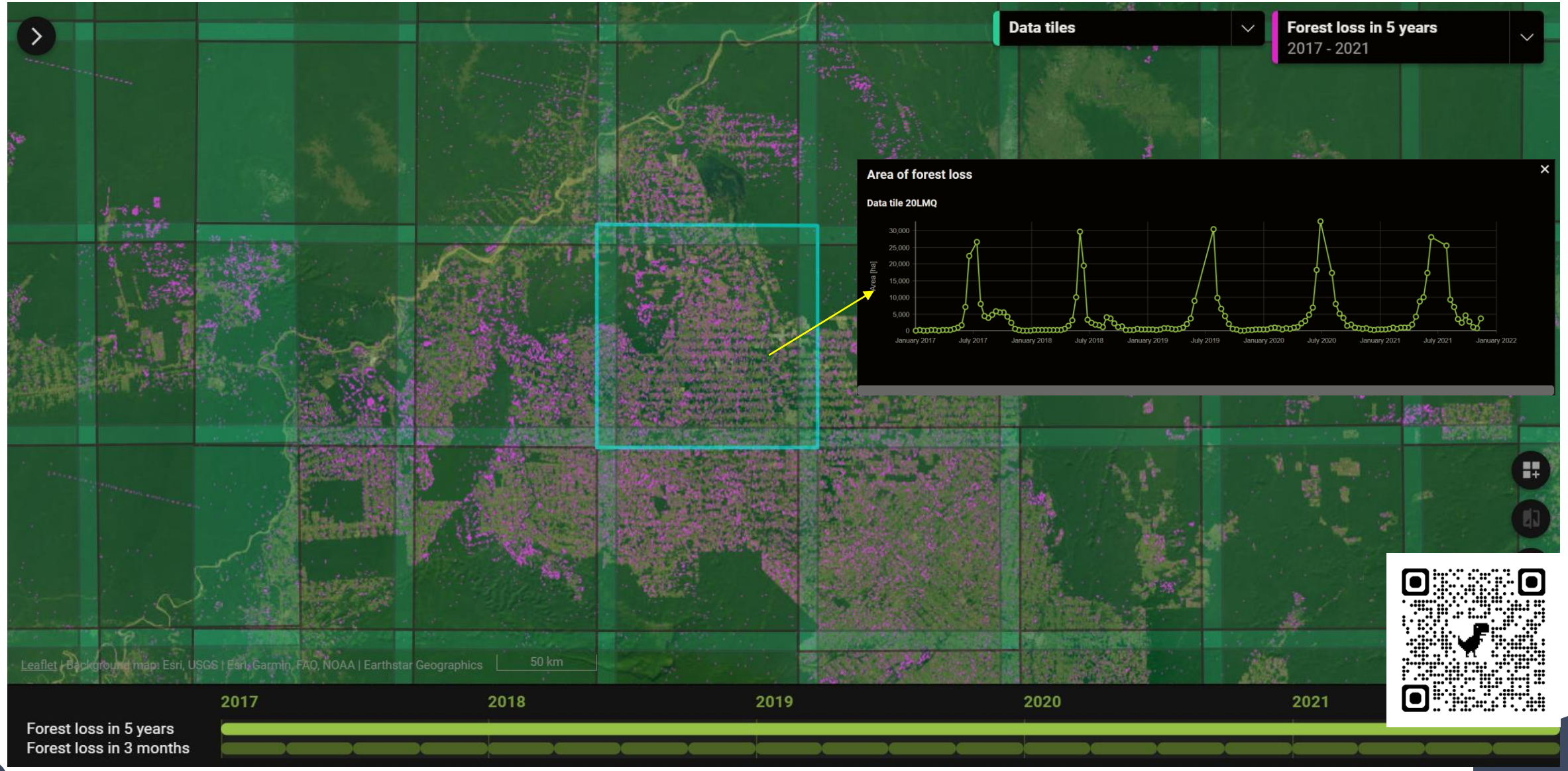
Sentinel-5P

- **Payload: Tropospheric Monitoring Instrument** (TROPOMI) – passive grating imaging spectrometer
- **Orbit:** Polar, Sun-synchronous at altitude of 824 km and in-flight formation with Suomi-NPP (US NOAA)
- **Revisit frequency: Daily global coverage** (13:30 local solar time)
- **Swath width of ~2600 km**
- **Life:** Minimum of 7 years (consumables for 10 years)

