

# Deliverable 1.5

## Data handling guidelines

|                           |   |
|---------------------------|---|
| <b>Creator</b>            | Lavreniuk M., Shumilo L., Kolotii A., Kussul N. (SRI, Ukraine)          |
| <b>Creation date</b>      | September. 1. 2018  |
| <b>Due date</b>           | August. 1. 2019   |
| <b>Last revision date</b> | Octobre. 8. 2019  |
| <b>Status</b>             | Final   |
| <b>Type</b>               | Report  |
| <b>Description</b>        | Data Handling Guidelines  |
| <b>Right</b>              | Public  |
| <b>Language</b>           | English   |
| <b>Citation</b>           | Lavreniuk et al. Data handling guidelines. GEOEssential Deliverable 1.5 |
| <b>Grant agreement</b>    | ERA-PLANET No 689443  |

## Executive Summary

In this deliverable we described and analyzed the main optical and radar satellites, in-situ data providers from European EO network, product services and data processing software in terms of optimized big data processing for essential variables and sustainable development goals indicators calculation in GEOEssential project. Brief descriptions, technical specifications and links to data access and usage guides are provided. Among the given sources are European services that are part of the GEOSS system and are supported by European or American programs as well as popular commercial products and software.

## Table of content

|  |           |
|--|-----------|
| <b>INTRODUCTION .....</b>                                      | <b>6</b>  |
| <b>SATELLITE DATA.....</b>                                     | <b>7</b>  |
| <b>OPTICAL.....</b>  | <b>7</b>  |
| SENTINEL-2 .....   | 7         |
| LANDSAT-8 .....  | 8         |
| SENTINEL-3 .....   | 9         |
| SENTINEL-5P .....  | 10        |
| MODIS .....  | 10        |
| <b>SAR.....</b>  | <b>11</b> |
| SENTINEL-1 .....   | 11        |
| RADARSAT-2 .....   | 12        |
| TERRASAR-X.....  | 12        |
| <b>IN-SITU DATA.....</b>                                       | <b>13</b> |
| <b>PRODUCTS AND SERVICES .....</b>                             | <b>15</b> |
| <b>DISSEMINATION PORTALS.....</b>                              | <b>15</b> |
| COPERNICUS OPEN ACCESS HUB.....                                | 15        |
| EARTHExplorer .....  | 16        |
| <b>SERVICES.....</b>   | <b>16</b> |
| THE COPERNICUS ATMOSPHERE MONITORING SERVICE (CAMS) .....      | 17        |
| COPERNICUS LAND MONITORING SERVICE (CLMS) .....                | 17        |
| COPERNICUS CLIMATE CHANGE SERVICE (C3S) .....                  | 18        |
| COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE (CMEMS) ..... | 18        |
| COPERNICUS EMERGENCY MANAGEMENT SERVICE (CEMS) .....           | 18        |
| COPERNICUS SERVICE FOR SECURITY .....                          | 18        |
| <b>OTHER DATA.....</b>   | <b>19</b> |
| <b>SOFTWARE .....</b>  | <b>19</b> |
| <b>OPEN-SOURCE SOFTWARE .....</b>                              | <b>19</b> |
| SNAP TOOLBOXES.....  | 19        |
| NANSAT.....  | 19        |
| SARPROZ .....  | 19        |
| SARSCAPE .....   | 19        |
| PANOPLY .....  | 20        |
| BEAT .....   | 20        |
| OPEN DATA CUBE (ODC).....                                      | 21        |
| ESA'S SEN2-AGRI SYSTEM.....                                    | 21        |
| <b>COMMERCIAL SOFTWARE .....</b>                               | <b>22</b> |
| ENVI.....  | 22        |
| ERDAS IMAGINE .....  | 22        |
| ECONITION.....   | 22        |
| <b>PLATFORMS.....</b>  | <b>23</b> |
| <b>OPEN-SOURCE SOLUTIONS.....</b>                              | <b>23</b> |
| GOOGLE EARTH ENGINE .....                                      | 23        |

|                                |                  |
|--------------------------------|------------------|
| COMMERCIAL SOLUTIONS.....      | 24               |
| DIAS.....                      | 24               |
| TEP .....                      | 29               |
| <b><u>CONCLUSION .....</u></b> | <b><u>30</u></b> |
| <b><u>REFERENCES .....</u></b> | <b><u>31</u></b> |

## List of Figures

|  |    |
|--|----|
| Figure 1 Dynamic graph on existing European EO networks..... | 14 |
| Figure 2 User interface of Copernicus Open Access Hub .....  | 15 |
| Figure 3 User interface of Earth Explorer .....              | 16 |
| Figure 4 User web-interface of Sen2-Agri system .....        | 22 |
| Figure 5 User interface of Google Earth Engine .....         | 23 |
| Figure 6 DIAS platforms .....                                | 24 |
| Figure 7 CREODIAS platform .....                             | 25 |
| Figure 8 Mundi web services .....                            | 26 |
| Figure 9 ONDA-DIAS.....                                      | 27 |
| Figure 10 WEKEO .....  | 28 |
| Figure 11 Sobloo public dashboard .....                      | 28 |
| Figure 12 Food Security TEP Analyst interface .....          | 30 |

## Introduction

In the context of the Global Earth Observation System of Systems (GEOSS), this deliverable lists and analyses a selection of satellite and in-situ data, products services and software in terms of optimized big data processing. The analysis contains technical characteristics and links for data access as well as links to the user manuals for the most useful optical and radar satellites, in-situ data providers in European EO network, product services that provide processed satellite data or results of data fusion for satellite and modelled data and software for satellite data processing.

Data and product services were selected according to the main themes of GEOEssential project and can be used for Essential variables and SDG indicators calculation.

## Satellite data

In this section we will talk about available satellites that can be useful in GEOEssential project. The list of them is shown in Table 1.

