Copernicus Data Space Ecosystem Get ready for the EO data revolution!

EARSC EXPANDEO

Brussels, 13-14 June 2023

dataspace.copernicus.eu

AGENDA

1. About Copernicus Data Space Ecosystem (Jan Musiał)
2. Copernicus Data Space Ecosystem vision (Jurry de la Mar)
3. OpenEO API (Dennis Clarijs)
4. Use case – Common Agriculture Policy (Andras Zlinszky)
5. Q&A session (all)

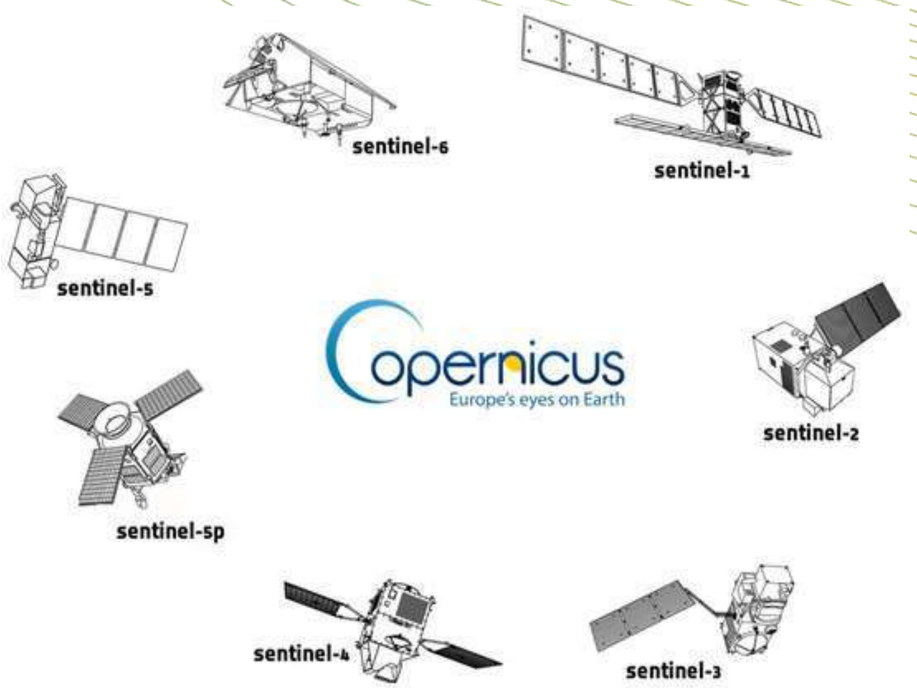
Copernicus Data Space Ecosystem - Earth Observation (EO) data access, discovery, visualization and processing (R)evolution

Jan Musiał, CloudFerro

About Copernicus

Copernicus is the Earth Observation (EO) component of the European Union's Space programme, looking at our planet and its environment to benefit all European citizens. It offers information services that draw from **satellite Earth Observation and in-situ (non-space) data.** The information services provided are **free** and **openly** accessible to users.

The European Commission manages the Programme. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan.

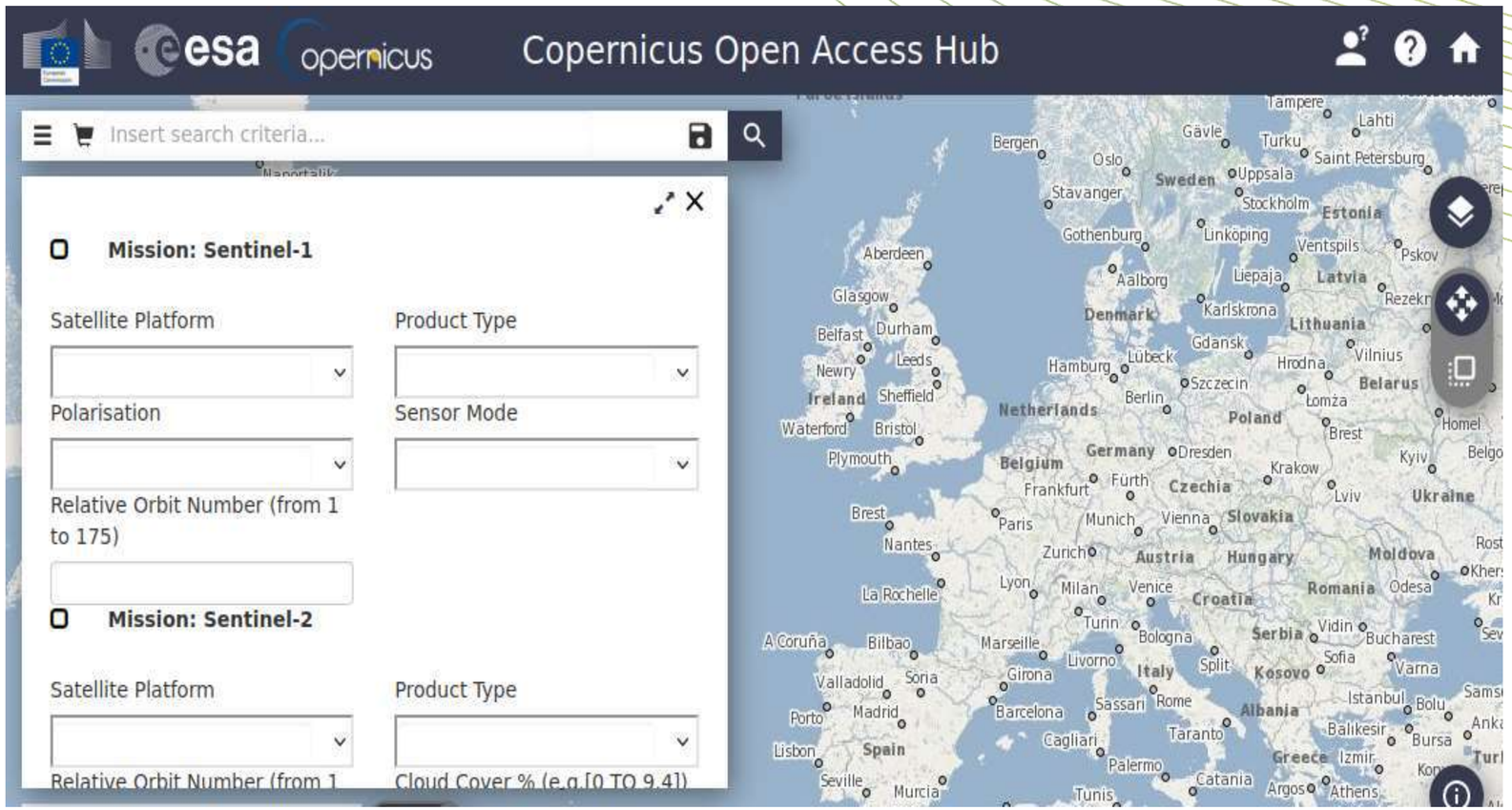


Copernicus Services

Data acquired by the constellation of the Sentinels satellites together with ancillary in-situ/satellite measurements are processed by the **Copernicus Services** in other to **generate value-added products**
e.g., weather forecast, flood warnings, vegetation indices.

Current way(s) to access Sentinel satellite products

- Copernicus Open Access Hub for Sentinel-1,2,3 data.
- Sentinel-5P has its own hub.
- Sentinel-6 is distributed by EUMETSAT.
- Rolling archive policy – no immediate access to archival data (older than 1-3 years)



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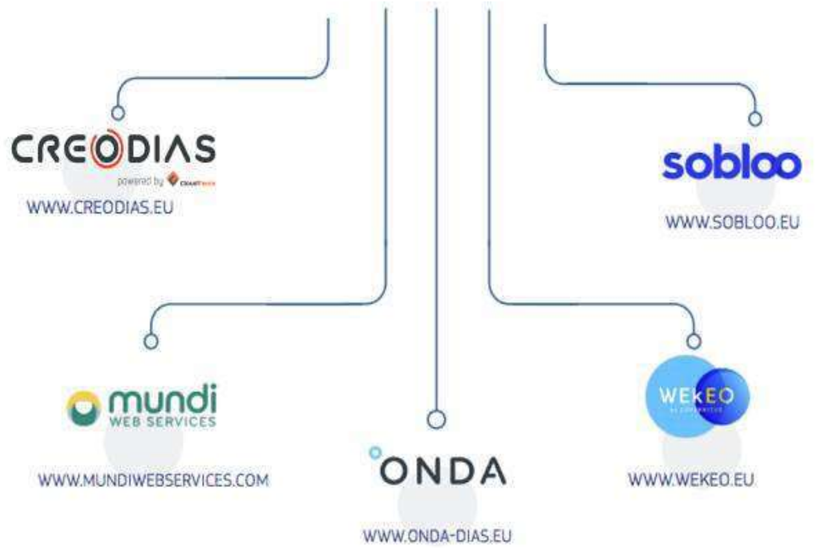
Copernicus cloud-based platforms for Data and Information Access Services (DIAS)

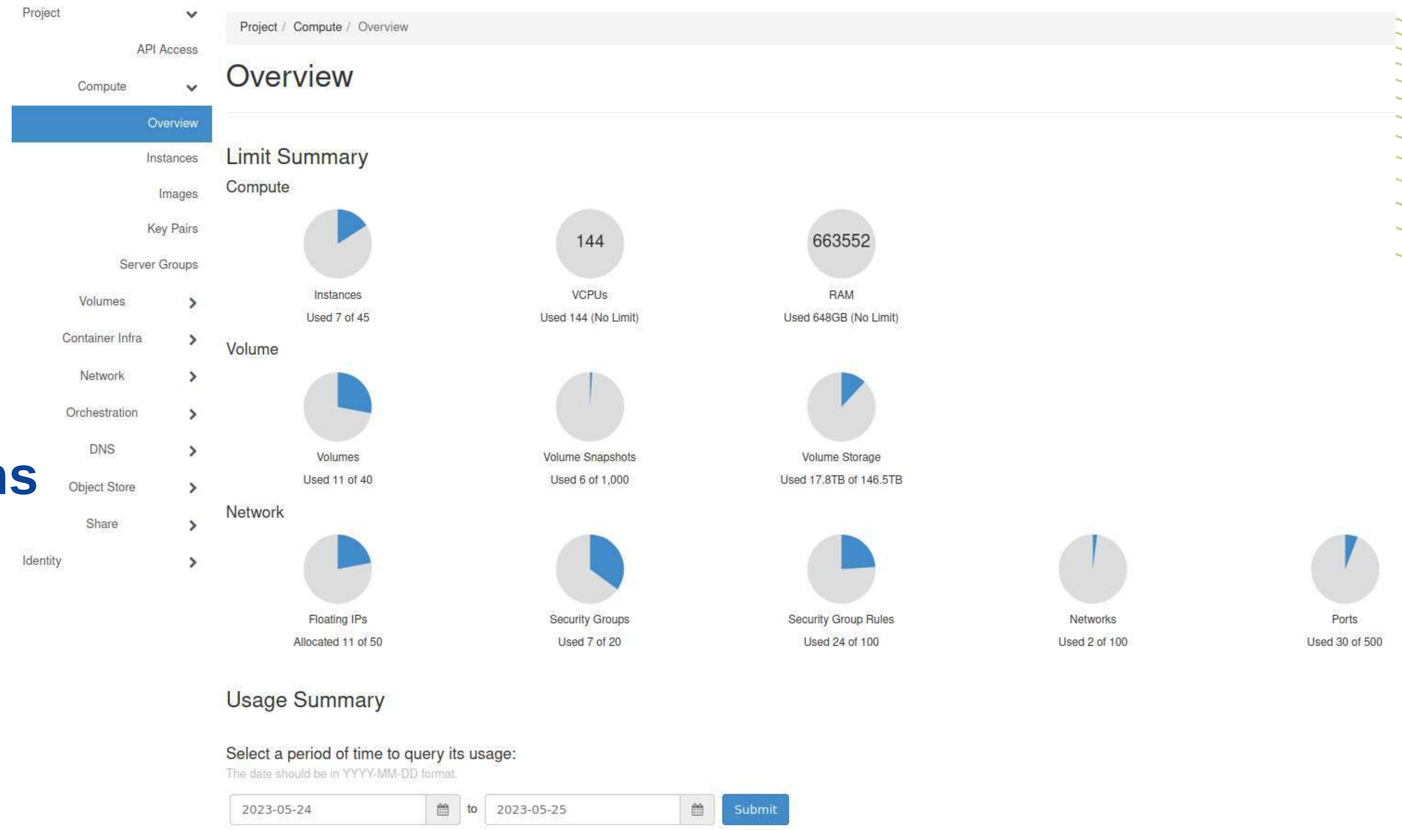
To facilitate and standardise access to data, the European Commission has funded the deployment of **five cloud-based platforms**. They provide centralised access to Copernicus data and information, as well as to processing tools.

The five DIAS online platforms allow users to **discover, manipulate, process and download Copernicus data** and information. All DIAS platforms provide access to Copernicus Sentinel data, as well as to the information products from the six operational services of Copernicus, together with cloud-based tools (open source and/or on a pay-per-use basis).