Sentinel-6

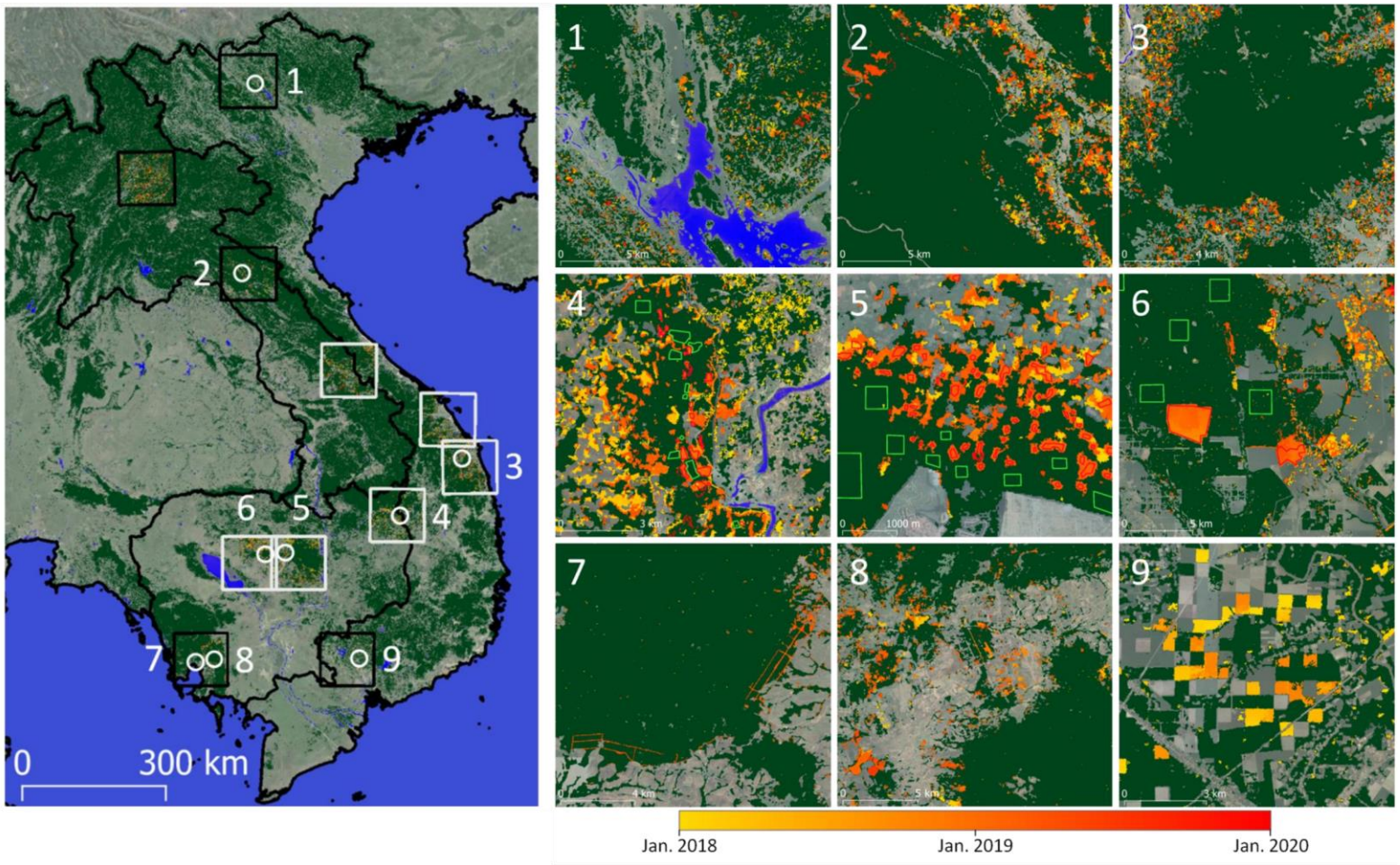
- Carries a radar altimeter to measure **global sea-surface height**.
- **Payload:**
  - Poseidon-4 - a Ku band nadir-pointing Synthetic Aperture Radar altimeter
  - Advanced Microwave Radiometer for Climate (AMR-C)
  - High-Resolution Microwave Radiometer (HRMR)
- **Orbit: Non-sun-synchronous** orbit at a mean altitude of 1336 km inclined at 66º
- Revisit frequency: 10-day repeat cycle
- **Life:** Minimum of 7 years