**Table 1. List of available satellites and specs**

| Satellite  | Resolution                     | Revisit time | Coverage     | Start date | Data access    | Spatial resolution (m) |
|------------|--------------------------------|--------------|--------------|------------|----------------|------------------------|
| Sentinel-2 | 10, 20, 60 m                   | 5 days       | Whole planet | 2015       | Free available | 30 m                   |
| Landsat-8  | 30 m, 100 m, 15 m (pan chrome) | 16 days      | Whole planet | 2013       | Free available | 30 m                   |
| Sentinel-3 | 300 m, 1 km                    | 1-2 days     | Whole planet | 2016       | Free available | 30 m                   |
| Sentinel-5 | 7 km                           | Daily        | Whole planet | 2017       | Free available | 30 m                   |
| MODIS      | 250 m, 1 km                    | Daily        | Whole planet | 1999       | Free available | 30 m                   |
| Sentinel-1 | 20 m                           | 6-12 days    | Whole planet | 2014       | Free available | 30 m                   |
| Radarsat   | 3 m, 100 m                     | 24 days      | Whole planet | 2007       | Commercial     | 30 m                   |
| TerraSAR-X | 25 cm, 1m, 3m, 18.5m, 40m      | 11 days      | Whole planet | 2014       | Commercial     | 15 m                   |

## Optical

In optical remote sensing, the energy of the sun light that is reflected from a surface is measured by the sensor. Satellites with optical sensors generate images of the Earth over relatively large areas and are useful in the production of vegetation maps or could be used for estimation of specific vegetation parameters.

### Sentinel-2

Sentinel-2 is a wide-swath, high-resolution, multi-spectral optical imaging mission, supporting Copernicus Land Monitoring studies, including the monitoring of vegetation, soil and water cover, as well as observation of inland waterways and coastal areas [1,2]. Main technical spectral characteristics are shown in Table 2.

**Table 2. Spectral bands for the Sentinel-2 sensors**

| Sentinel-2 bands | Sentinel-2A | Sentinel-2B |  |
|------------------|-------------|-------------|--|
|------------------|-------------|-------------|--|

|                              | Wavelength (nm) | Bandwidth (nm) | Wavelength (nm) | Bandwidth (nm) | Spatial resolution (m) |
|------------------------------|-----------------|----------------|-----------------|----------------|------------------------|
| Band 1 – Coastal aerosol     | 443.9           | 27             | 442.3           | 45             | 60                     |
| Band 2 – Blue                | 496.6           | 98             | 492.1           | 98             | 10                     |
| Band 3 – Green               | 560.0           | 45             | 559             | 46             | 10                     |
| Band 4 – Red                 | 664.5           | 38             | 665             | 39             | 10                     |
| Band 5 – Vegetation red edge | 703.9           | 19             | 703.8           | 20             | 20                     |
| Band 6 – Vegetation red edge | 740.2           | 18             | 739.1           | 18             | 20                     |
| Band 7 – Vegetation red edge | 782.5           | 28             | 779.7           | 28             | 20                     |
| Band 8 – NIR                 | 835.1           | 145            | 833             | 133            | 10                     |
| Band 8A – Narrow NIR         | 864.8           | 33             | 864             | 32             | 20                     |
| Band 9 – Water vapor         | 945             | 26             | 943.2           | 27             | 60                     |
| Band 10 – SWIR – Cirrus      | 1373.5          | 75             | 1376.9          | 76             | 60                     |
| Band 11 – SWIR               | 1613.7          | 143            | 1610.4          | 141            | 20                     |
| Band 12 – SWIR               | 2202.4          | 242            | 2185.7          | 238            | 20                     |

To achieve frequent revisits and high mission availability, two identical Sentinel-2 satellites (Sentinel-2A and Sentinel-2B) operate simultaneously. At high latitudes, Sentinel-2 swath overlap, and some regions will be observed twice or more every 5 days, but with different viewing angles.

Sentinel data access - <https://sentinel.esa.int/web/sentinel/sentinel-data-access>;  
Sentinel-2 user handbook - [https://sentinel.esa.int/documents/247904/685211/Sentinel-2 User Handbook](https://sentinel.esa.int/documents/247904/685211/Sentinel-2_User_Handbook).

## Landsat-8

Landsat-8 is an American Earth observation satellite launched on February 11, 2013. It is the eighth satellite in the Landsat program; the seventh to reach orbit successfully. Originally called the Landsat Data Continuity Mission (LDCM), it is a collaboration between NASA and the United States Geological Survey (USGS). Main technical spectral characteristics are shown in Table 3.

**Table 3. Spectral bands for the Landsat-8 sensors**

| Band                       | Wavelength (μm) | Spatial resolution (m) |
|----------------------------|-----------------|------------------------|
| Band 1 - Coastal / Aerosol | 0.433 – 0.453   | 30 m                   |
| Band 2 – Blue              | 0.450 – 0.515   | 30 m                   |
| Band 3 – Green             | 0.525 – 0.600   | 30 m                   |
| Band 4 – Red               | 0.630 – 0.680   | 30 m                   |



|                                    |               |       |
|------------------------------------|---------------|-------|
| Band 5 - Near Infrared             | 0.845 – 0.885 | 30 m  |
| Band 6 - Short Wavelength Infrared | 1.560 – 1.660 | 30 m  |
| Band 7 - Short Wavelength Infrared | 2.100 – 2.300 | 30 m  |
| Band 8 - Panchromatic              | 0.500 – 0.680 | 15 m  |
| Band 9 - Cirrus                    | 1.360 – 1.390 | 30 m  |
| Band 10 - Long Wavelength Infrared | 10.30 – 11.30 | 100 m |
| Band 11 - Long Wavelength Infrared | 11.50 – 12.50 | 100 m |

The Landsat-8 satellite images cover the entire Earth every 16 days in an 8-day offset from Landsat-7. Data collected by the instruments onboard the satellite are available to download at no charge from EarthExplorer, GloVis, or the LandsatLook Viewer within 24 hours of acquisition.