CREODIAS

- Cloud computing platform
- Hosting 35 PB EO data repository
- Open source based
  - OpenStack
  - CEPH storage
- Deployed in several clouds and locations
- Kubernetes ready
- On-demand data processing
- Free for testing (150 EUR credits)



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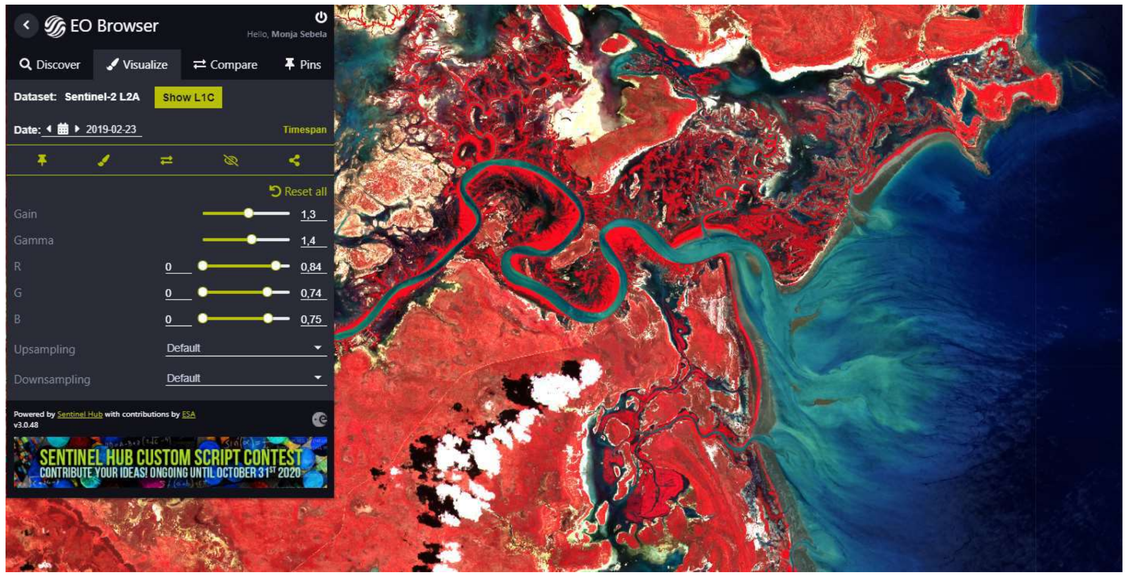
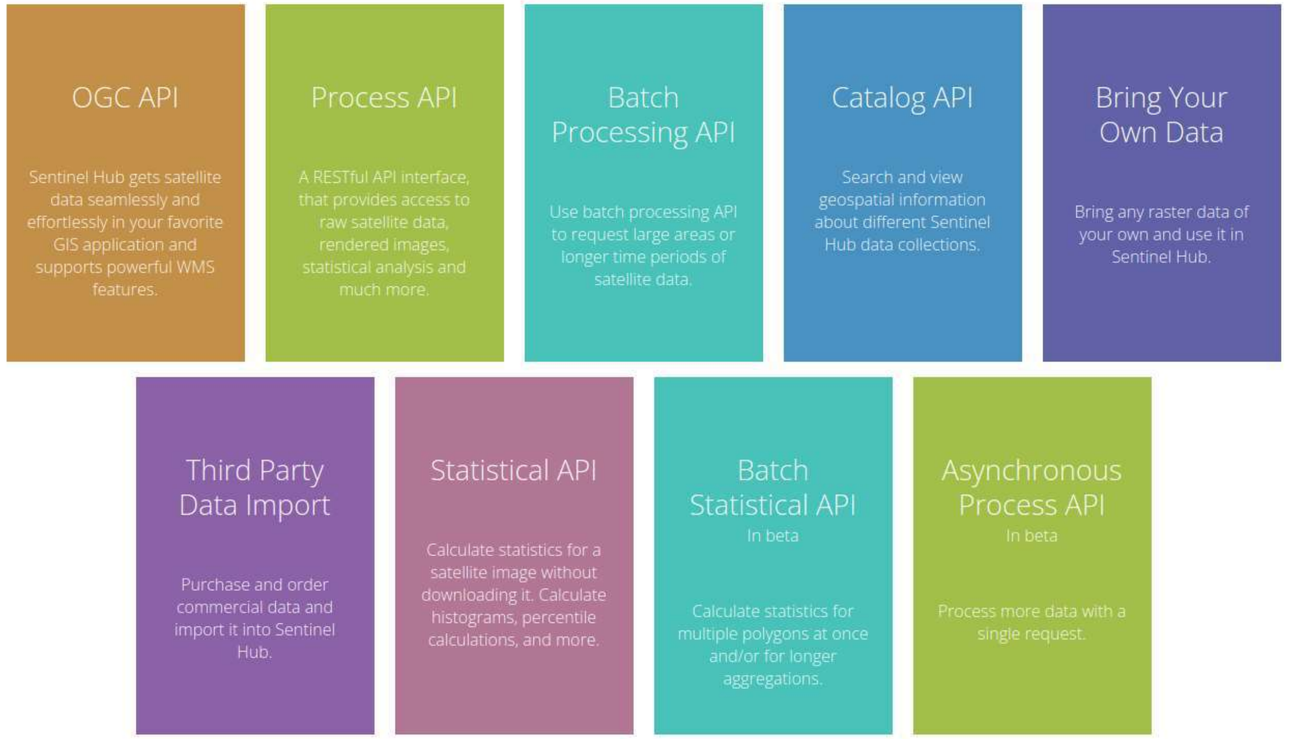
PROGRAMME OF THE EUROPEAN UNION

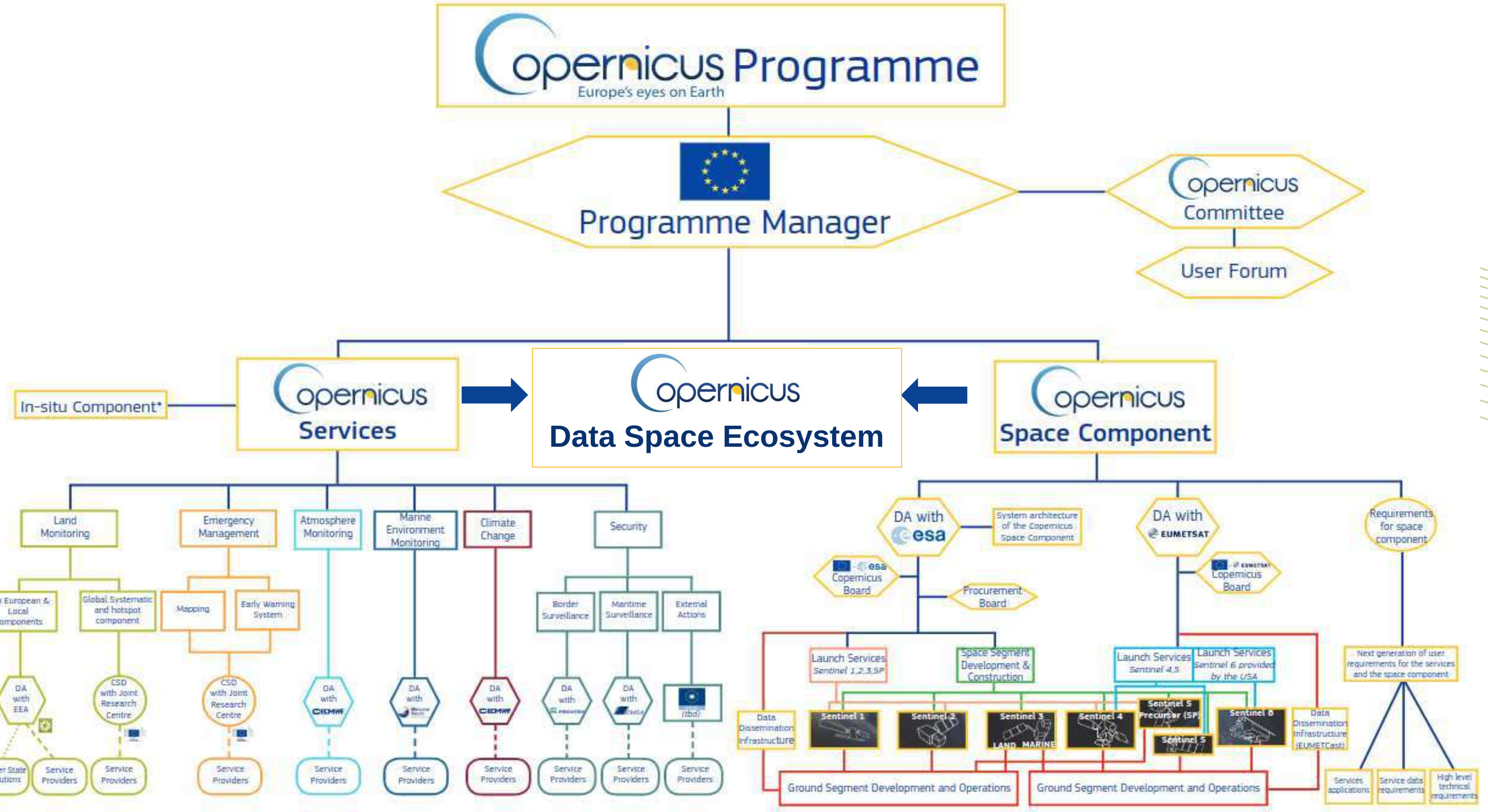
sentinelhub platform for EO data processing and visualization



Sentinel Hub EO Browser



Wide portfolio of APIs



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About Copernicus Data Space Ecosystem

The **Copernicus Data Space Ecosystem** is the next step in the evolution of Earth observation data access to replace current data hubs. The Ecosystem aims to gather EO data, tools and computing resources to unlock the full potential of the EO data. This will allow developing new applications to increase impact of Earth Observation data for a sustainable society.

The Ecosystem offers immediate access to large amounts of open and free EO data and scalable interfaces on top the Copernicus Sentinel satellites, including both new and historical Sentinel images, commercial datasets, as well as Copernicus Contributing Missions.

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What revolution does the Copernicus Data Space Ecosystem bring to Earth Observation?

Cooperation of experts across Europe!

The Copernicus Data Space Ecosystem is powered by leading European cloud and earth observation service providers.

The combination of the partners' experience and the guidance of ESA ensures a comprehensive, high-quality and user-friendly ecosystem.

T Systems

CloudFerro

SINERGISE

vito remote sensing

DLR

ACRI ST

RHEA GROUP

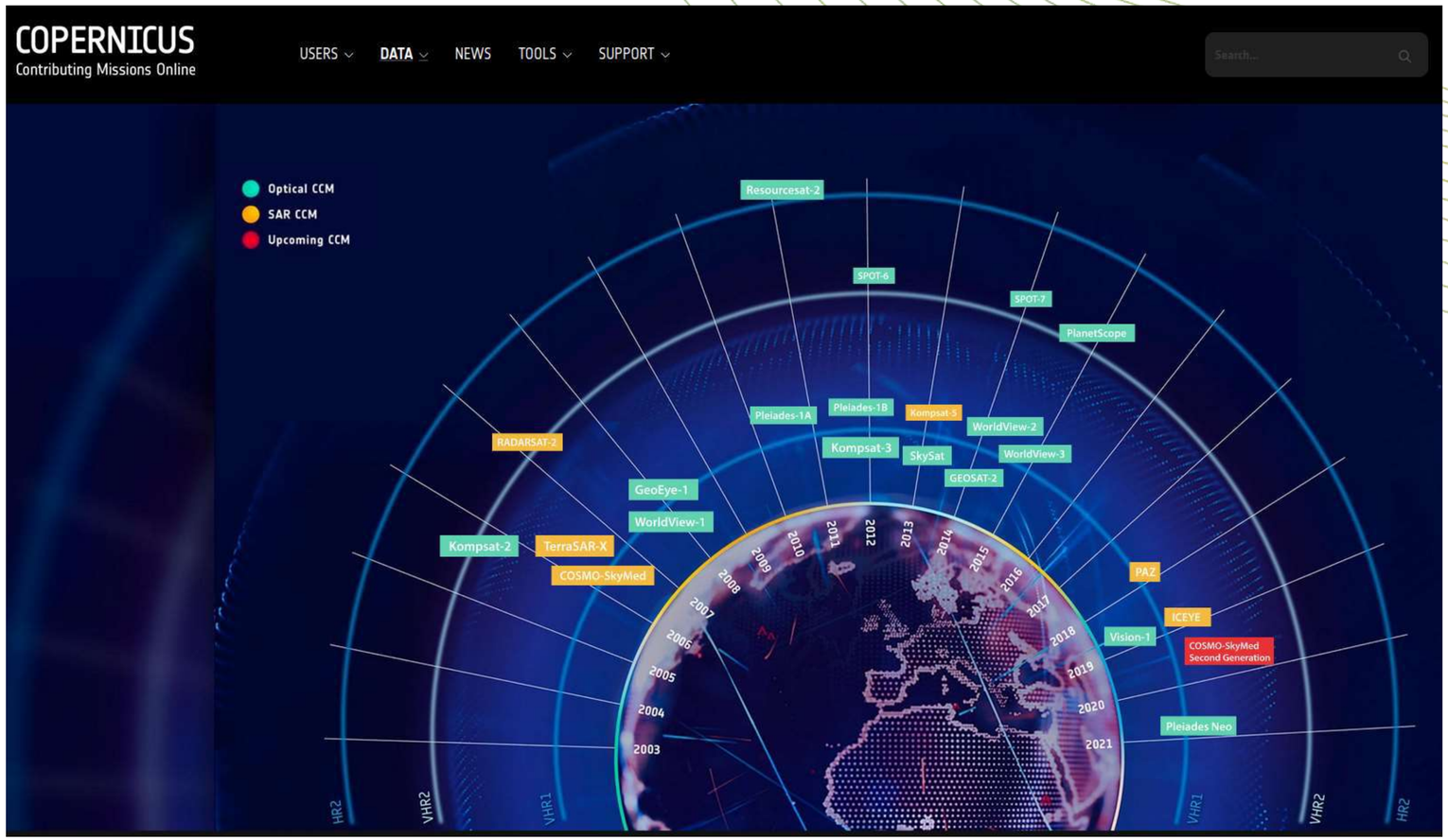
Free and instantaneous access to EO data

- All Sentinel's products including upcoming Sentinel-2 Collection 1
- Level-3 Sentinel-1 & -2 temporal mosaics (i.e. monthly, quarterly, yearly)
- On-demand processing in a "best effort" mode (e.g. Sentinel-1 coherence generation)
- Landsat imagery over Europe
- SMOS (Soil Moisture and Ocean Salinity)
- Jason-3 altimetry
- Envisat MERIS and ASAR
- Selected products generated by the Copernicus Services
- more to come ….

Access to Copernicus Contributing Missions (CCMs)

The Copernicus Contributing Missions play a vital role in Earth observation, delivering data that complements the output of the Copernicus Sentinel missions.

Comprising missions from ESA, its Member States and other European and international third party operators, these satellites help cover the needs of Copernicus Service Providers, particularly for very high resolution data.