Sentinel-1 | Applications

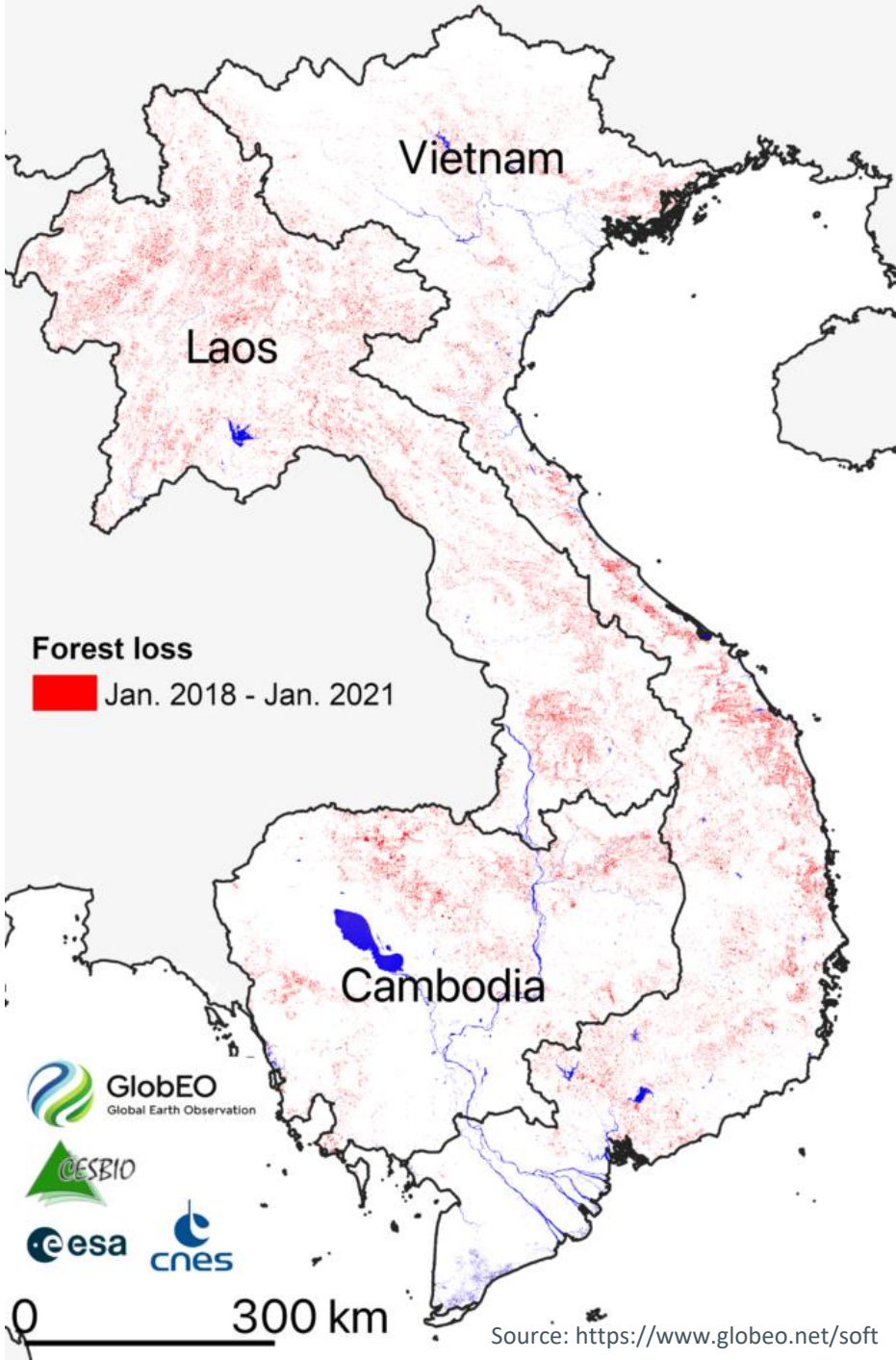


Source: https://sen4ama.gisat.cz/

Sentinel-1 | Applications

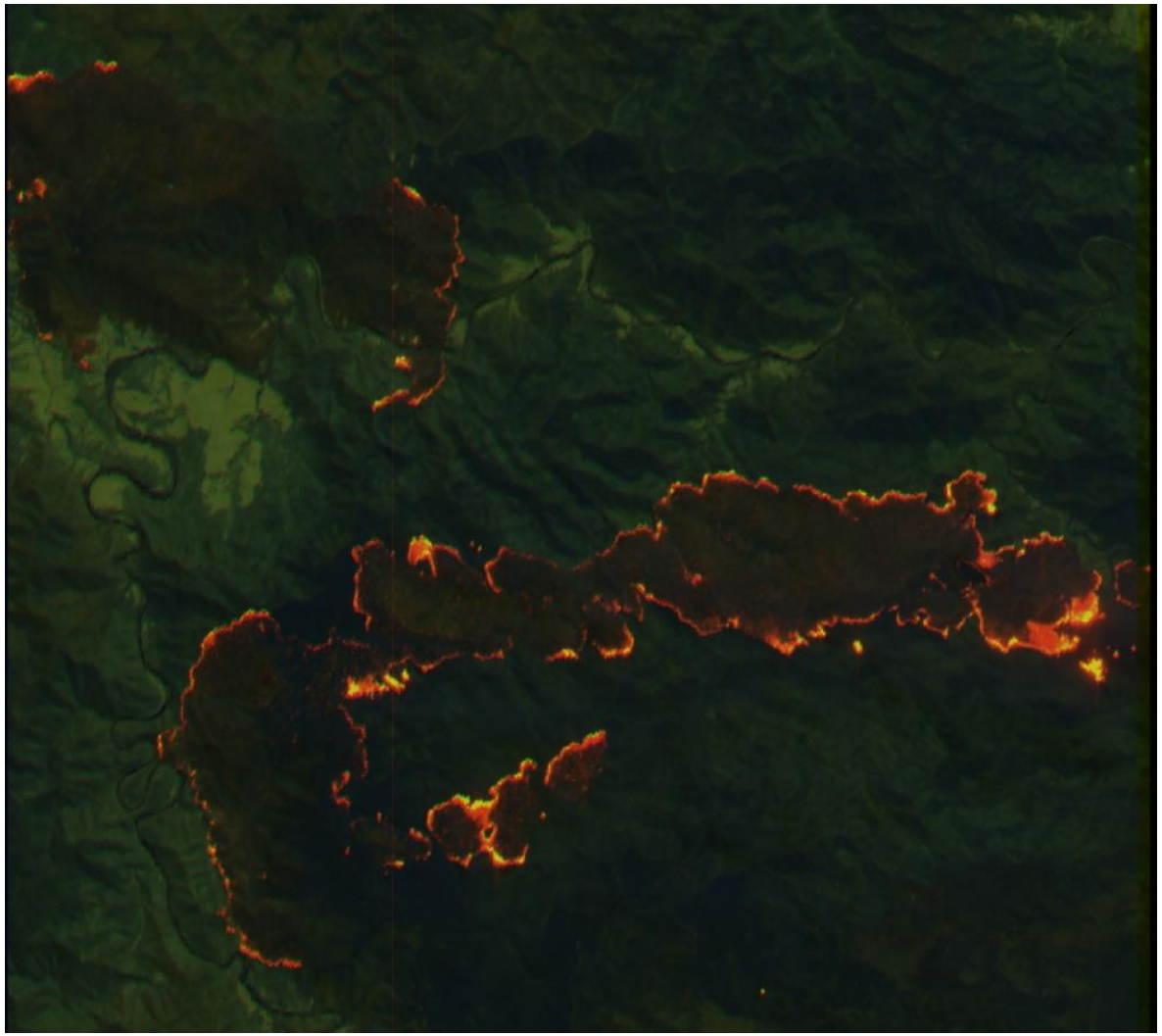


Deforestation detection map over Laos, Cambodia and Vietnam from 2018 to 2020. [Credits: EO Science for Society – ESA]
Source: https://eo4society.esa.int/projects/soft/