Landsat-8 carries two push-broom instruments: The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). The spectral bands of the OLI sensor provide enhancement from prior Landsat instruments, with the addition of two additional spectral bands: a deep blue visible channel (band 1) specifically designed for water resources and coastal zone investigation, and a new shortwave infrared channel (band 9) for the detection of cirrus clouds.

Landsat data access - <https://earthexplorer.usgs.gov/>;

Landsat-8 data users handbook - <https://landsat.usgs.gov/landsat-8-data-users-handbook>.

## Sentinel-3

SENTINEL-3 is a European Earth Observation satellite mission developed to support GMES ocean, land, atmospheric, emergency, security and cryospheric applications. The main objective of the SENTINEL-3 mission is to measure sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring [3].

The spacecraft carries four main instruments:

- OLCI: Ocean and Land Colour Instrument. Have 21 bands [0.4-1.02]  $\mu\text{m}$
- SLSTR: Sea and Land Surface Temperature Instrument. Have 9 bands [0.55-12]  $\mu\text{m}$
- SRAL: SAR Radar Altimeter.
- MWR: Microwave Radiometer.

A pair of Sentinel-3 satellites will enable a short revisit time of less than two days for the OLCI instrument and less than one day for SLSTR at the equator. This will be achieved using both Sentinel-3A and Sentinel-3B satellites in conjunction. The satellite orbit provides a 27-day repeat for the topography package, with a 4-day sub-cycle.

The Copernicus Open Access Hub provides several L2 products: Land Surface and Sea Surface Temperature, Synergy products (Land Surface Reflection and Aerosol Load over Land), combined VGT-like products TOA Reflection, VGT-S like products (Surface Reflection and NDVI).

Sentinel-3 User Handbook: [https://earth.esa.int/documents/247904/685236/Sentinel-3\\_User\\_Handbook](https://earth.esa.int/documents/247904/685236/Sentinel-3_User_Handbook)

Sentinel Product List:

<https://sentinel.esa.int/documents/247904/685154/Sentinel+Products+List-Issue1-Rev1.pdf>

Sentinel-3 Data Access: <https://scihub.copernicus.eu/s3>

## Sentinel-5P

The Sentinel-5P mission focuses on monitoring of trace gas concentrations and aerosols in the atmosphere to support operational services covering air-quality near-real time applications, air-quality protocol monitoring and climate protocol monitoring.

The Sentinel-5/UVNS instrument is a spectrometer system operating in the ultraviolet to shortwave infrared range with 7 different spectral bands: UV-1 (270-300nm), UV-2 (300-370nm), VIS (370-500nm), NIR-1 (685-710nm), NIR-2 (755-773nm), SWIR-1 (1590-1675nm) and SWIR-3 (2305-2385nm). Its spatial resolution is below 8km for wavelengths above 300nm and below 50km for wavelength below 300nm.

Copernicus provides several L2 products like total column of: Aerosol, CH<sub>4</sub>, CO, HCHO, NO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>.

Sentinel-5 data access - <https://s5phub.copernicus.eu/dhus/#/home>;

Sentinel-5 data users handbook - <https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-5p/products-algorithms>.

## MODIS

The Moderate Resolution Imaging Spectroradiometer (MODIS) is a payload imaging sensor built by Santa Barbara Remote Sensing that was launched into Earth orbit by NASA in 1999 on board the Terra (EOS AM) Satellite, and in 2002 on board the Aqua (EOS PM) satellite. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4  $\mu\text{m}$  to 14.4  $\mu\text{m}$  and at varying spatial resolutions (2 bands at 250 m, 5 bands at 500 m and 29 bands at 1 km) [4]. Main technical spectral characteristics are shown in Table 4.

**Table 4. Spectral bands for the MODIS sensors**

| Band | Wavelength<br>(nm) | Resolution<br>(m) |
|------|--------------------|-------------------|
| 1    | 620–670            | 250               |
| 2    | 841–876            | 250               |
| 3    | 459–479            | 500               |
| 4    | 545–565            | 500               |
| 5    | 1230–1250          | 500               |
| 6    | 1628–1652          | 500               |
| 7    | 2105–2155          | 500               |
| 8    | 405–420            | 1000              |
| 9    | 438–448            | 1000              |
| 10   | 483–493            | 1000              |
| 11   | 526–536            | 1000              |
| 12   | 546–556            | 1000              |

| Band | Wavelength<br>( $\mu\text{m}$ ) | Resolution<br>(m) |
|------|---------------------------------|-------------------|
| 20   | 3.660–3.840                     | 1000              |
| 21   | 3.929–3.989                     | 1000              |
| 22   | 3.929–3.989                     | 1000              |
| 23   | 4.020–4.080                     | 1000              |
| 24   | 4.433–4.498                     | 1000              |
| 25   | 4.482–4.549                     | 1000              |
| 26   | 1.360–1.390                     | 1000              |
| 27   | 6.535–6.895                     | 1000              |
| 28   | 7.175–7.475                     | 1000              |
| 29   | 8.400–8.700                     | 1000              |
| 30   | 9.580–9.880                     | 1000              |
| 31   | 10.780–11.280                   | 1000              |

|    |         |      |  |    |               |      |
|----|---------|------|--|----|---------------|------|
| 13 | 662–672 | 1000 |  | 32 | 11.770–12.270 | 1000 |
| 14 | 673–683 | 1000 |  | 33 | 13.185–13.485 | 1000 |
| 15 | 743–753 | 1000 |  | 34 | 13.485–13.785 | 1000 |
| 16 | 862–877 | 1000 |  | 35 | 13.785–14.085 | 1000 |
| 17 | 890–920 | 1000 |  | 36 | 14.085–14.385 | 1000 |
| 18 | 931–941 | 1000 |  |    |               |      |

Together the instruments image the entire Earth every 1 to 2 days. They are designed to provide measurements in large-scale global dynamics including changes in Earth's cloud cover, radiation budget and processes occurring in the oceans, on land, and in the lower atmosphere. MODIS utilizes four on-board calibrators in addition to the space view in order to provide in-flight calibration: solar diffuser (SD), solar diffuser stability monitor (SDSM), spectral radiometric calibration assembly (SRCA), and a v-groove black body.