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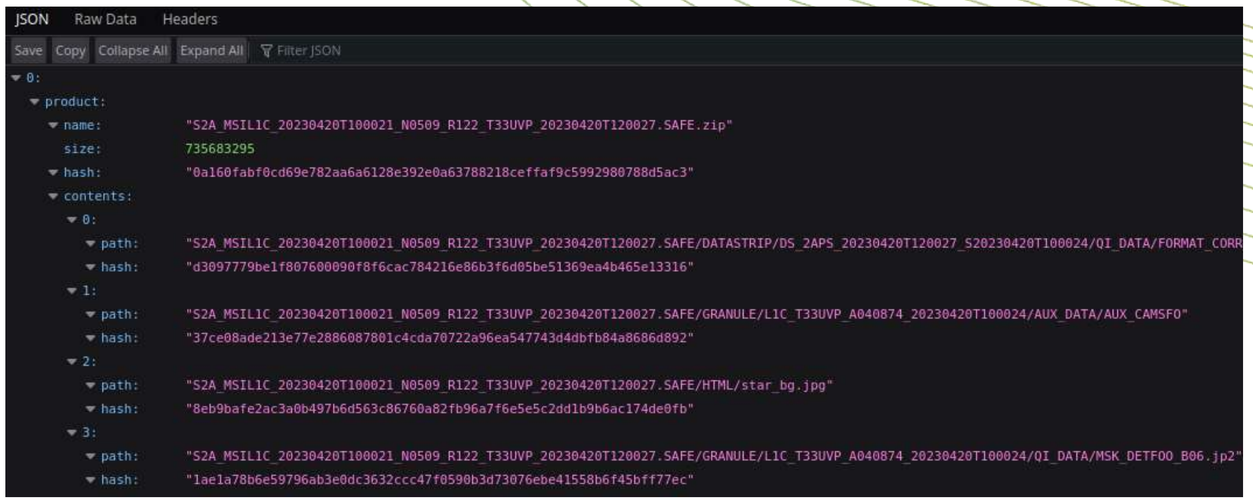
PROGRAMME OF THE EUROPEAN UNION

Access to Very High Resolution (VHR) imagery via API & Help Desk

Traceability of data sets via dedicated API

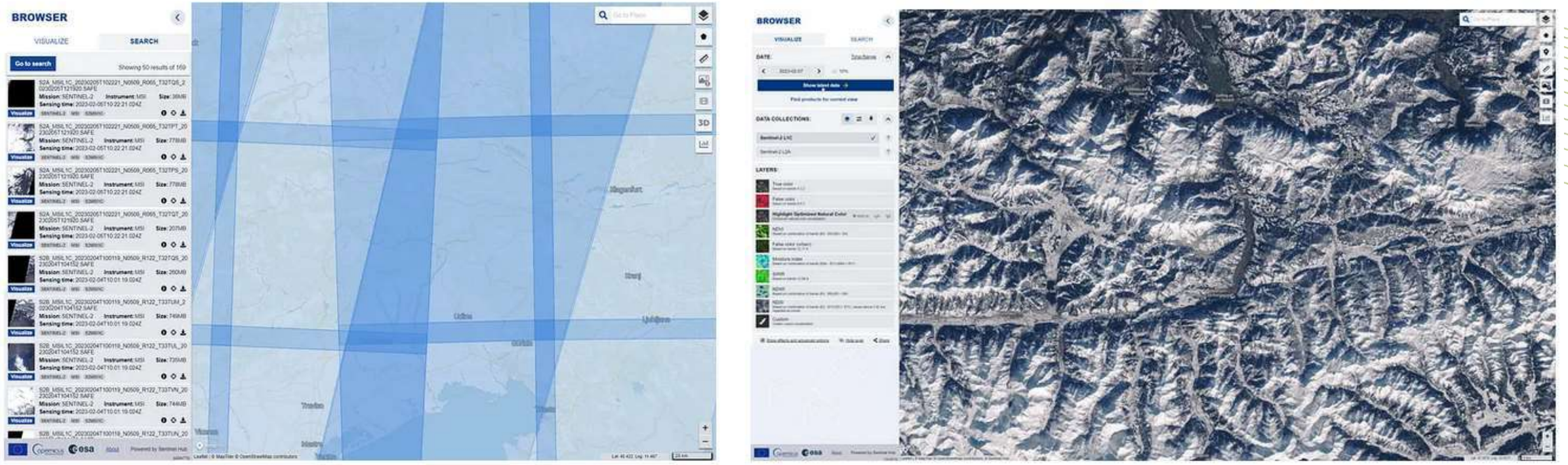
Traceability Service provides the user with means to track the lifecycle of a data product. It acts as a historian of the product's lifecycle, collecting the traces of all related events. These traces then can be used to check the integrity of the product, its current whereabouts, its impact on other products or ultimately its inadequacy for continued use in case of obsolescence.

Digital signatures on the traces provide users with the ability to verify authenticity and integrity of the traces themselves – this also enables users to detect any alterations of the product during its lifecycle.



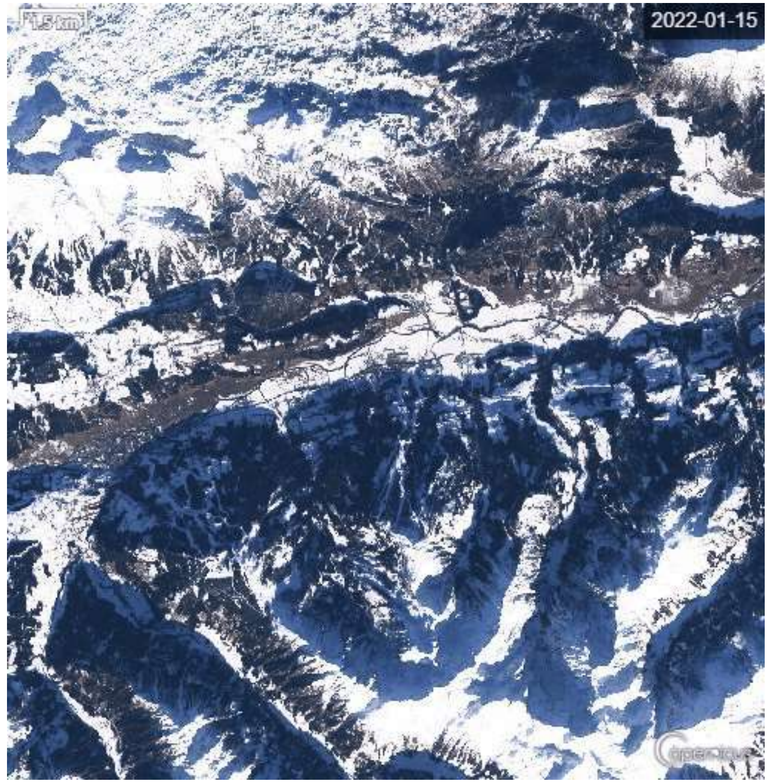
Traceability Service API endpoint:
https://trace.dataspace.copernicus.eu/api

Advanced data discovery and visualization



Copernicus Data Space Ecosystem browser.

Timelapse videos and advanced 3D modelling



Copernicus Data Space Ecosystem browser.

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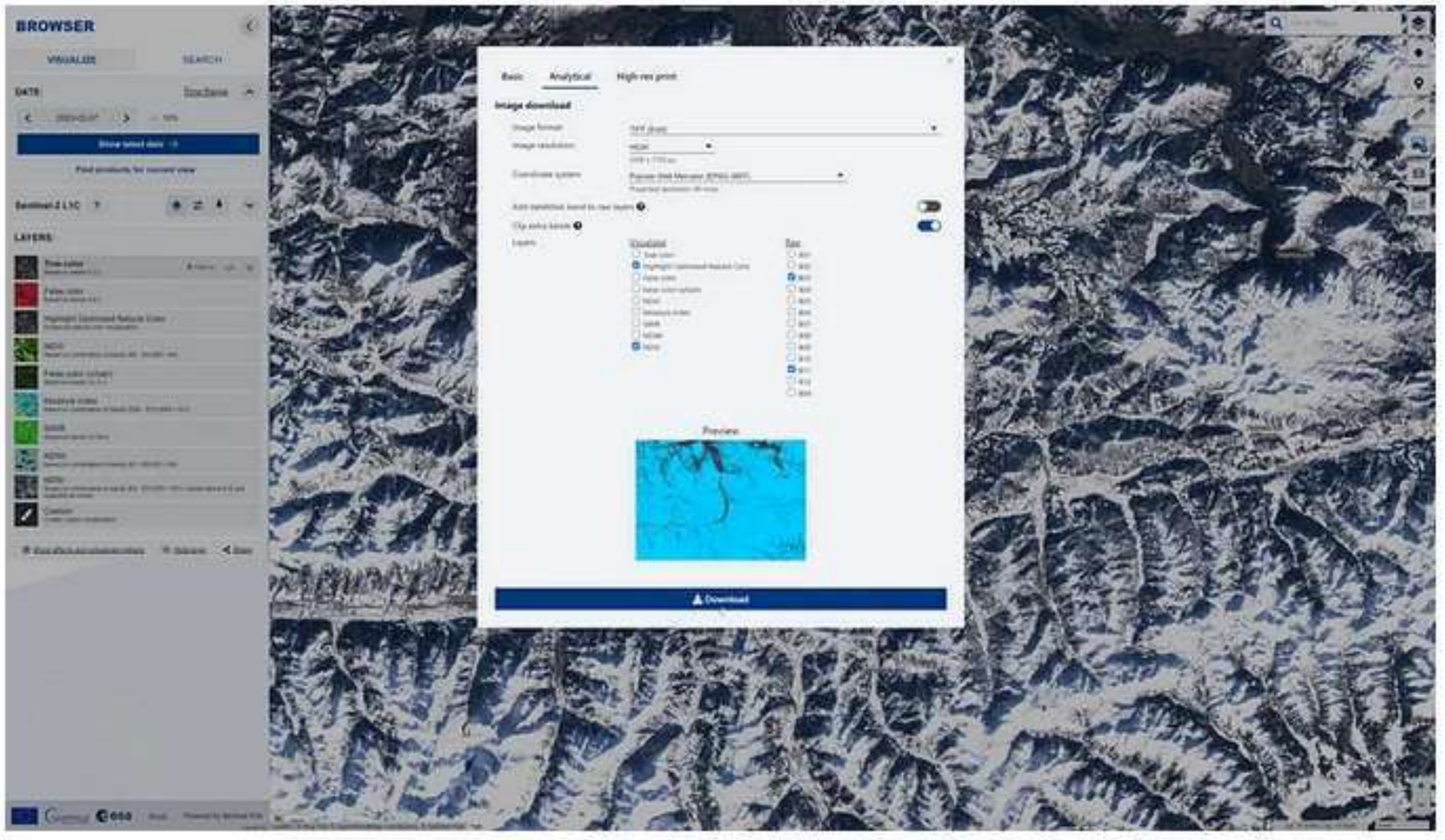
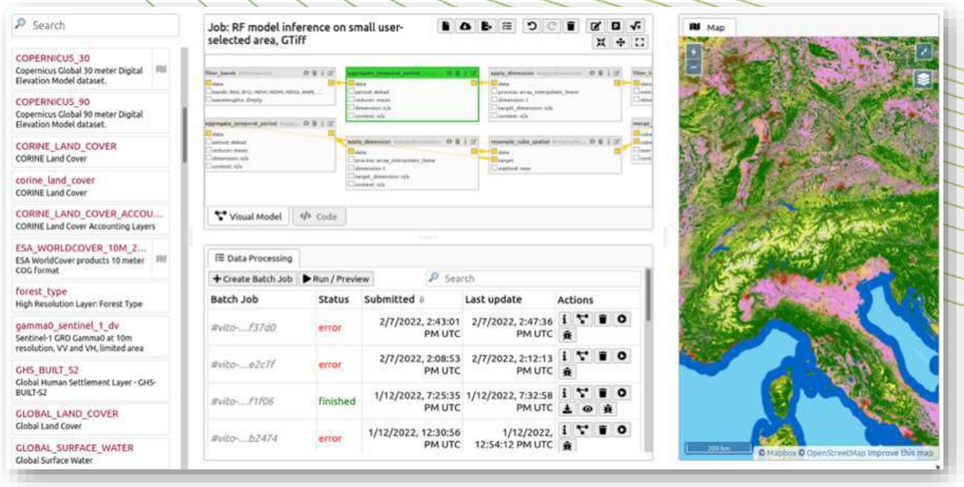
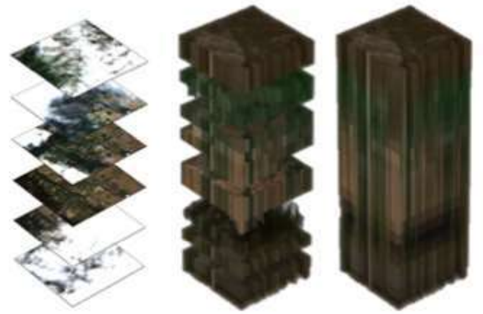
Advanced data download



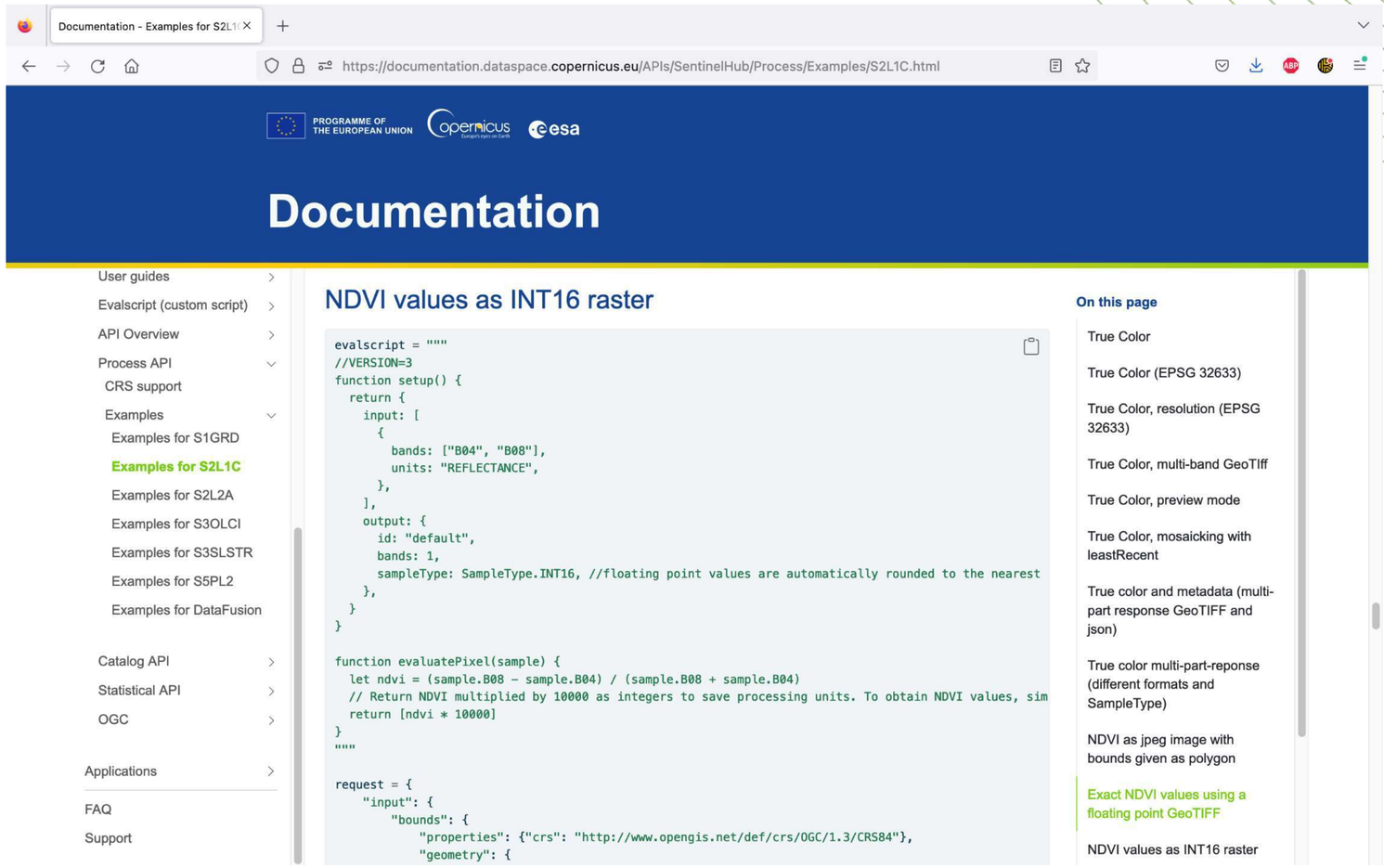
Advanced data access and processing APIs