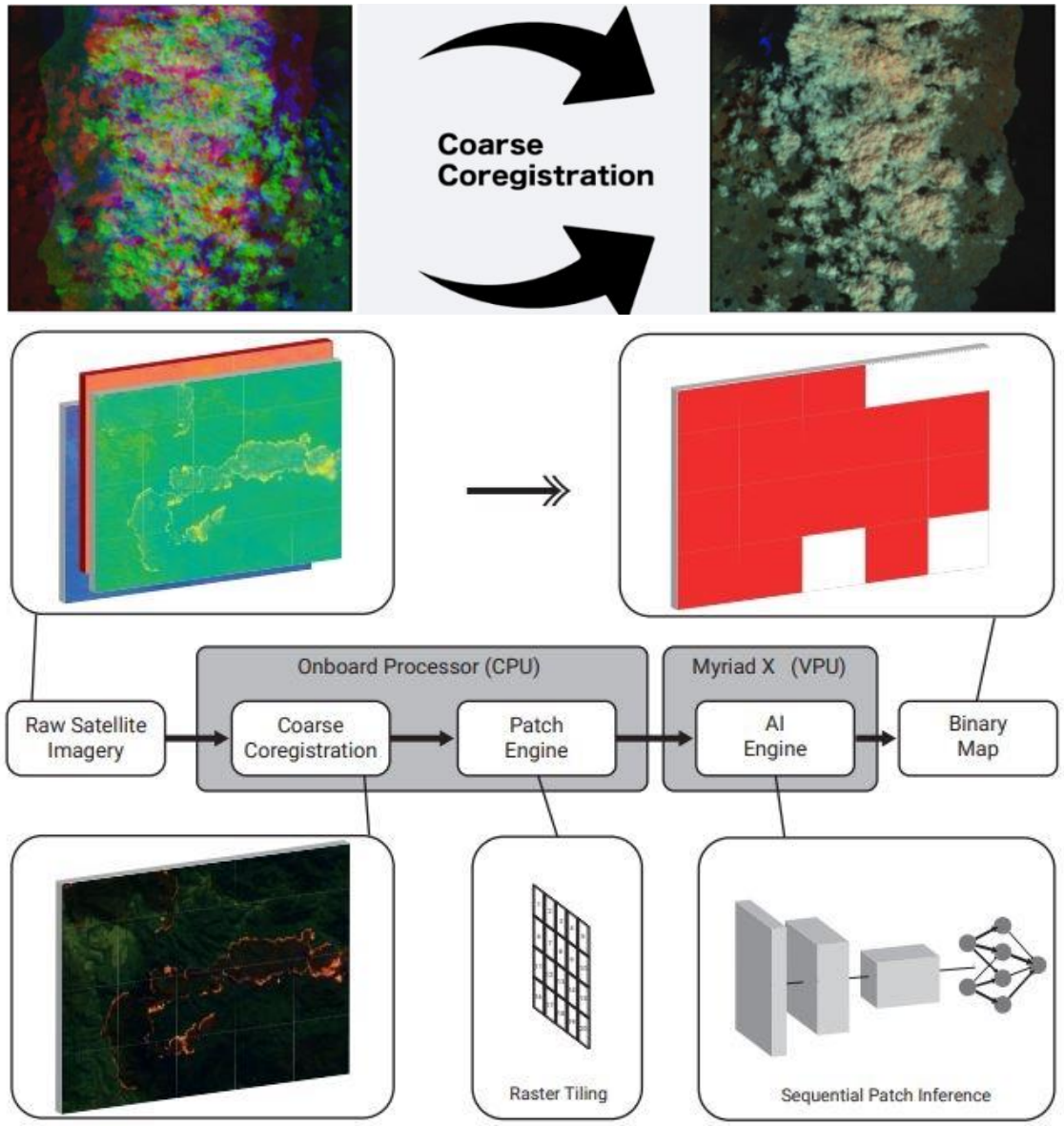


Source: https://www.globeo.net/soft

Sentinel-2 | Applications



Wildfire detected in raw Copernicus Sentinel-2 raw imagery using the co-registration technique.
Source: Meoni, Gabriele, et al. "THRawS: A Novel Dataset for Thermal Hotspots Detection in Raw Sentinel-2 Data." arXiv preprint arXiv:2305.11891 (2023).