Data access: <https://modis.gsfc.nasa.gov/data/>

MODIS Product User's Guide:

[https://mcst.gsfc.nasa.gov/sites/mcst.gsfc/files/file\\_attachments/M1054.pdf](https://mcst.gsfc.nasa.gov/sites/mcst.gsfc/files/file_attachments/M1054.pdf)

## SAR

The use of radar systems, in the first order, synthetic aperture radar (SAR) sensors, is explained by several known advantages as ability to acquire data during day and night as well as in all-weather conditions. However, data (images) collected by SAR systems have specific features that should be taken into account. They are the presence of noise-like phenomenon called speckle that can be also treated as multiplicative noise, non-Gaussian character (probability density function (PDF)) of this noise and its spatial correlation, possible geometric and radiometric distortions in original (raw) images, etc. This makes highly desirable to carry out pre-processing of such data before offering them to potential users (customers) or before exploiting these data for extracting valuable information from them [5].

### Sentinel-1

The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather [6]. Sentinel-1 has four operational modes:

- Strip Map (SM) Mode features 5-by-5-metre (16 by 16 ft) spatial resolution and an 80 km (50 mi) swath. Offers data products in single (HH or VV) or double (HH + HV or VV + VH) polarization
- Interferometric Wide Swath (IW) Mode features 5-by-20-metre (16 by 66 ft) spatial resolution and a 250 km (160 mi) swath. Offers data products in single (HH or VV) or double (HH + HV or VV + VH) polarization
- Extra Wide Swath (EW) Mode features 25-by-100-metre (82 by 328 ft) spatial resolution and a 400 km (250 mi) swath. Offers data products in single (HH or VV) or double (HH + HV or VV + VH) polarization

- Wave (WV) Mode features 5-by-20-metre (16 by 66 ft) resolution and a low data rate. It produces 20 by 20 km (12 by 12 mi) sample images along the orbit at intervals of 100 km (62 mi). Offers data products only in single (HH or VV) polarization.

Sentinel data access - <https://sentinel.esa.int/web/sentinel/sentinel-data-access>;

Sentinel-1 user guide - <https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar>.

## Radarsat-2

The RADARSAT-2 mission design and construction incorporate new capabilities that ensure Canada's continued leadership in the global marketplace for radar image data. The primary mission objective is the supply and distribution of data and products to meet the needs of present and future markets using a commercially viable approach. This is achieved by leveraging the knowledge and experience gained through the long and successful RADARSAT-1 mission while taking advantage of new technologies [7].

Radarsat resolution is 1x3 m in spotlight mode and have HH, VV, HV and VH polarization.

Radarsat data ordering - <http://www.asc-csa.gc.ca/eng/satellites/radarsat2/order-contact.asp>

Radarsat product description - [https://mdacorporation.com/docs/default-source/technical-documents/geospatial-services/52-1238\\_rs2\\_product\\_description.pdf?sfvrsn=10](https://mdacorporation.com/docs/default-source/technical-documents/geospatial-services/52-1238_rs2_product_description.pdf?sfvrsn=10)

## TerraSAR-X

TerraSAR-X1 (also referred to as TSX or TSX-1) is a German X-band SAR satellite mission for scientific and commercial applications (national project). The science objectives are to make multi-mode and high-resolution X-band data available for a wide spectrum of scientific applications in such fields as: hydrology, geology, climatology, oceanography, environmental and disaster monitoring, and cartography (DEM generation) making use of interferometry and stereometry. Main technical spectral characteristics are shown in Table 5.

Data Ordering: <http://www.asc-csa.gc.ca/eng/satellites/radarsat2/order-contact.asp>

Data Description: [https://mdacorporation.com/docs/default-source/technical-documents/geospatial-services/52-1238\\_rs2\\_product\\_description.pdf?sfvrsn=10](https://mdacorporation.com/docs/default-source/technical-documents/geospatial-services/52-1238_rs2_product_description.pdf?sfvrsn=10)

**Table 5. Spectral bands for the TerraSAR-X sensors**

| Mode                                       | Coverage Azimuth<br>x Range (km <sup>2</sup> ) | Resolution (m) |
|--|--|----------------|
| ScanSAR Wide (SCW)                         | 200 x (194–266)                                | 40             |
| ScanSAR (SC)                               | 150 x 100                                      | 18             |
| StripMap (SM)                              | 50 x 30  | 3              |
| Spotlight (SL)                             | 10 x 10  | 1.7 - 3.5      |
| High-Resolution Spotlight (HS)             | 5 x 10   | 1.4 - 3.5      |
| 300 MHz High-Resolution Spotlight (HS 300) | 5 x (5-10)                                     | 1.1 - 1.8      |
| Staring Spotlight (ST)                     | (2.5 – 2.8) x ~ 6                              | 0.24 azimuth   |

TerraSAR data access - <https://terrasar-x-archive.terrasar.com/>;

TerraSAR user guide - [https://mdacorporation.com/docs/default-source/product-spec-sheets/geospatial-services/image\\_product\\_guide.pdf?sfvrsn=4](https://mdacorporation.com/docs/default-source/product-spec-sheets/geospatial-services/image_product_guide.pdf?sfvrsn=4).