- **Discovery/catalogue** (STAC, OData, OpenSearch)
- **Download products** (S3, OData)
- **Streamlined access** (Sentinel Hub, OpenEO)
  - STAC Catalogue API
  - Visualisation (OGC)
  - Process (instant, batch)
  - Statistical (instant, batch)
  - Bring your own data (COG, Zarr)
- **SDK** (Phyton, JavaScript)
- **Clients** (JavaScript, Phyton, R)



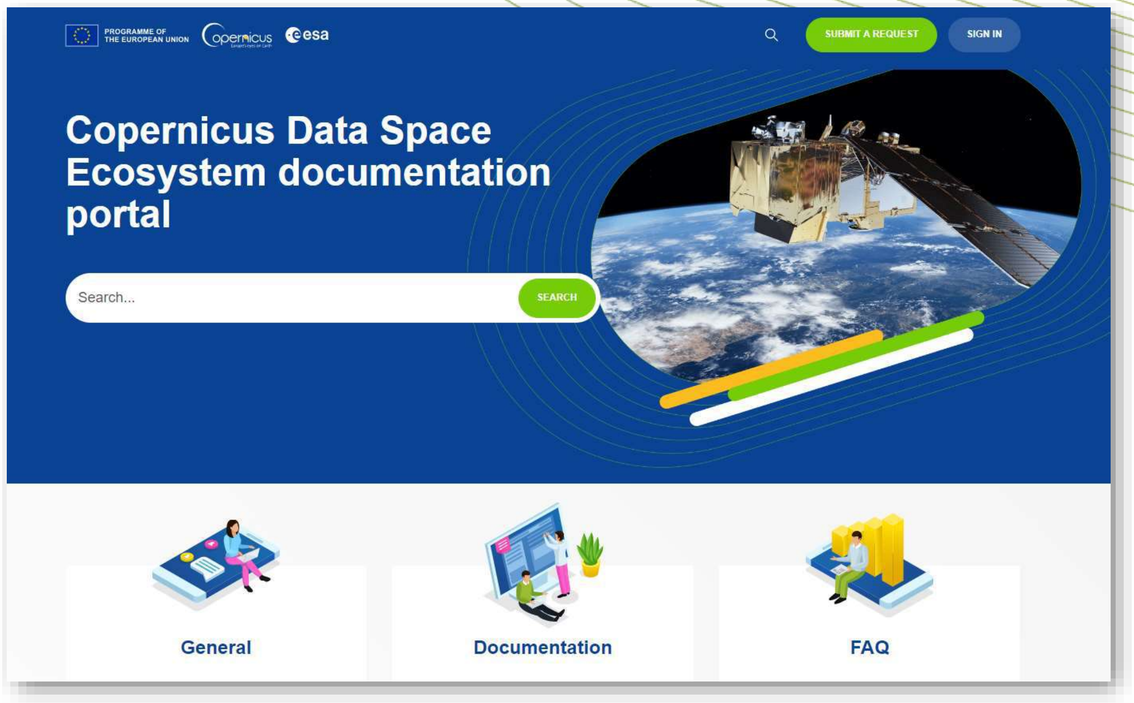


Documentation



Service desk

- **User forum**
  - Peer to peer sharing of knowledge
  - Actively supported by helpdesk staff
- **Web form and email support**
  - Automatic suggested answers
  - FAQ
  - Documentation portal
- **(Video) Tutorials & code snippets**



Public and commercial offering

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- **Free to use (funded by EU)**
  - Self-onboarding for general users
- **Pre-configured service quotas**
  - Based on user-type
  - Customization possible for ESA and EU-approved activities
- **Copernicus data and open data**
- **On-boarding of Copernicus and public services**

Federated identity
Synced data offering
Consistent APIs

commercial offering by 3rd parties

- **Payable services**
  - Self-onboarding
  - Free trials for most functions
  - Self-service check-out
- **Pay-per use and packaged subscriptions**
- **Credits for research and pre-commercial exploitation**
- **Copernicus, open and commercial data**

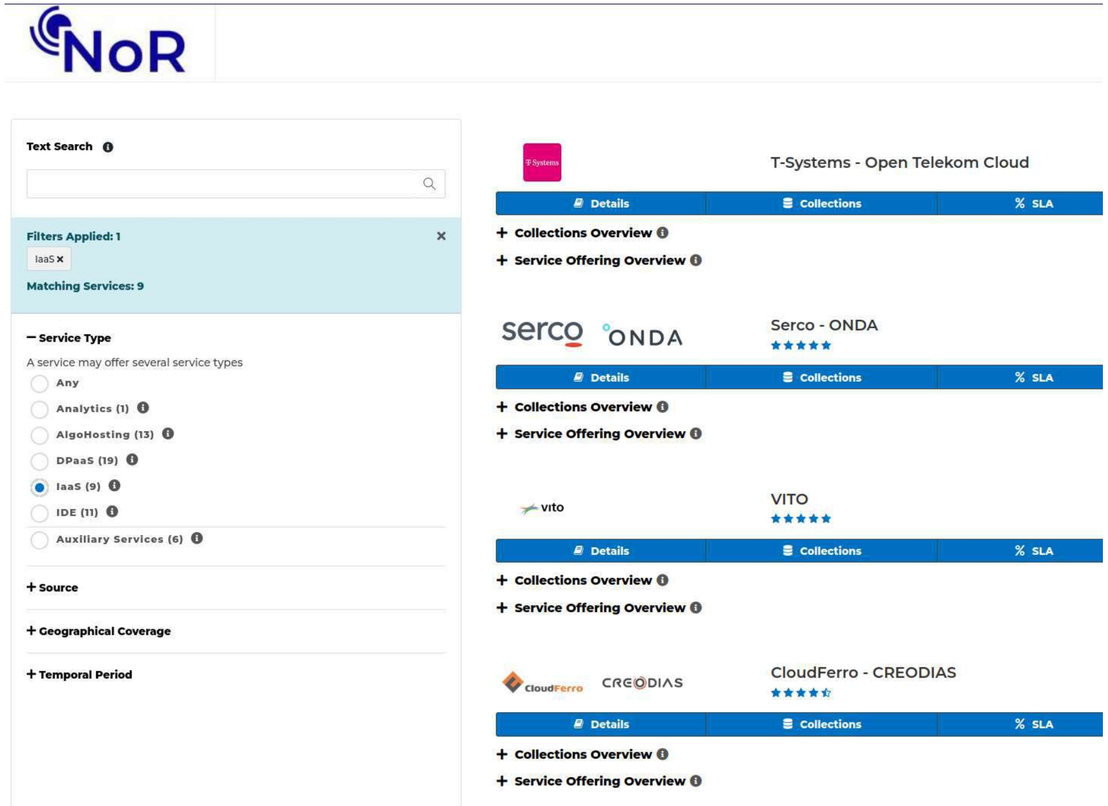
Public utility with free services under fair use policy
Seamless expansion for large-scale use under commercial models by 3rd party operators

Infrastructure as a Service (IaaS) offered by CREODIAS

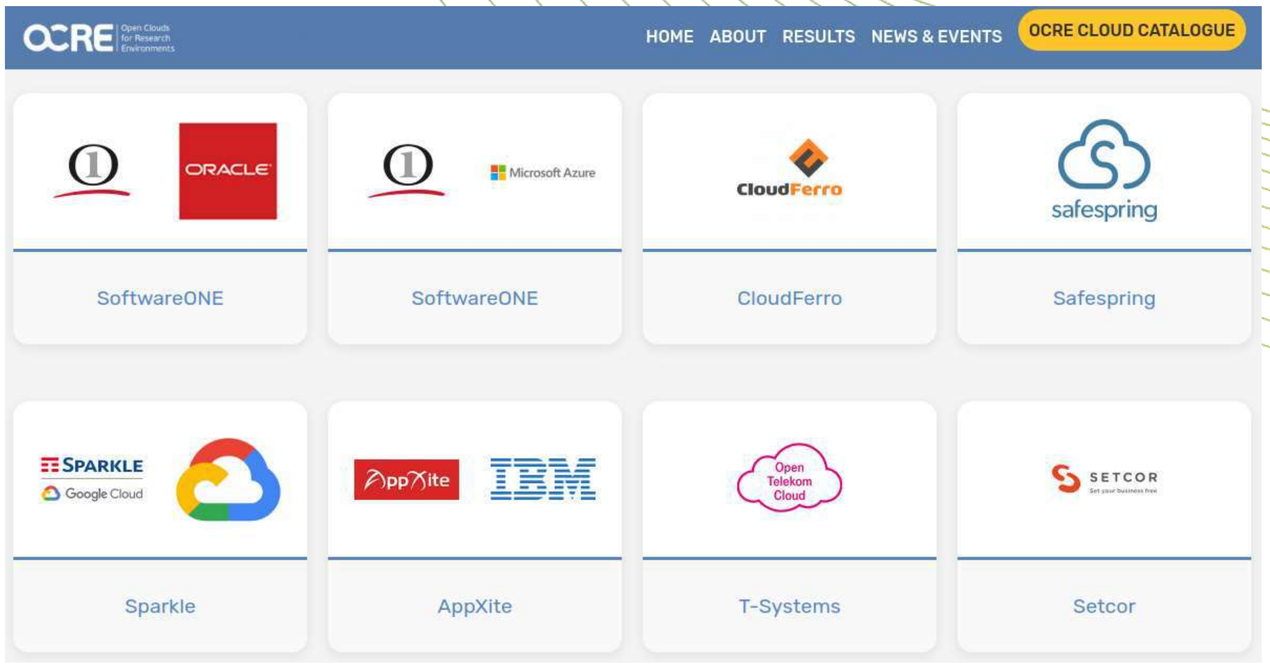
Cloud services provided by CloudFerro and OTC:

- Virtual Machines (VM) with many flavours
- GPU accelerated for complex AI tasks
- Object Storage with S3 interface
- Flexible billing modes (Pay-As-You-Go)
- Long-term contracts with discounts
- Discounts for scientific users
- 24/7 support

Funding opportunities for commercial offering!



Network of Resources
https://nor-discover.cloudeo.group/



Open Clouds for Research Environments
https://www.ocre-project.eu/services/cloud-suppliers

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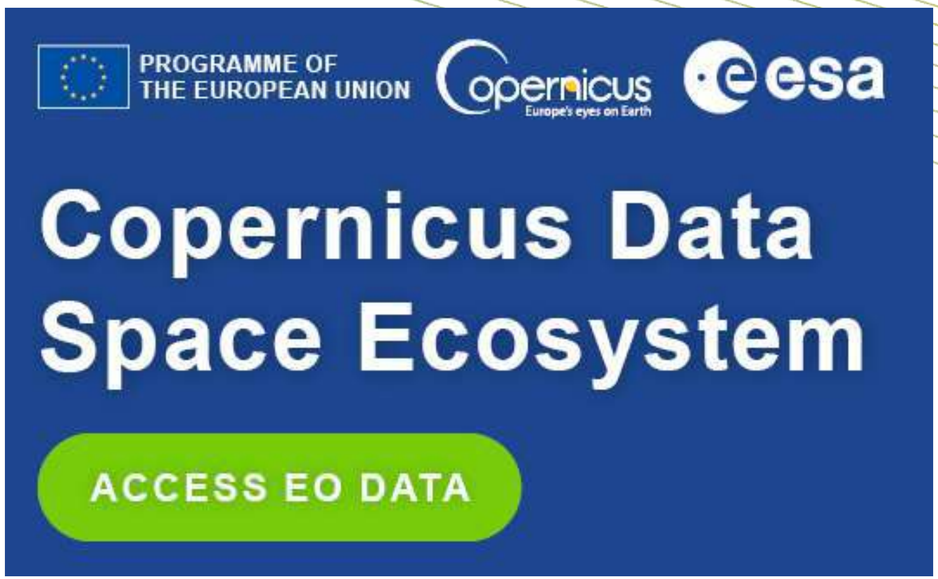
Take home messages

- Copernicus Data Space Ecosystem grants free, immediate access to EO data (Sentinels and more e.g. Landsat). It will replace the Copernicus Open Data Hub in Q4 2023.
- Along with data the Ecosystem offers powerful data discovery, visualization and processing tools & APIs.
- Free-public offering in complemented by commercial one for:
  - Cloud computing (virtual machines)
  - Very High Resolution (VHR) imagery
- Ecosystem is **OPEN** for any entity willing to federate.
- Long term perspective for fruitful cooperation (6-10 years contract)!
- Copernicus Data Space Ecosystem is a joint European effort!!