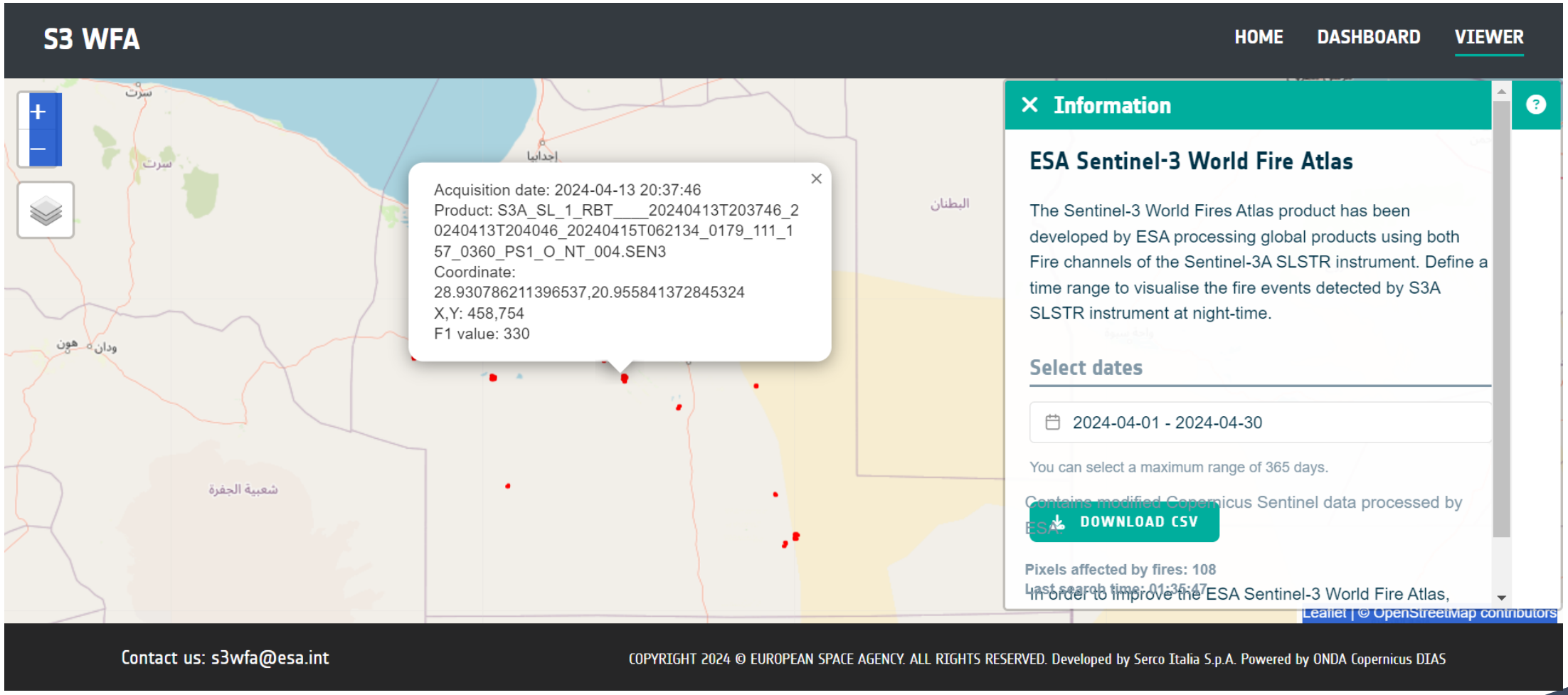


Processing scheme of the raw wildfire detection application from Sentinel-2 imagery.
Source:Del Prete et al, 2023

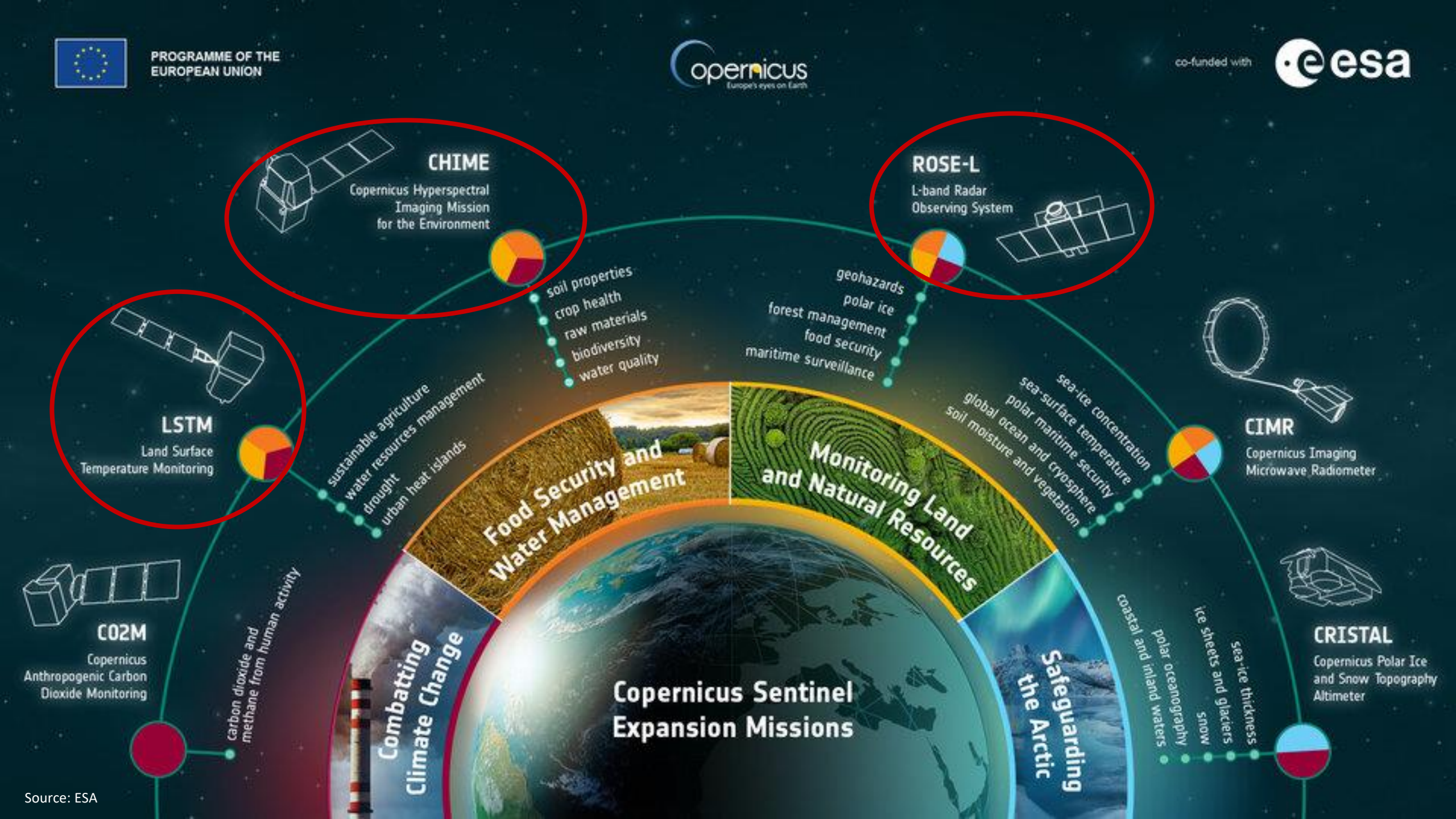
Sentinel-2 | Applications

Reforestation in Rio Capim, Amazon from 1985 to 2022 with Sentinel-2 and USGS Landsat data.
Source: Heinrich, V.H.A., Vancutsem, C., Dalagnol, R. et al. The carbon sink of secondary and degraded humid tropical forests. Nature 615, 436–442 (2023). https://doi.org/10.1038/s41586-022-05679-w

Sentinel-3 | Applications



Worldwide fires from the World Fire Atlas between May 2016 and June 2023
Source: https://s3wfa.esa.int/.