## In-situ data

In-situ data are vital and useful for two main purpose:

1. As point measurements.

There are a lot of special networks in Europe that provide in-situ data as point measurements for different domains. One of such networks that are relevant in this project is European Network of Earth Observation Networks (ENEON). At the moment there are several projects, integrating knowledge on existing in-situ measurements. For example, project ConnectinGEO (Coordinating an Observation Network of Networks EnCompassing saTellite and IN-situ to fill the Gaps in European Observations) [8] focused on three basic topics: create and maintain ENEON [9], conduct a gap analysis in the European in-situ Earth Observation networks and coordinate and stimulate the European contribution to GEOSS. ENEON network is a common network of in-situ Earth observation (EO) networks which shall provide an integrated and harmonized perspective on observation resources, helping to reduce redundancies and detect gaps in the European EO arena (Fig. 1). Also, there are others national and global networks of in-situ data measurements. For example, for food security JECAM (Joint Experiment of Crop Assessment and Monitoring) [10] initiative collect in-situ data with further reaching a convergence of approaches, develop monitoring and reporting protocols and best practices for a variety of global agricultural systems.

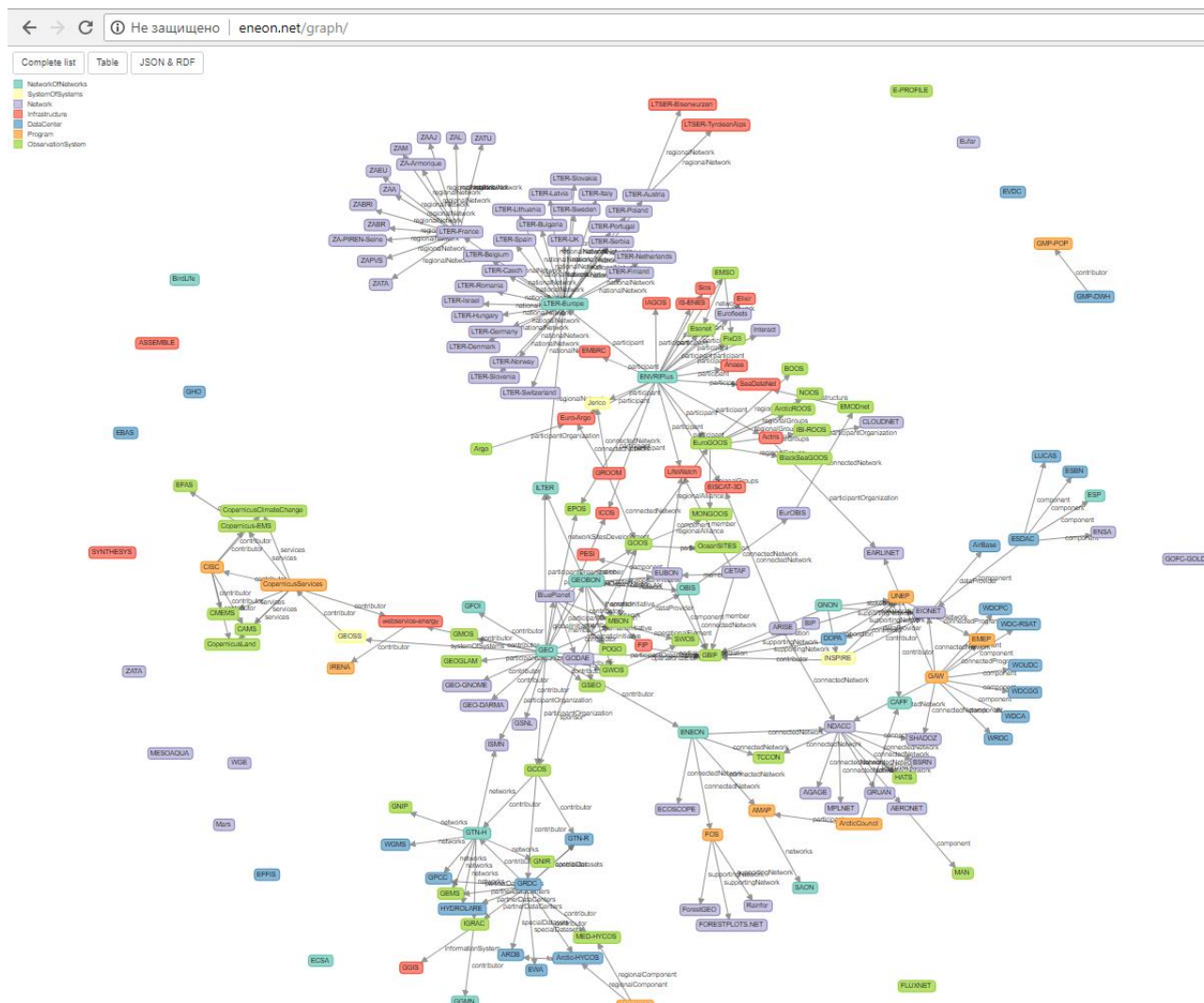


Figure 1 Dynamic graph on existing European EO networks

## 2. For calibration and validation (cal/val) activities.

CEOS (The Committee on Earth Observation Satellites) [11] Cal/Val Portal [12] provides support to worldwide activities on calibration and validation, and specifically ensures that sensor intercalibration is favored in a standardized way. The overall goal is to increase measurement accuracy of all the sensors, which will be supported by this system and to increase the inter-operability between EO platforms.