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Copernicus Data Space Ecosystem vision

Jurry de la Mar, T-Systems

What is the relevance for the EO community?

- Paradigm shift for end-users and service providers:
  - **„instead of questioning what users need, we let users ask the questions“**

- Enabling new apps and business at very low incremental cost:
  - immediate access to complete missions, provide more data than anywhere else

- Participate, promote and control your service:
  - Fair and transparent Data Space Ecosystem membership
  - Full compliance with the European Data Strategy
  - State-of-the-art federation functions

What do we want to achieve for the EO community?

- Provide the best service attractiveness
- Continuously extend the available data sets, tools and services according to user and service provider demand
- To promote European EO service providers and start-ups in the world-wide Copernicus community and be the global champions

Road map

The Copernicus Data Space Ecosystem will continuously expand over the upcoming months.

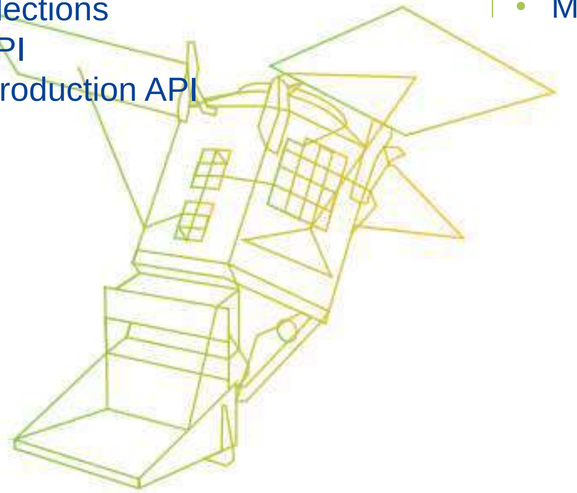
All data and services will be fully accessible by July 2023.

January 2023

- Release Copernicus Data Space Ecosystem
- Start of user registration
- Initial Sentinel data offering
- Browser
- Catalogue APIs: Odata and OpenSearch

April 2023

- Catalogue API: STAC, S3
- Processing API: Sentinel Hub and OGC for supported collections
- Traceability API
- On-demand production API



01 July 2023

- Full archive of Sentinel missions
- Complementary open datasets
- Access to commercial data
- Processing API: extended Sentinel Hub API's, OpenEO
- Jupyter Lab
- Marketplace

November 2023

- Sentinel engineering and auxiliary data
- Copernicus Contributing Missions
- Streamlined data access of federated data sets

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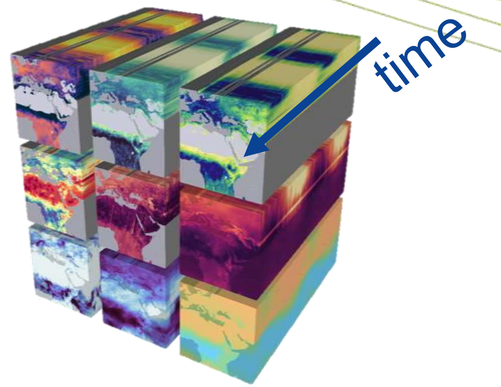
OpenEO

in the Copernicus Data Space Ecosystem

Dennis Clarijs, VITO

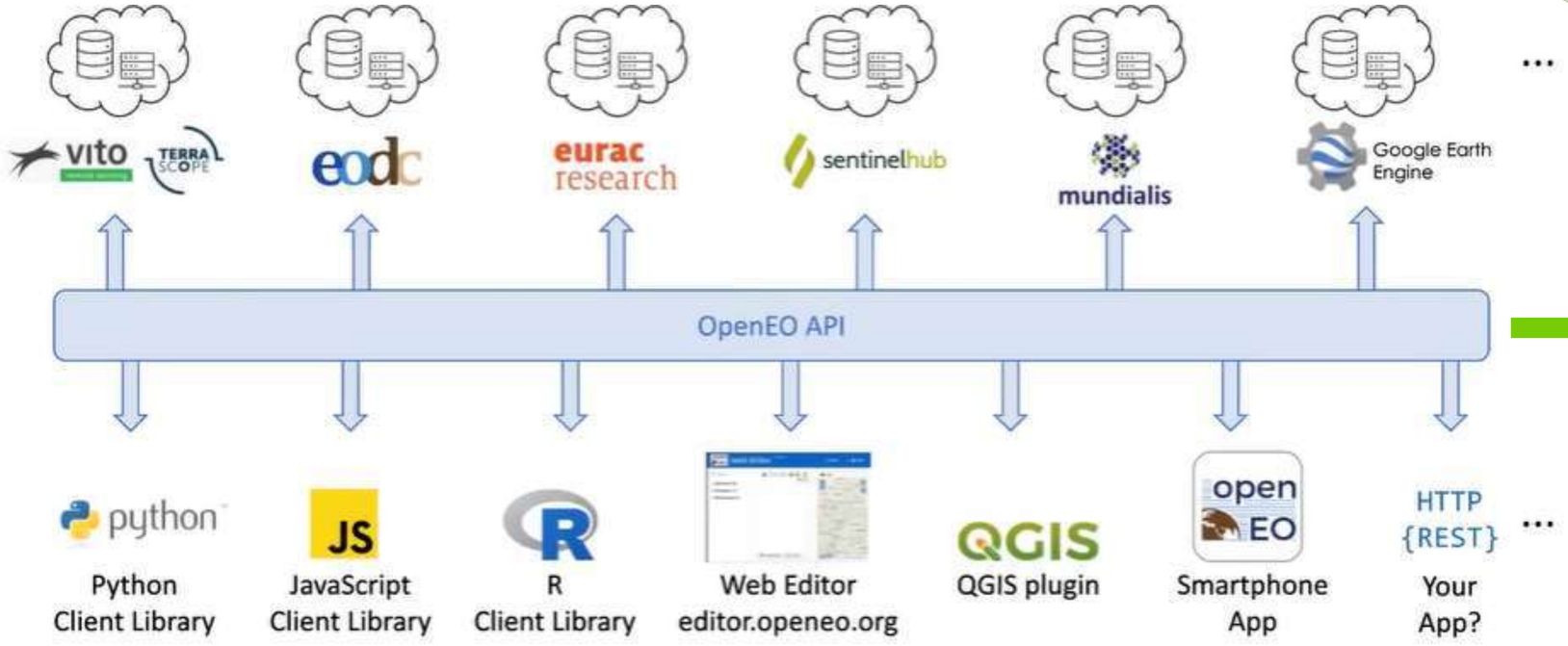
Why openEO?

To serve users with a **local to continental scale** Earth Observation data analytics solution allowing **simplification and unification**:



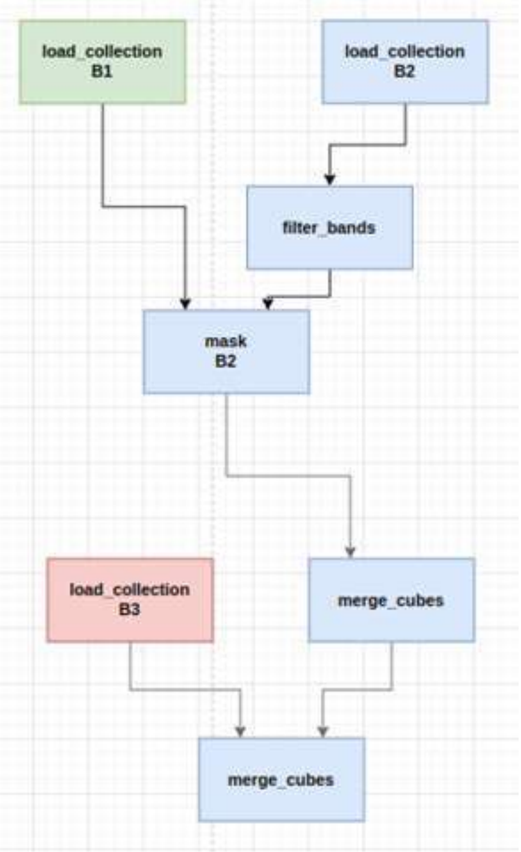
- To **run workflows** locally, in a browser, Notebook or Rstudio
- **Connection to cloud platforms** in a **technology agnostic** way
- Carrying out **discovery, composition and distributed processing**
- Showing **results** (low res) or download (high res)
- Inserting **custom** Python / R **scripts** to be executed close to the data (User defined functions)
- Community contributions through **Open Source**

openEO Ecosystem



openEO Platform

openEO Federation



Federation can be achieved in two scenarios using process graphs:

- The same graph is sent to different back-ends that host all the required data and execution is optimized to work on different areas as an extra level of parallelization in processing.

- The graph contains datasets that are not all available in one place. In this case the graph should be split, and subgraphs should be sent to different backends that have all the required data and processing resources. The smallest set of intermediate results is transferred to the backend running the larger part of the job.

openEO in Copernicus Data Space Ecosystem

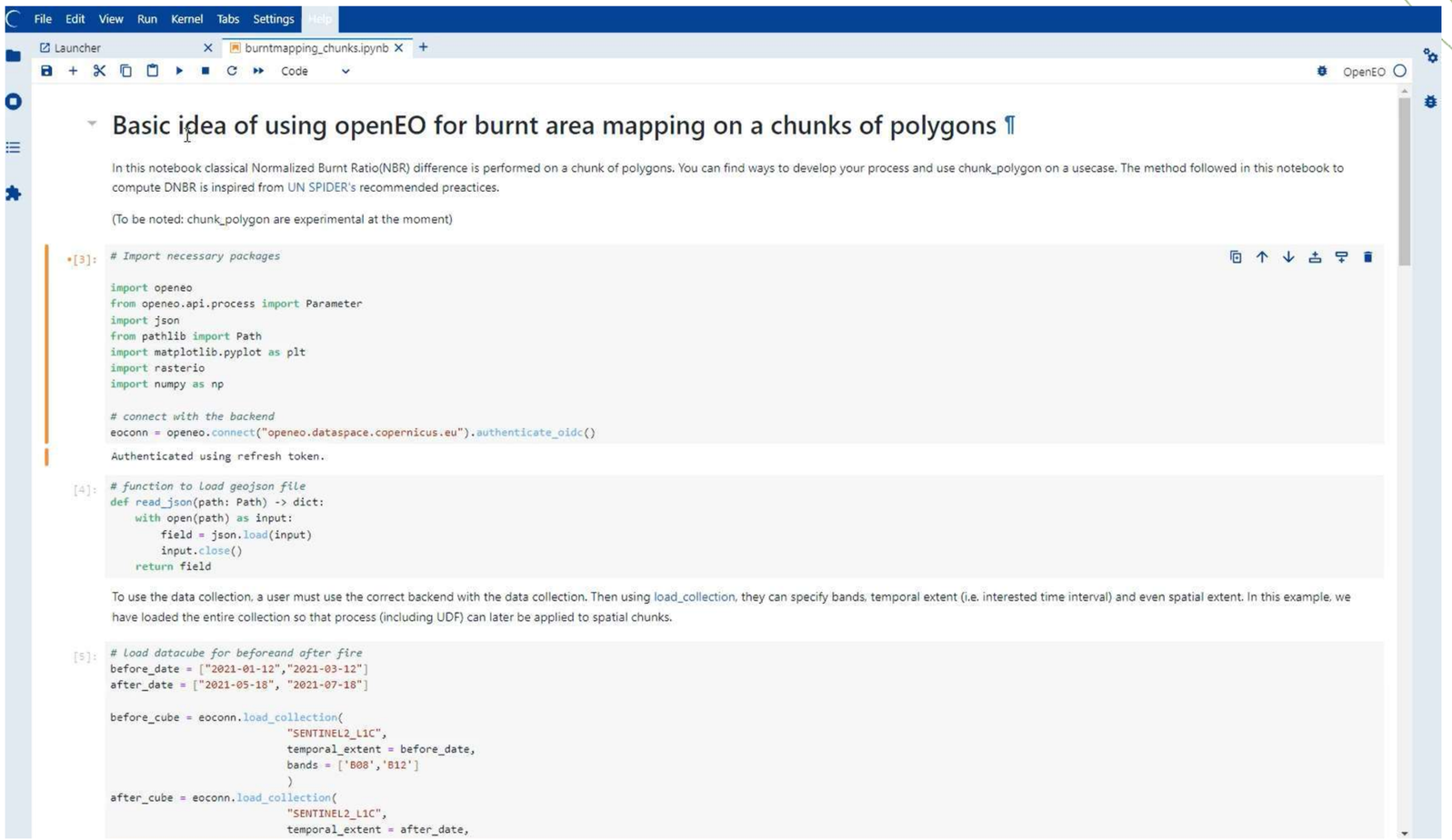
- Data offering
- openEO Capabilities
- Use Case

Data offering in the Copernicus Data Space Ecosystem

- From July 1st onwards:
  - Sentinel-1
  - Sentinel-2
  - Sentinel-3
  - Sentinel-5p