PROGRAMME OF THE EUROPEAN UNION
copernicus
Europe's eyes on Earth
co-funded with
esa
CHIME
Copernicus Hyperspectral Imaging Mission for the Environment
ROSE-L
L-band Radar Observing System
LSTM
Land Surface Temperature Monitoring
CIMR
Copernicus Imaging Microwave Radiometer
CO2M
Copernicus Anthropogenic Carbon Dioxide Monitoring
CRISTAL
Copernicus Polar Ice and Snow Topography Altimeter
soil properties
crop health
raw materials
biodiversity
water quality
geohazards
polar ice
forest management
food security
maritime surveillance
sustainable agriculture
water resources management
drought
urban heat islands
sea-ice concentration
sea-surface temperature
polar maritime security
global ocean and cryosphere
soil moisture and vegetation
carbon dioxide and methane from human activity
coastal and inland waters
polar oceanography
ice sheets and glaciers
snow
sea-ice thickness
Food Security and Water Management
Monitoring Land and Natural Resources
Combatting Climate Change
Safeguarding the Arctic
Copernicus Sentinel Expansion Missions

Source: ESA

EARTH EXPLORERS

Pioneering scientific and technical excellence

cryosat
ICE

goce
GRAVITY FIELD

smos
WATER

swarm
MAGNETIC FIELD

aeolus
WIND

earthcare
CLOUD AND AEROSOL

biomass
FOREST CARBON

flex
PHOTOSYNTHESIS

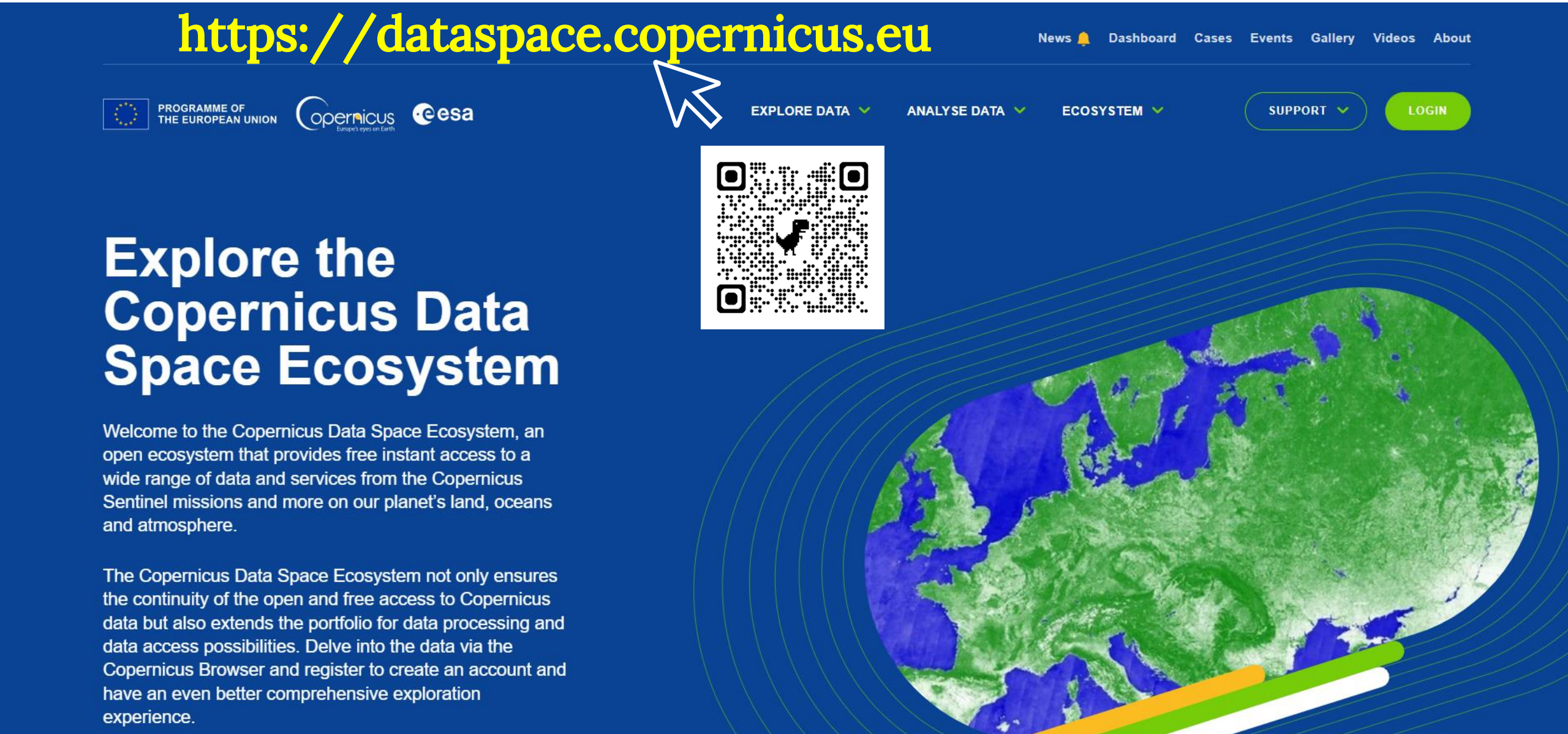
forum
THERMAL RADIATION

harmony
SURFACE DYNAMICS

Source: ESA

Data Access | Copernicus Data Space Ecosystem

https://dataspace.copernicus.eu



Data Access | Copernicus Land Monitoring Service

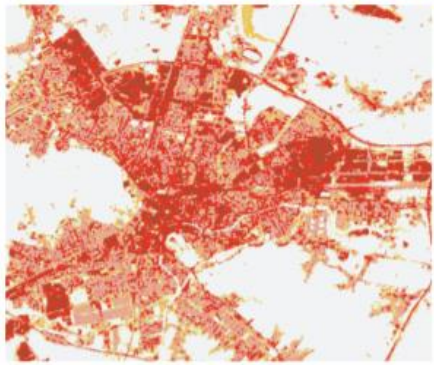
Access: (Free registration) → **https://land.copernicus.eu**