Copernicus provides access to in-situ measurements via Copernicus In-situ Component (<https://insitu.copernicus.eu/>). Copernicus offers a world of insight about our planet to European and global citizens, public authorities, policy makers, scientists, entrepreneurs and businesses. Copernicus is openly and freely available to everyone at no cost. Copernicus transforms information from multiple sources, including satellites, into operational services for keeping watch over the planet Earth's land, ocean and atmosphere, monitoring climate change, supporting European emergency management and safeguarding civil security. The Copernicus Services rely on many environmental measurements collected by data providers



external to Copernicus, from ground-based, sea-borne or air-borne monitoring systems, as well as geospatial reference or ancillary data, collectively referred to as “in situ” data.

Geo-wiki (<https://www.geo-wiki.org/>) is a platform for engaging citizens in environmental monitoring. It aids in both the validation of existing geographical information and the collection of new geographical information through crowdsourcing. Using tools such as Google Earth, Bing Maps, Geotagged photographs and the internet, individual volunteers are able to contribute valuable information. It provides feedback on existing information overlaid on satellite imagery or by contributing entirely new data. Data can be input via the traditional desktop platform or mobile devices, with campaigns and games used to incentivize input. Resulting data are available without restriction.

## Products and Services

### Dissemination portals

#### Copernicus Open Access Hub

The Open Access Hub provides complete, free and open access to Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5P user products (<https://sentinel.esa.int/web/sentinel/sentinel-data-access>). The Data Hub Graphical User Interface (GUI) can be used to identify and order offline products (Fig. 2).

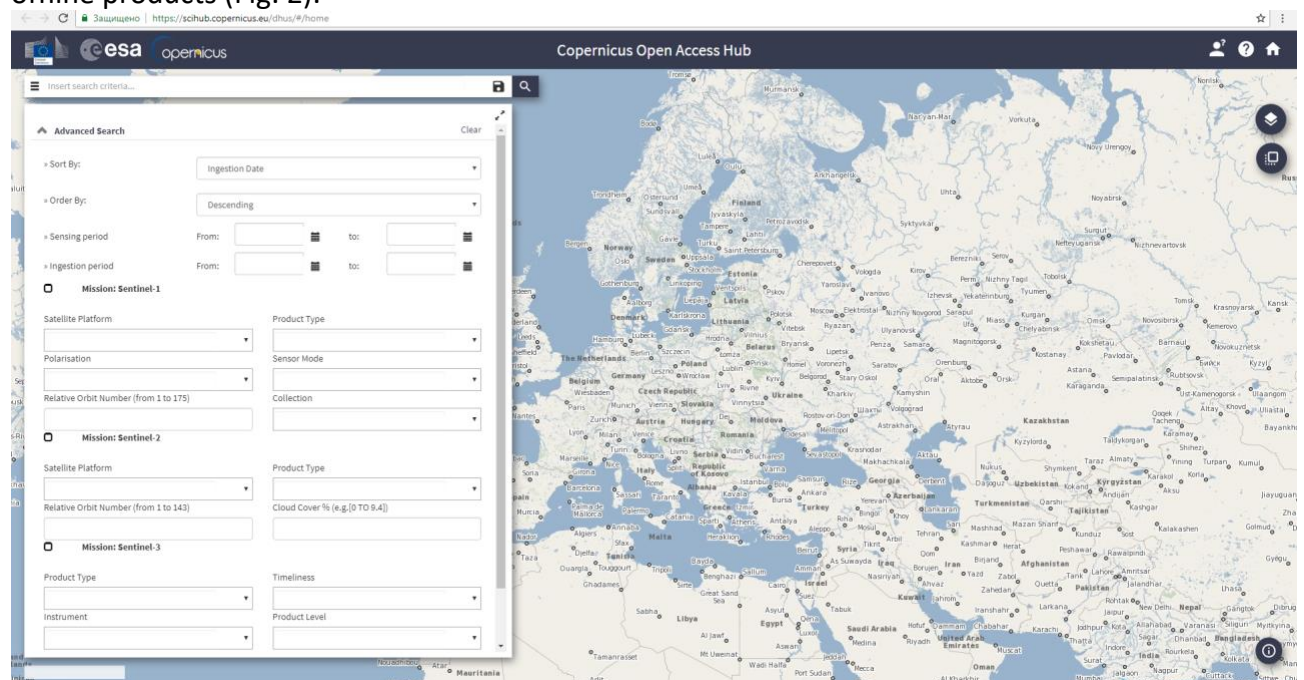


Figure 2 User interface of Copernicus Open Access Hub

The Data Hub exposes the Open Data Protocol (OData) interface for accessing the EO data stored on the archive. This protocol is based on top of the well-supported HTTPS/ REST transfer protocol that can be handled by a large set of client tools as simple as common Web browsers, download-managers or computer programs such as curl or wget. The Odata protocol provides easy access to the Data Hub and can be used

for building URI for performing search queries and product downloads offering to the users the capability to remotely run scripts in batch mode.

## EarthExplorer

EarthExplorer (EE) (<http://earthexplorer.usgs.gov>) provides online search, browse display, metadata export, and data download for earth science data from the archives of the U.S. Geological Survey (USGS). EE provides an enhanced user interface using state-of-the-art JavaScript libraries, Hypertext Preprocessor (PHP), and the advanced Oracle spatial engine (Fig. 3).