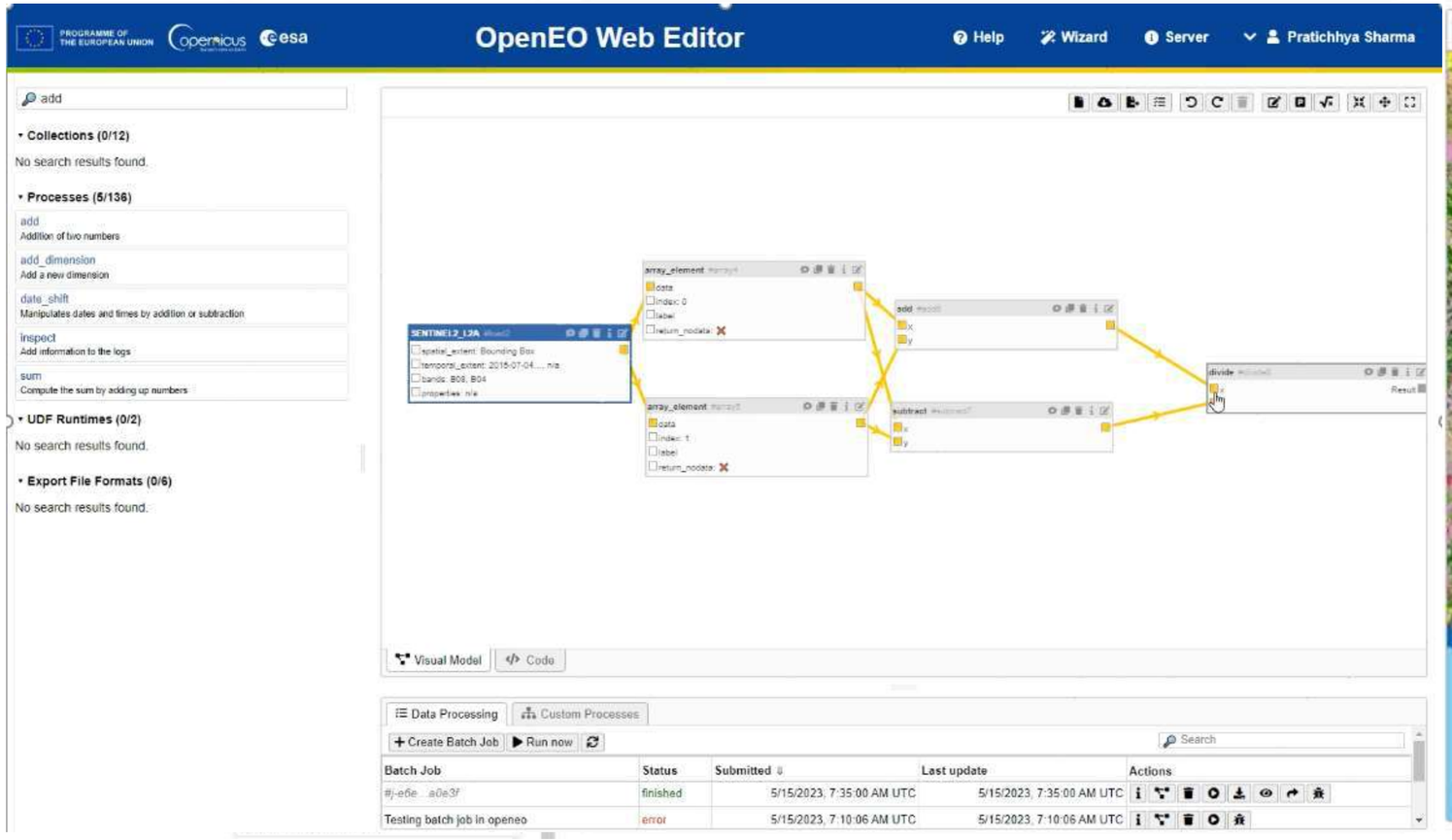
- From November 2023 onwards:
  - Federated datasets through aggregation:
    - Terrascope
    - …

openEO Capabilities



- For interactive prototyping, programming and visualization
- Most convenient way for Python programmers to interact with the openEO API.

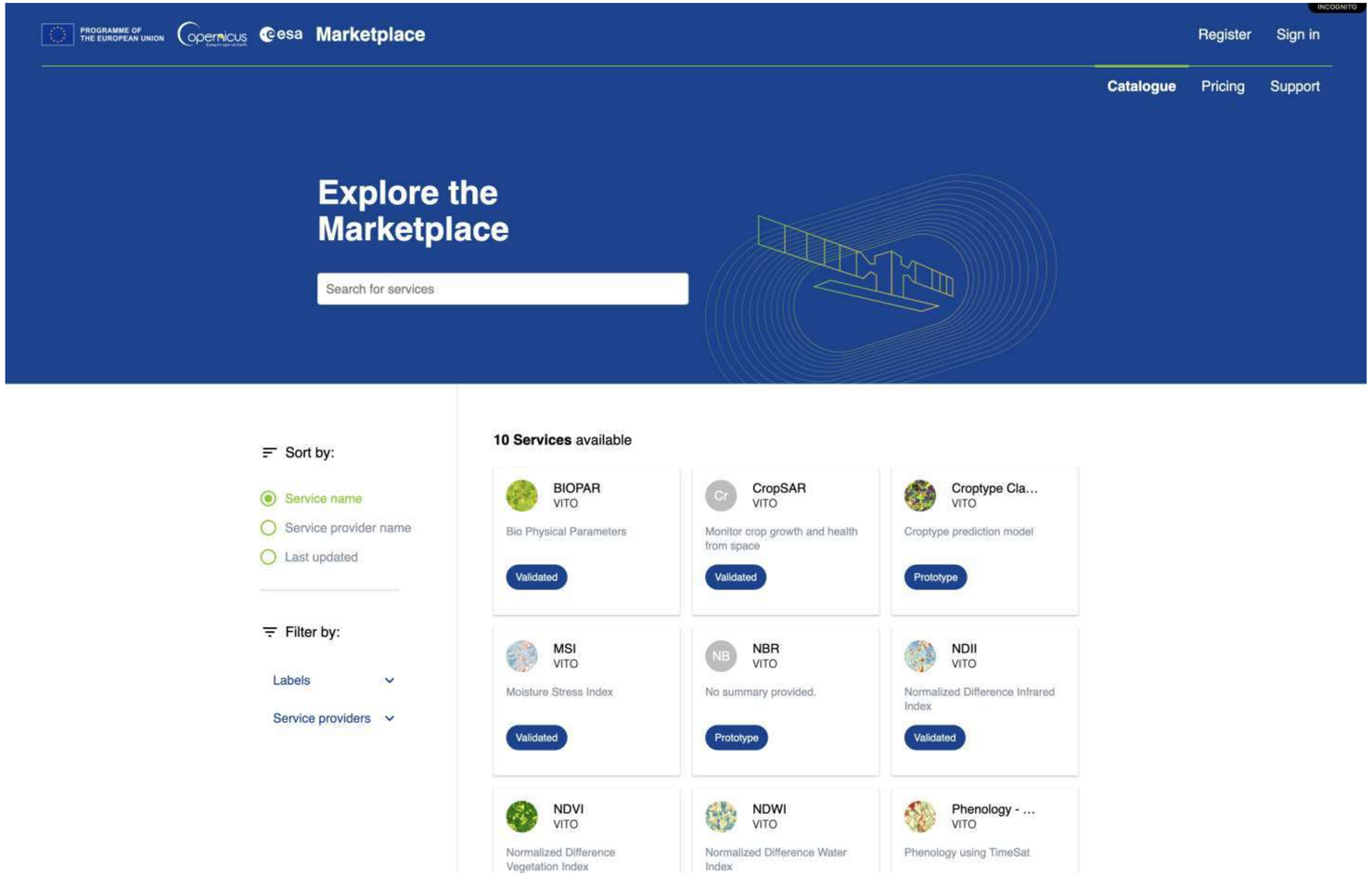
openEO Capabilities



- An interactive low-code and visual user interface for a block-based workflow editor.
- Get an overview of available data sets and processes or monitor the status of their processing workflows.

openEO algorithm Marketplace

openEO Capabilities



- Share user-defined processes, bring reproducible science
- For users looking for a simple workflow without necessarily knowing the details of creating workflows in openEO.
- Maturity assessment for contributors, but added value return is possible

Data access & processing using openEO

VITO example use case: EU27 crop map

- Processed on data space infrastructure
- Based on:
  - Sentinel-2 L2A
  - Sentinel-1 GRD + on the fly backscatter
  - Copernicus 30m DEM
- Workflow game changer!
  - Federated archives
  - Removing back-end complexity

Summary

Advanced API for efficient handling of pre- and user defined EO algorithms supported across the Copernicus Data Space and federated ecosystem.

Hosted web editor and Jupyter lab, supporting various data analysis and processing tasks, from prototyping to full scale continental processing.

openEO Algorithm marketplace for integrating reusable user-defined openEO based algorithms-as-a-service to promote reproducible science, add visibility and possible return for users and companies.

The Copernicus Data Space Ecosystem enables a reference gateway to the golden standard EO datasets and federated datasets with openEO

CAP monitoring use case

András Zlinszky, Sinergise

„When digital transformation is done right, it’s like a caterpillar turning into a butterfly, but when done wrong, all you have is a really fast caterpillar”

George Westerman, MIT Sloan Initiative on the digital economy

CAP monitoring is the most demanding operational application of Sentinel data

- Carried out at national scale across the whole EU
- Done by national/regional paying agencies and their (IT/EO) subcontractors
- Repeated several times every year
- Typically involves image time series of several months
- Parcel-level output (red/yellow/green)

Copernicus Data Space Ecosystem transforms CAP monitoring

Copernicus Data Space Ecosystem – beyond the incremental

Finding the right image at the right time for visual inspection
→ Most of the images we collect will never be seen by a human eye

Copernicus Data Space Ecosystem aims to be the ideal platform for both

CAP monitoring use-case demonstrates ecosystem’s impact to transformation of EO industry

Common Agricultural Policy (CAP) monitoring in a nutshell

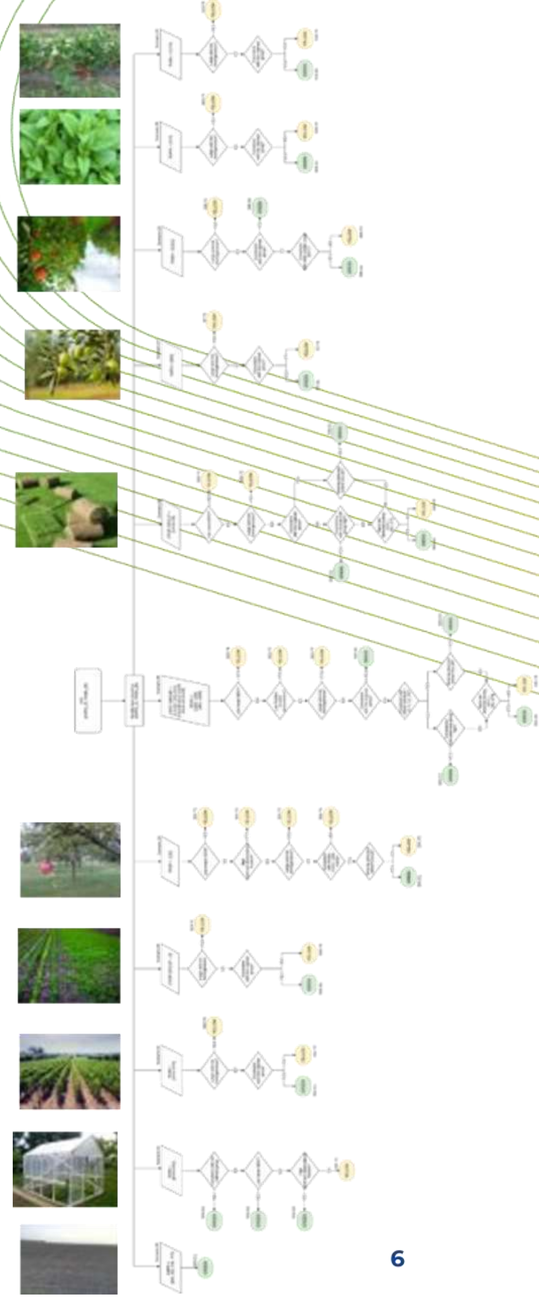
Direct payment → accurate monitoring of compliance

- **A multi-indicator system**
  - **Parcel integrity**
  - **Cultivation practices and timing**
  - **Presence of ineligible areas**
  - **Crop type**

Satellite-based monitoring is a game changer, from 5% field checks to full evaluation of all parcels

Requirements for successful CAP monitoring – what paying agencies want

- Accuracy, high performance and extreme reliability
- Traceability of all processing steps from final decision all the way to initial satellite imagery
- Compatibility with image sharing & viewing to allow farmers to follow up on notifications
- New functionality should easily be added on top of existing code



Example of a typical approach

Farmer claims
- Geometry
- Crop type
- Cultivation

Make FOI-s
- Filtering by size/shape
- Merging where necessary and possible
- Data augmentation

Agro-ecological zones

Crop classes

Sentinel-2 imagery

Make ARD
- Downloading
- Geometric and radiometric correction
- Cloud masking

FORCE

Make DB
- Select overlapping FOI-s and image tiles
- Filter by cloud mask
- Calculate zonal statistics of image bands within each FOI
- Interpolate missing values
- Calculate spectral indices

PostgreSQL

Categorize parcels
- Training data selection
- Random forest training
- Random forest evaluation
- Calculate probability of crop classes
- **Predict class**
- **Calculate probability surplus**

Scikit-learn

Identify cultivation
- Calculate NDVI time series
- **Identify mowing dates**
- **Identify cropping period**
- **Identify overgrazed parcels**

Cultivation requirements

Evaluate compliance
- Match with claimed crop
- Compliance with required cultivation