Available datasets provided by the Copernicus Global Land Service component:

- Land Cover
- Vegetation (e.g. biophysical variables – LAI, fAPAR; vegetation indexes – NDVI)
- Energy (e.g. LST, top-of-canopy reflectance, surface albedo)
- Water (e.g. water bodies, lake water quality, lake water temperature, water level)
- High resolution hot spot monitoring (land cover change in hight resolution over areas of
- Cryosphere

Coverage: Global, regional and European

Use case examples: Forest damage monitoring; carbon storage in land and soil



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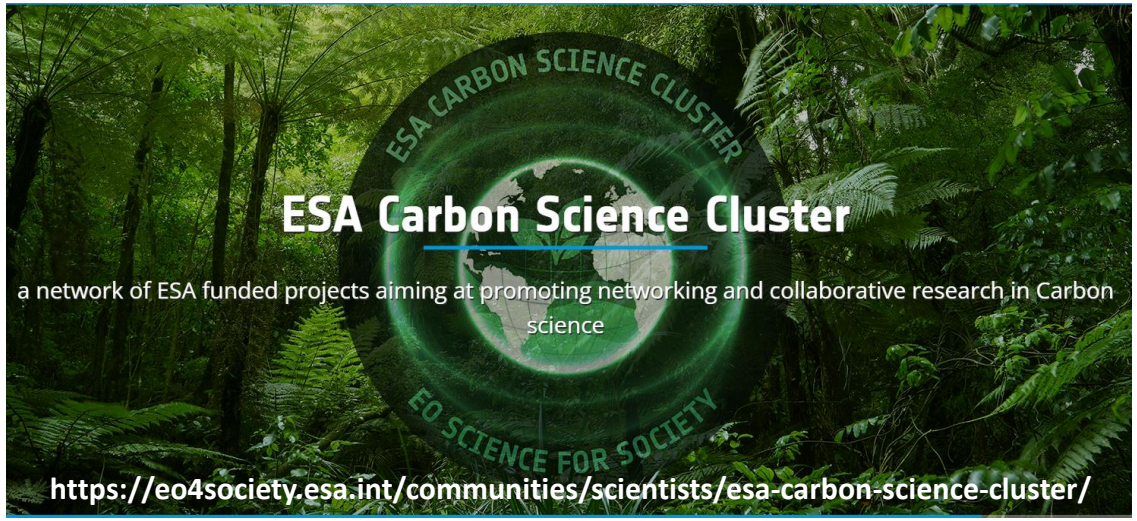
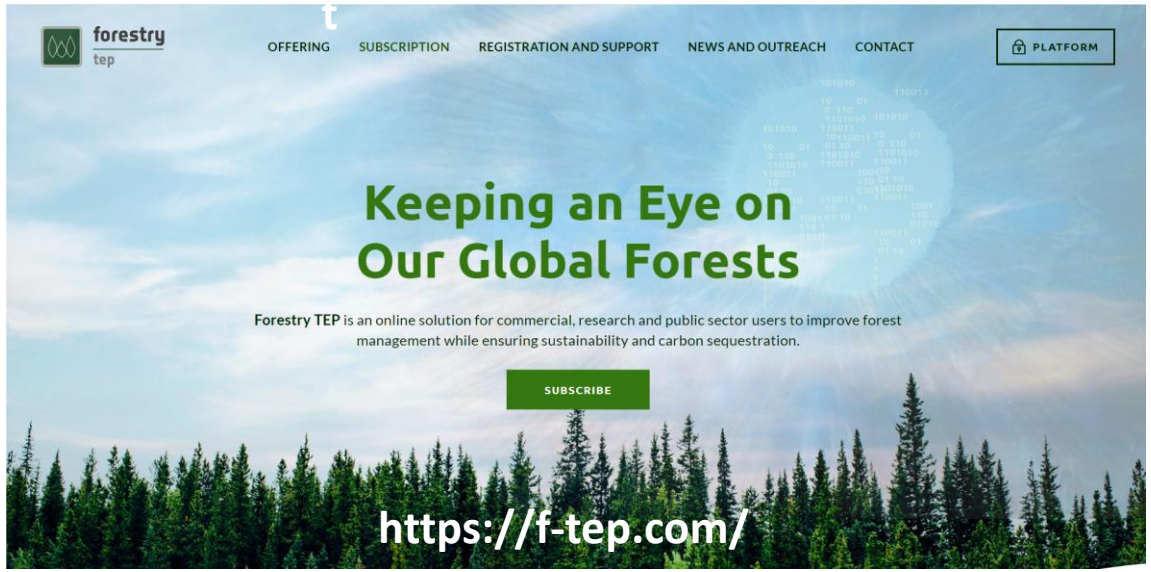
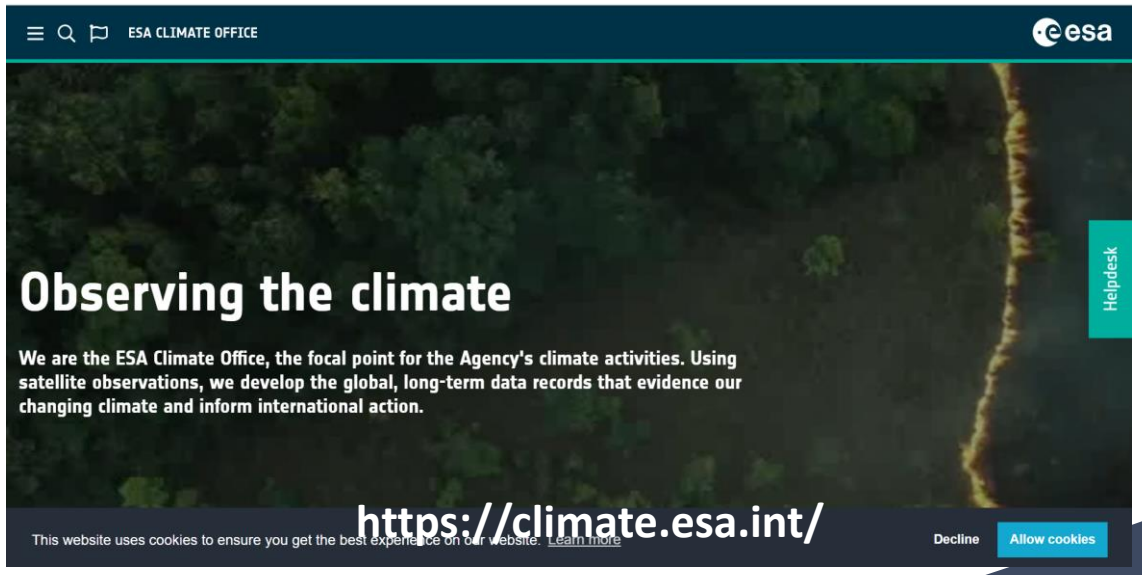
Platforms and opportunities