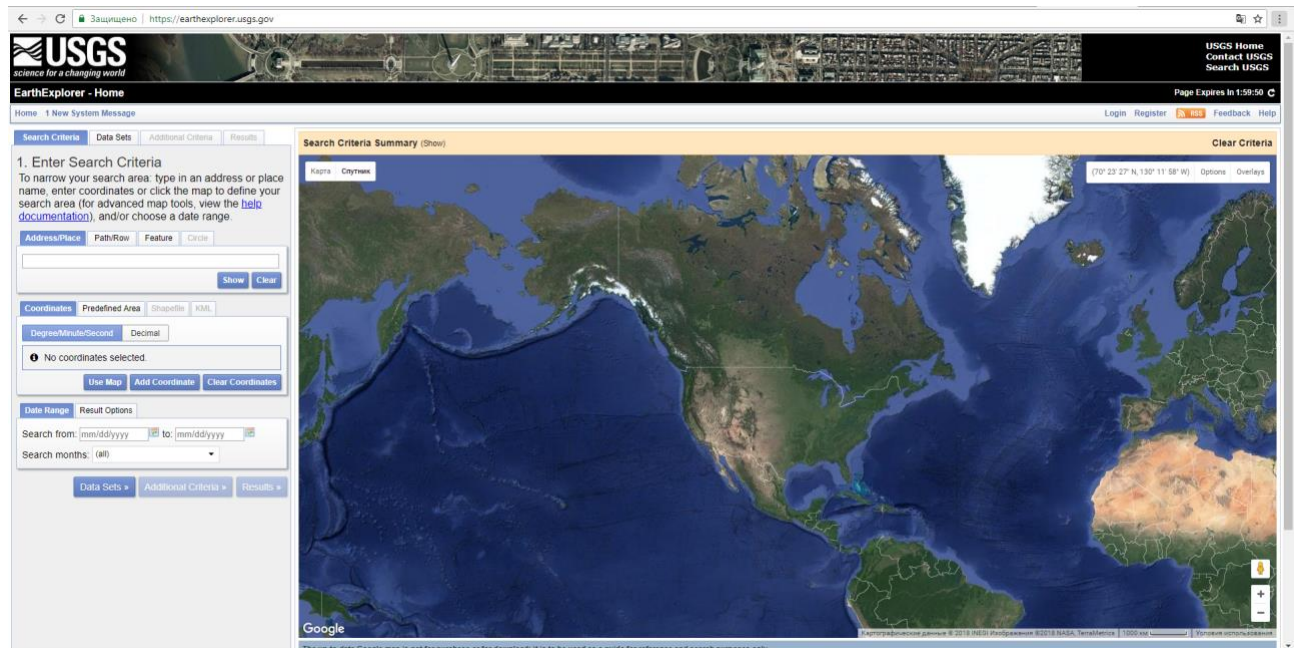


Figure 3 User interface of Earth Explorer

The Bulk Download Application (<https://earthexplorer.usgs.gov/bulk/>) is an easy-to-use tool for downloading large quantities of satellite imagery and geospatial data. ESPA Bulk Download Client utilizes python scripts for data downloads.

## Services

Copernicus (<http://www.copernicus.eu>) has been specifically designed to meet user requirements. Based on satellite and in-situ observations, the Copernicus services deliver near-real-time data on a global level which can also be used for local and regional needs, to help us with better understanding of our planet and to manage the environment where we live in sustainable way. Copernicus is served by a set of dedicated satellites (the Sentinel families) and contributing missions (existing commercial and public satellites). Copernicus also collects information from in-situ systems such as ground stations that deliver data acquired by multiple sensors on the ground, at sea or in the air [13]. The Copernicus services transform this numerous sets of satellite and in-situ data into value-added information by processing and analysing the data. These value-adding activities are streamlined through six thematic streams of Copernicus services: Atmosphere (CAMS), Marine (CMEMS), Land



(CLMS), Climate (C3S), Emergency (EMS), and Security. In this project we consider more in detail Atmosphere (CAMS) and Land (CLMS).

## The Copernicus Atmosphere Monitoring Service (CAMS)

The Copernicus Atmosphere Monitoring Service (CAMS, <http://copernicus.eu/main/atmosphere-monitoring>) provides continuous data and information on atmospheric composition. The service describes the current situation, forecasts the situation a few days ahead, and analyses consistently retrospective data records for recent years.

The service focuses on five main areas:

1. Air quality and atmospheric composition;
2. Ozone layer and ultra-violet radiation;
3. Emissions and surface fluxes;
4. Solar radiation;
5. Climate forcing.

This service has around 10 years of developments, and its current precursor project, MACC-III (Monitoring Atmospheric Composition and Climate - Interim Implementation), is delivering the pre-operational Copernicus Atmosphere Service. The service is being implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF). Every day, CAMS provides five-day forecasts of aerosols, atmospheric pollutants, greenhouse gases, stratospheric ozone and the Ultraviolet –Index [14].

## Copernicus Land Monitoring Service (CLMS)

Copernicus Land Monitoring Service (CLMS, <http://copernicus.eu/main/land-monitoring>) processes Earth Observation data in order to provide qualified added-value products and information about the land surface, while ensuring continuity and timely delivery to a broad range of users [15].

CLMS consists of three main components:

1. The Global component is coordinated by the European Commission DG Joint Research Centre (JRC). It produces data across a wide range of biophysical variables at a global scale (i.e. worldwide), which describe the state of vegetation (e.g. leaf area index, fraction of green vegetation cover, vegetation condition index), the energy budget (e.g. albedo, land surface temperature, top of canopy reflectance) and the water cycle (e.g. soil water index, water bodies).
2. The Pan-European component is coordinated by the European Environment Agency (EEA) and will produce 5 high resolution data sets describing the main land cover types: artificial surfaces (e.g. roads and paved areas), forest areas, agricultural areas (grasslands), wetlands, and small water bodies. The pan-European component is also updating the Corine Land Cover dataset to the reference year 2012.
3. The Local component is coordinated by the European Environment Agency (EEA) and aims to provide specific and more detailed information that is complementary to the information obtained through the Pan-European component. It focuses on "hotspots" which are prone to specific environmental challenges. It provides detailed land cover and land used information (over major European cities, which are the first type of "hotspots"). This is the so-called Urban Atlas.