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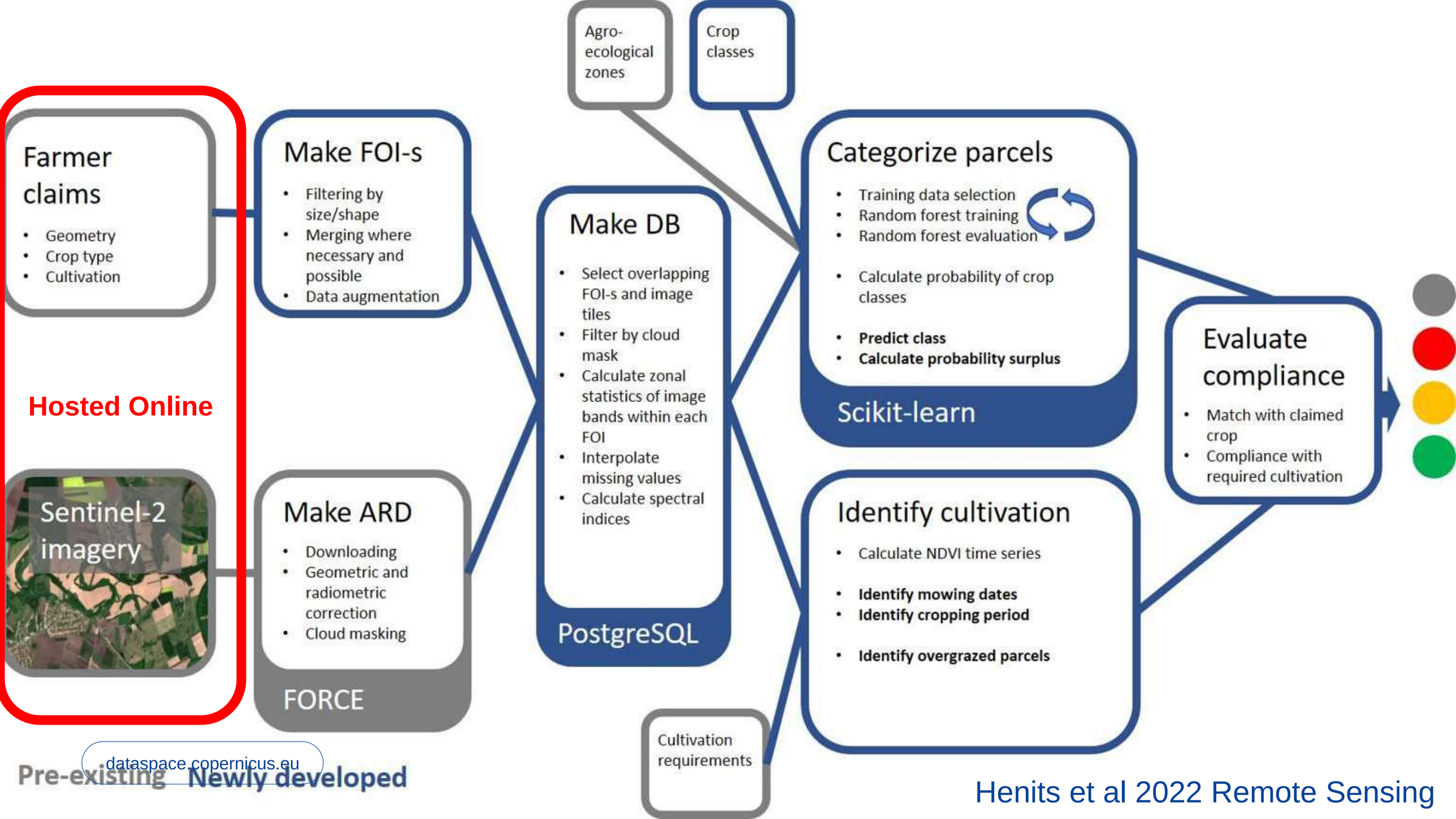
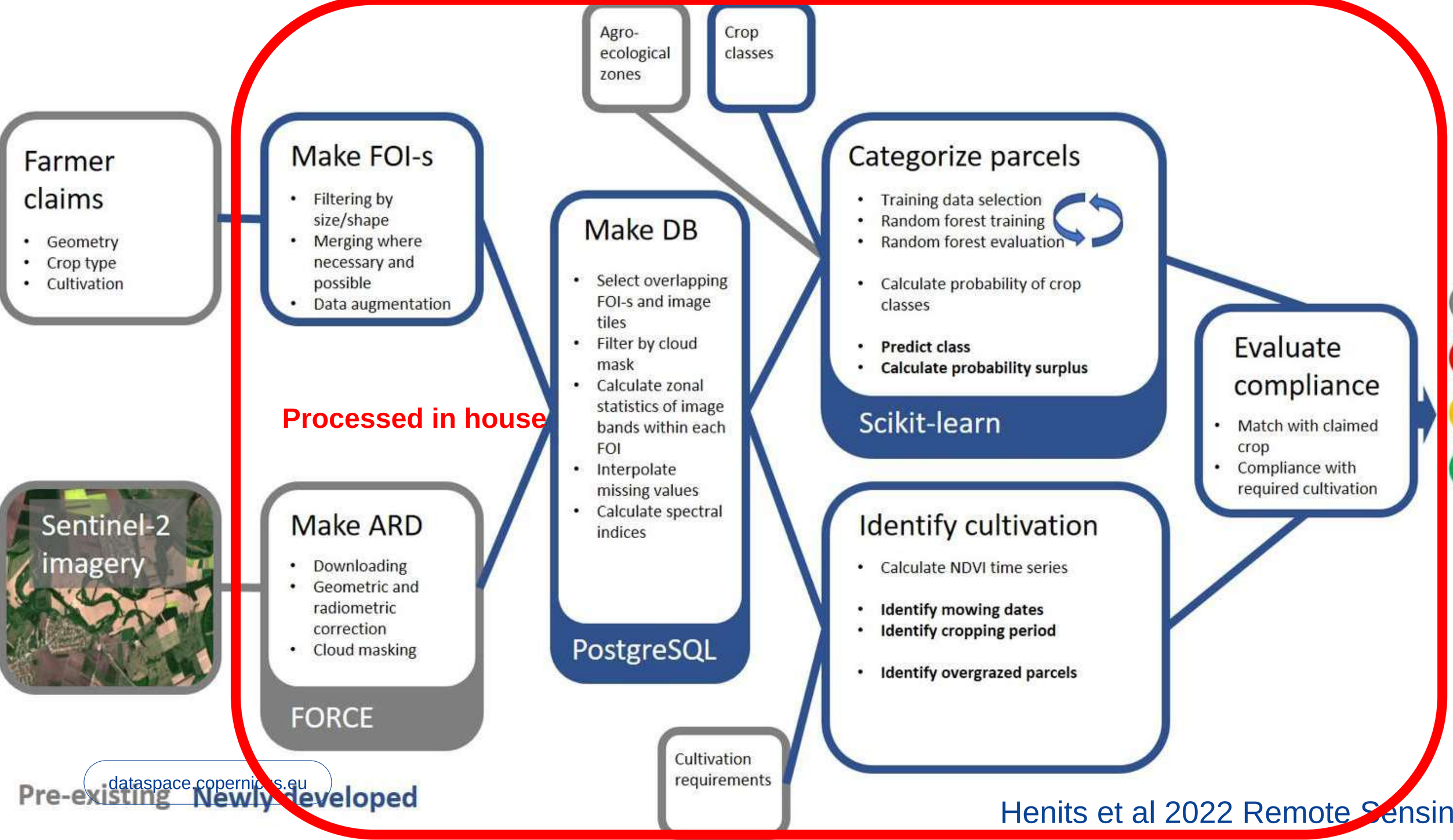
Pre-existing Newly developed

Henits et al 2022 Remote Sensing



Henits et al 2022 Remote Sensing


Farmer claims
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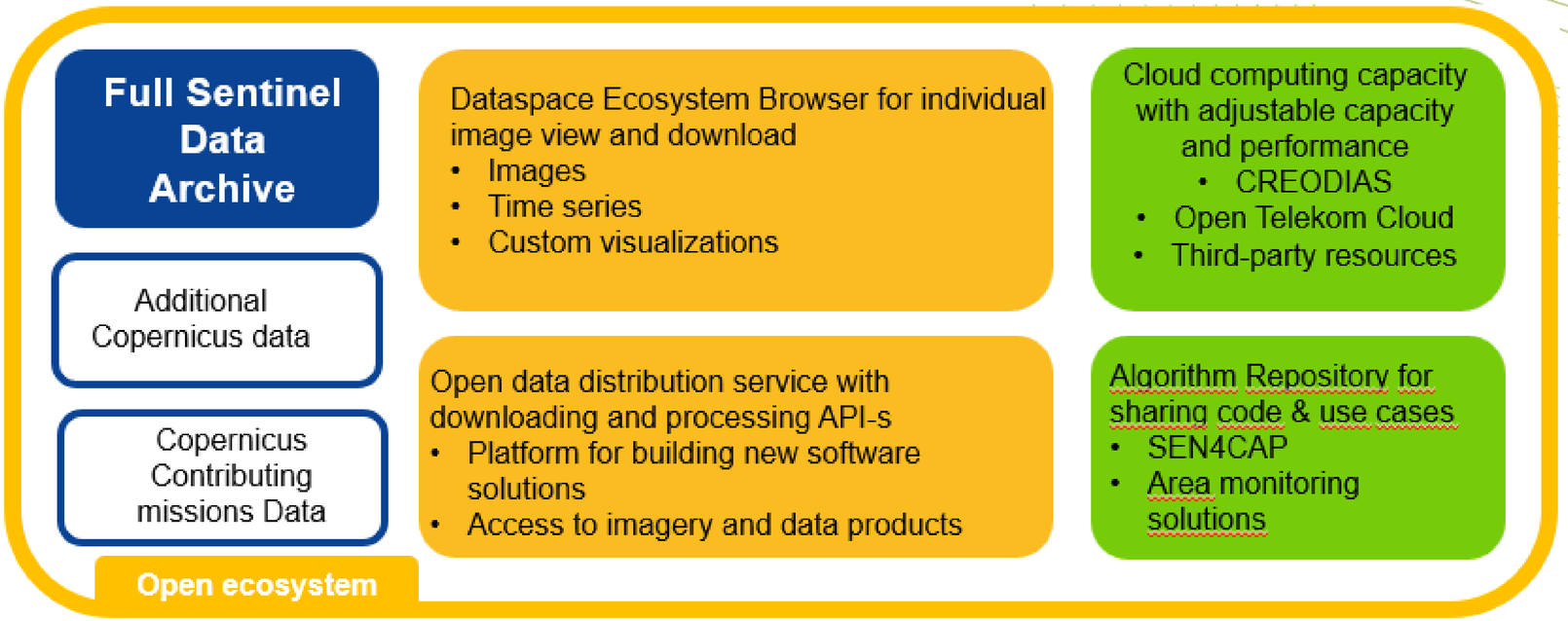
Calculate spectral indices
PostgreSQL
Categorize parcels
Training data selection
Random forest training
Random forest evaluation
Calculate probability of crop classes
Predict class
Calculate probability surplus
Scikit-learn
Evaluate compliance
Match with claimed crop
Compliance with required cultivation
Processed in house
Sentinel-2 imagery
Make ARD
Downloading
Geometric and radiometric correction
Cloud masking
FORCE
Identify cultivation
Calculate NDVI time series
Identify mowing dates
Identify cropping period
Identify overgrazed parcels
Cultivation requirements
dataspace.copernicus.eu
Pre-existing
Newly developed
Henits et al 2022 Remote Sensing

State of the art for most paying agencies

What paying agencies want	How this is achieved
Accuracy, high performance, reliability	High-performance in-house computing centers at paying agencies/contractors
Traceability of all processing steps from final decision all the way to initial satellite imagery	Storing many intermediate products
Compatibility with image sharing & viewing for farmers to follow up	Re-hosting the data and sharing to farmers
New functionality should easily be added on top of existing code	External open code modules, in-house code bases

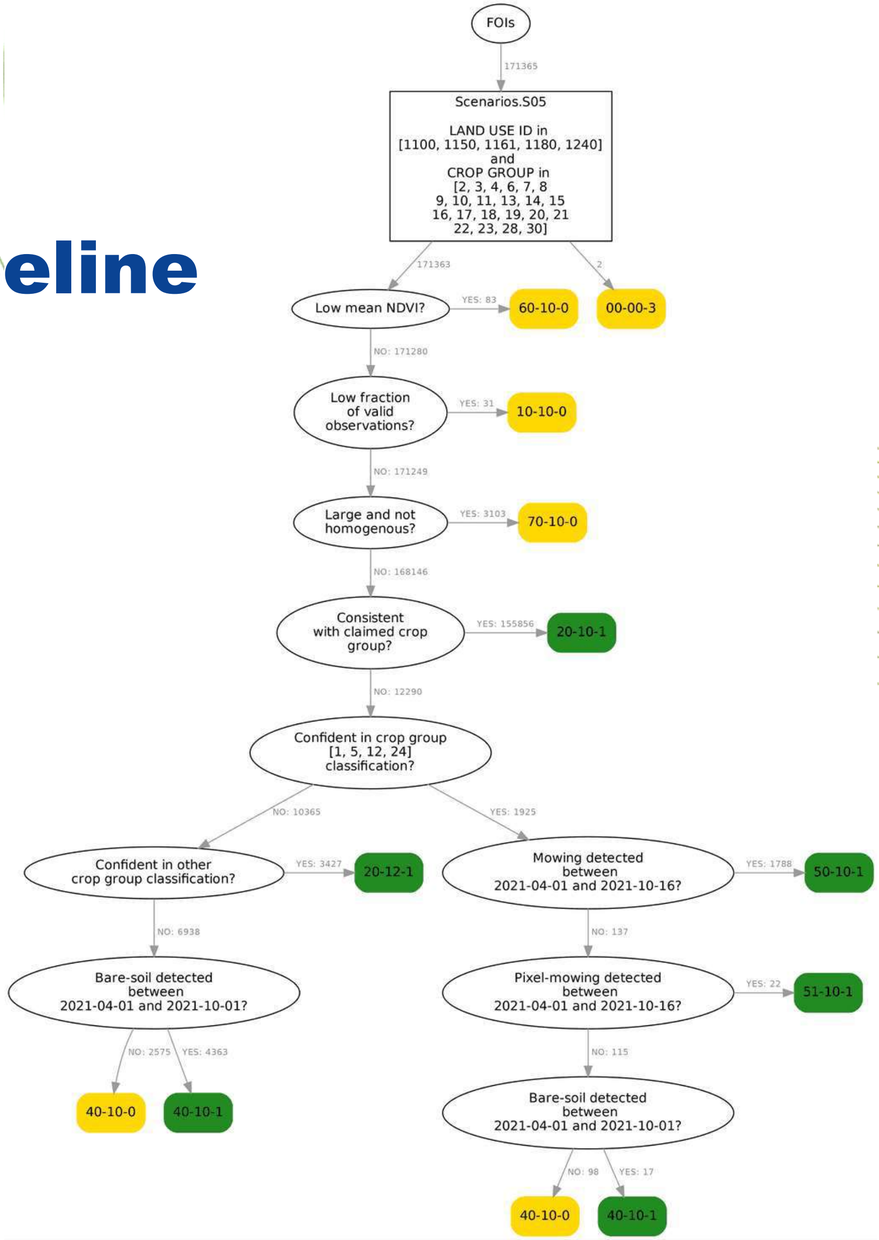
With the Copernicus Data Space Ecosystem, any part of this can be hosted online

- **Virtual machine processing capacity directly connected to the data archive**
- System of API-s for streamlined in-application data access and machine learning
- **Code libraries/packages directly on board**
- Software as a service solutions available
- Fast prototyping and high scalability, easy commercialization



Example of an API-based analysis pipeline

- Selecting imagery, Cloud masking, Outlier filtering
- Integration with parcel outlines and claim data
- Mean NDVI – Cultivation
- Size and homogeneity
- Consistency with claimed crop group
- Mowing detection or bare soil detection
- Output of monitoring results for parcel