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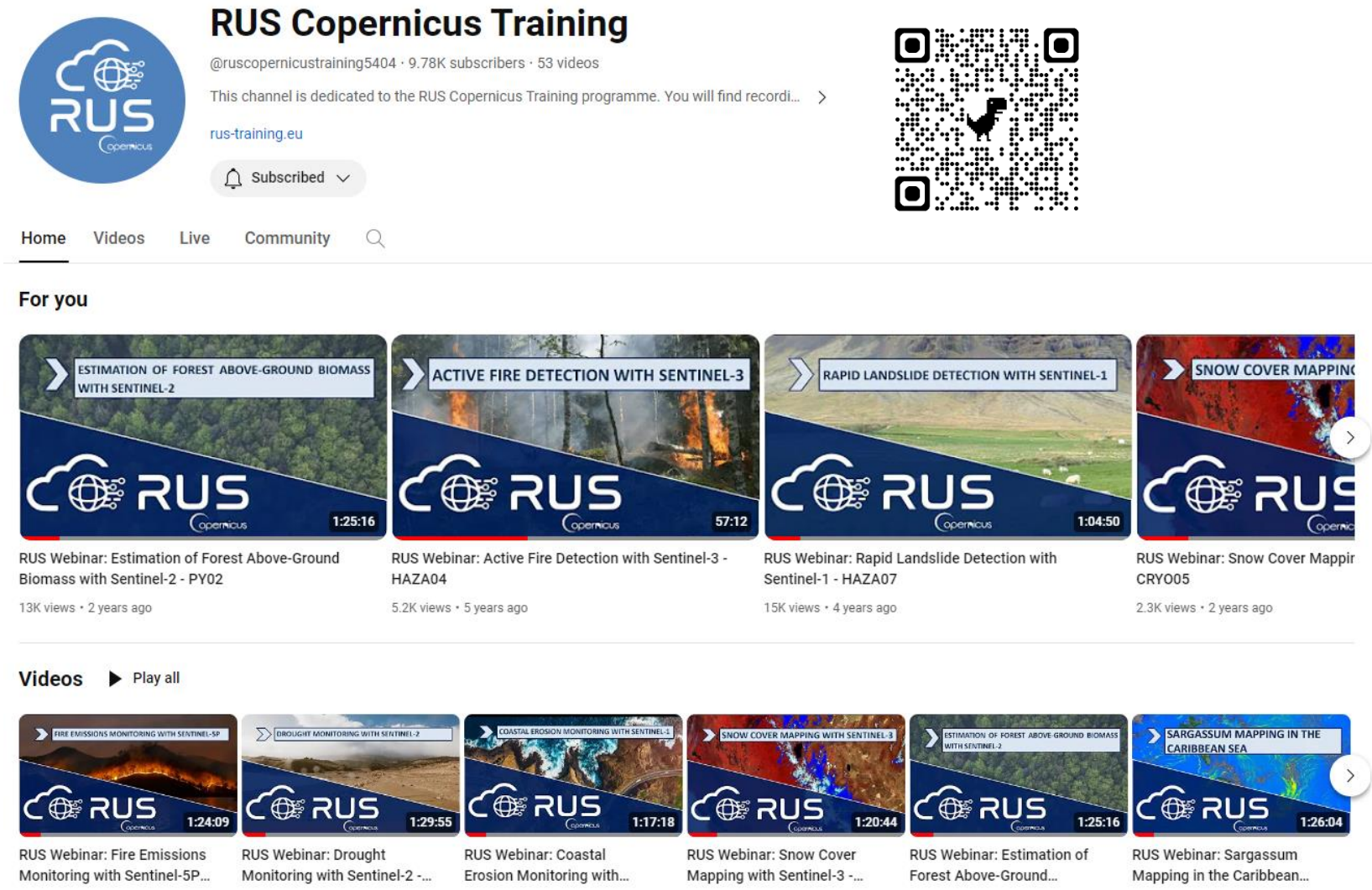
Knowledge sharing and learning materials



Access open-access training materials on:

- Land monitoring
- Ocean/Coasts
- Risk Monitoring
- Hydrology
- Geology/Cryology
- Atmosphere
- Data Processing methods: Python, R

https://eo4society.esa.int/resources/copernicus-rus-training-materials/

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Remarks from the presentation:

- Open access to Copernicus Sentinel EO data revolutionizes forest monitoring: enables precise vegetation tracking, biomass estimation, and forest disturbance detection.
- SAR and optical data acquisition, regardless of weather conditions, aids monitoring of deforestation and degradation, posing the challenge of extracting meaningful indicators from vast datasets.
- Transparent, understandable environment monitoring methods foster collaboration for sustainable management including biodiversity conservation, democratizing scientific research.

Feel free to contact!

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