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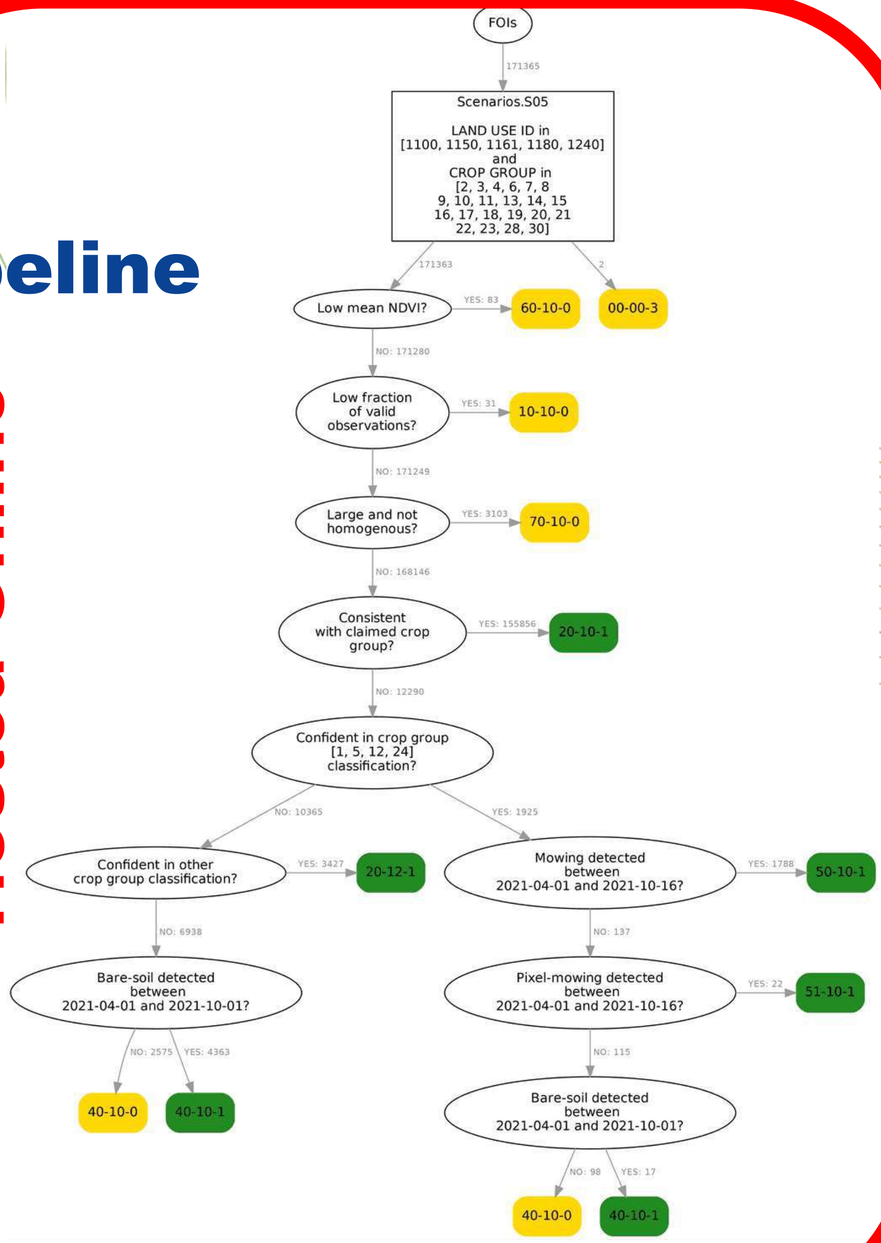
- **The complete pipeline can be processed online**

Hosted Online

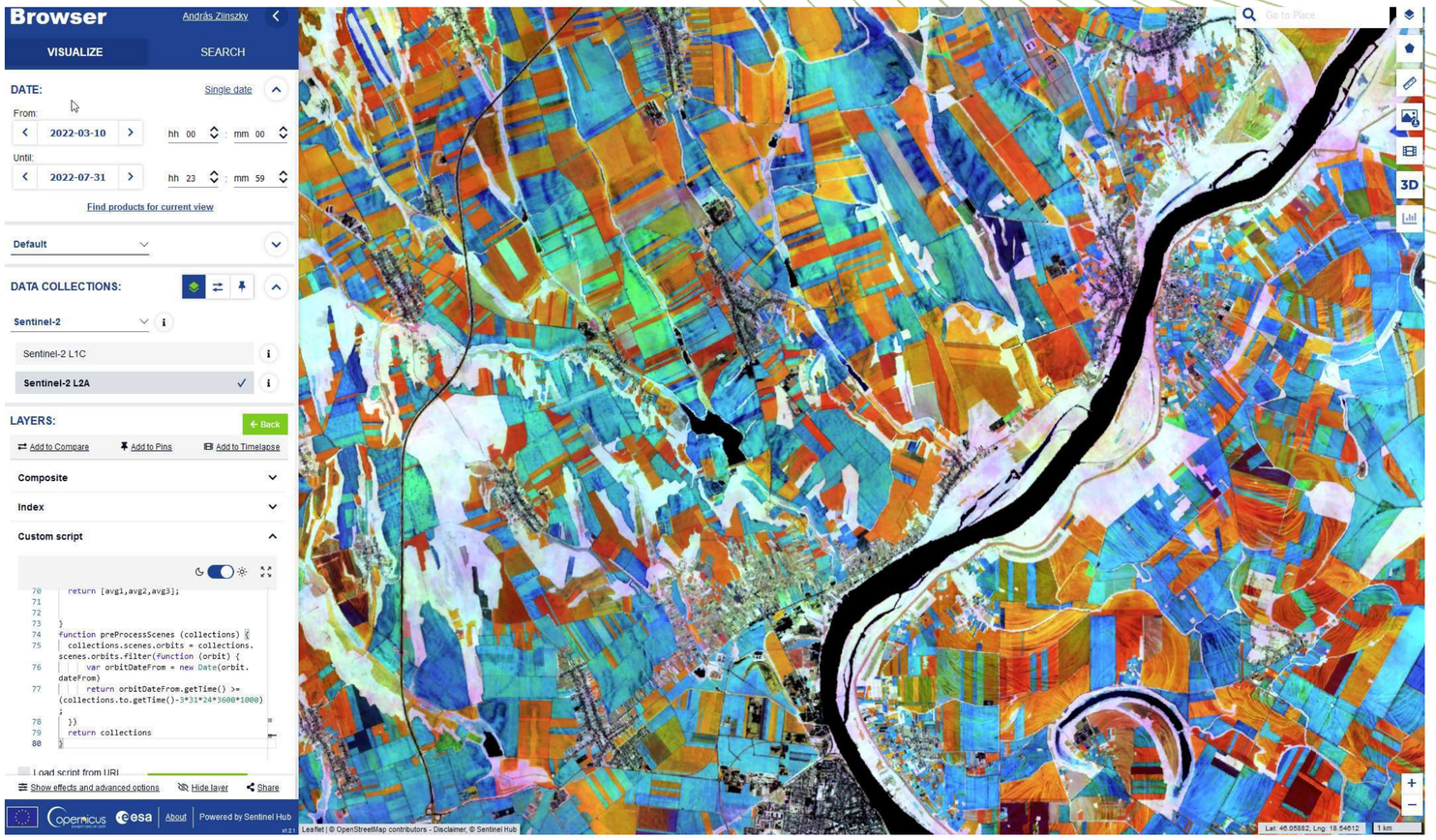


Benefits of the Copernicus Data Space Ecosystem hosted CAP monitoring

What paying agencies want	How this is achieved
Accuracy, high performance, reliability	• Long-term commitment to stable processing environment, data archives and virtual machines • Standard-ready pipelines
Traceability of all processing steps from final decision all the way to initial satellite imagery	• Traceability of satellite data and products • Documented processing tools • Open code
Compatibility with image sharing & viewing for farmers to follow up	• Direct links to interactive visualization of hosted imagery in Copernicus Browser
New functionality should easily be added on top of existing code	• Flexible, modular processing tools • Rapid prototyping and scaling

Open and free data visualization service: Copernicus Browser

- Free satellite image visualization service provided by ESA
- Interactive environment for operators of the paying agency
- Highly suitable for sharing imagery with farmers related to their claim process
- Advanced custom script visualizations available – eg. Agricultural Growth stage



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Additional benefits of Copernicus Data Space Ecosystem - upstream

- Wide range of code libraries/packages and analysis tools already available in the ecosystem, eg.
  - VITO CropSAR data integration as a service
  - EO-learn, a full set of data processing and machine learning tools in a python package
  - Sen4CAP, a complete CAP monitoring service

README.md

pypi package 1.4.2 | conda-forge v0.10.1 | python 3.8 | 3.9 | 3.10 | 3.11 | build passing
docs passing | license MIT | downloads 100k | downloads/month 2k | docker pulls 1.1k
codecov 89% | DOI 10.5281/zenodo.7966005

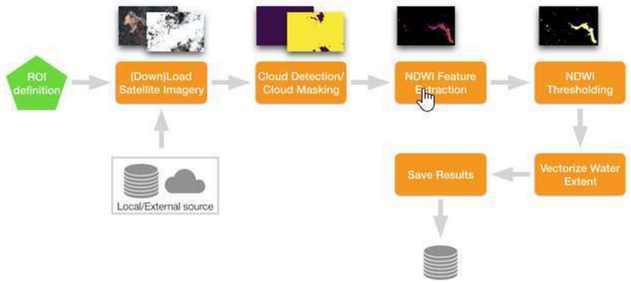
eo-learn

eo-learn makes extraction of valuable information from satellite imagery easy.

The availability of open Earth observation (EO) data through the Copernicus and Landsat programs represents an unprecedented resource for many EO applications, ranging from ocean and land use and land cover monitoring, disaster control, emergency services and humanitarian relief. Given the large amount of high spatial resolution data at high revisit frequency, techniques able to automatically extract complex patterns in such *spatio-temporal* data are needed.

`eo-learn` is a collection of open source Python packages that have been developed to seamlessly access and process *spatio-temporal* image sequences acquired by any satellite fleet in a timely and automatic manner. `eo-learn` is easy to use, it's design modular, and encourages collaboration -- sharing and reusing of specific tasks in a typical EO-value-extraction workflows, such as cloud masking, image co-registration, feature extraction, classification, etc. Everyone is free to use any of the available tasks and is encouraged to improve the, develop new ones and share them with the rest of the community.

`eo-learn` makes extraction of valuable information from satellite imagery as easy as defining a sequence of operations to be performed on satellite imagery. Image below illustrates a processing chain that maps water in satellite imagery by thresholding the Normalised Difference Water Index in user specified region of interest.

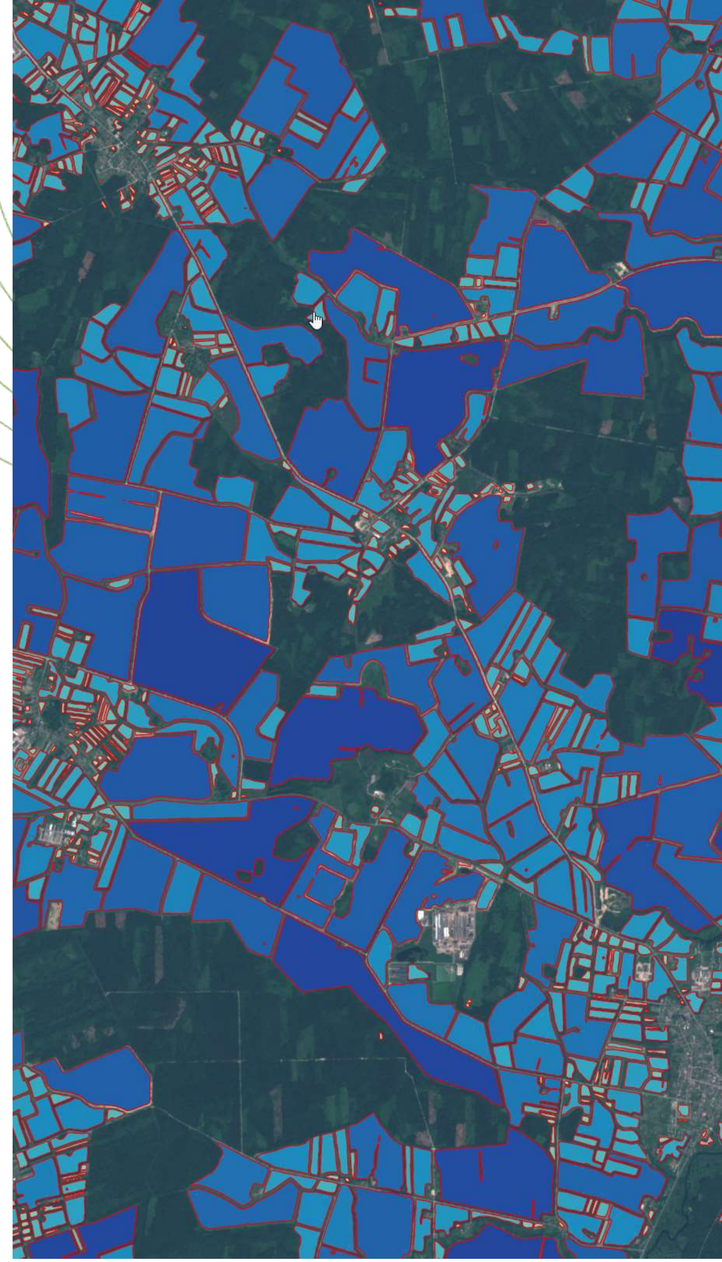


`eo-learn` *library acts as a bridge between Earth observation/Remote sensing field and Python ecosystem for data science and machine learning.* The library is written in Python and uses NumPy arrays to store and handle remote sensing data. Its aim is to make entry easier for non-experts to the field of remote sensing on one hand and bring the state-of-the-art tools for computer vision, machine learning, and deep learning existing in Python ecosystem to remote sensing experts.

Package Overview

Additional benefits of Copernicus Data Space Ecosystem - downstream

- Experience has already shown that many of these methods adapt well to different locations
  - Parcel delineation
  - Crop identification
  - Ineligible area detection
- Code repository structure supports sharing of best practices
  - Adaptation to local needs and legislation possible without starting from scratch
- **Spin-off applications of CAP monitoring expected in precision agriculture and habitat conservation**



Copernicus Data Space Ecosystem is transformative

Major transformation opportunity for CAP monitoring

This will contribute to a more value-for-money CAP monitoring for Europe

Many new applications possible beyond CAP with a similar approach

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Thank You!