## Copernicus Climate Change Service (C3S)

The Copernicus Climate Change Service (C3S, <https://www.copernicus.eu/en/services/climate-change>) supports society by providing authoritative information about the past, present and future climate in Europe and the rest of the World. C3S is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF) on behalf of the European Commission. C3S relies on climate research carried out within the World Climate Research Programme (WCRP) and responds to user requirements defined by the Global Climate Observing System (GCOS). C3S provides an important resource to the Global Framework for Climate Services (GFCs).

1. The service provides: a single point of access to a variety of climate datasets, including observations, reanalyses of past observations, seasonal forecasts and climate model projections;
2. powerful toolbox for processing and visualising data in the cloud;
3. real applications of Climate Data Store data and tools that demonstrate how businesses, governments and citizens can make informed decisions on how to mitigate the effects of climate change;
4. quality assurance for all Climate Data Store data, tools and applications.

## Copernicus Marine Environment Monitoring Service (CMEMS)

The Copernicus Marine Environment Monitoring Service (CMEMS, <https://www.copernicus.eu/en/services/marine>) provides regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas.

The observations and forecasts produced by the service support all marine applications, including:

- Marine safety;
- Marine resources;
- Coastal and marine environment;
- Weather, seasonal forecasting and climate.

## Copernicus Emergency Management Service (CEMS)

The Copernicus Emergency Management Service (Copernicus EMS, <https://www.copernicus.eu/en/services/emergency>) provides all actors involved in the management of natural disasters, man-made emergency situations, and humanitarian crises with timely and accurate geo-spatial information derived from satellite remote sensing and completed by available in situ or open data sources.

The Copernicus EMS consists of two components:

1. a mapping component;
2. an early warning component.

## Copernicus service for Security

The Copernicus service for Security applications aims to support European Union policies by providing information in response to Europe's security challenges (<https://www.copernicus.eu/en/services/security>). It improves crisis prevention, preparedness and response in three key areas:

- Border surveillance;
- Maritime surveillance;
- Support to EU External Action.

## Other data

Among other data, mostly model data are used. As well as models require input data, it could be implemented as services (see section **Services**).

## Software

Let us now briefly discuss available open-source and commercial software for basic operations of radar and optical images pre-processing. Existing tools can be classified to general purpose image processing ones, specialized tools for radar data processing and tools for performing particular operations.

### *Open-source software*

#### SNAP toolboxes

A common architecture for all Sentinel Toolboxes is being jointly developed by Brockmann Consult, Array Systems Computing and C-S called the Sentinel Application Platform (SNAP, <http://step.esa.int/main/toolboxes/snap/>). The SNAP architecture is ideal for Earth Observation processing and analysis due to the following technological innovations: Extensibility, Portability, Modular Rich Client Platform, Generic EO Data Abstraction, Tiled Memory Management, and a Graph Processing Framework.

#### Nansat

Another example is Nansat software (<http://nansat.readthedocs.io/en/latest/>). It has been developed by remote sensing group at the Nansen Environmental and Remote Sensing Center. This is an open-source Python package that provides mapping and reading facilities for several Earth observation radars like ASAR, Radarsat-2, and Sentinel-1. It is more difficult to process multichannel data using this software.

#### SARPROZ

SARPROZ (<https://www.sarproz.com/>) can be an alternative. One advantage could be that this software is based on Matlab. This allows a user to design his/her own software blocks. Interferometric imaging mode is supported. Besides, the software can run on multiple CPU cores that accelerates processing.

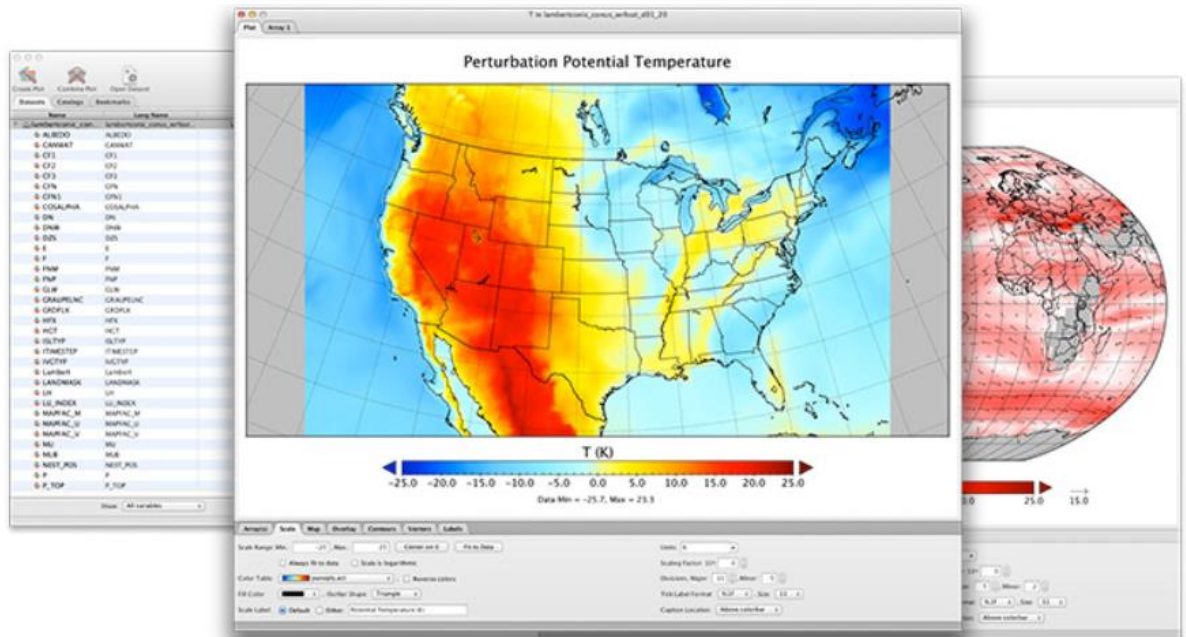
#### SARScape

SARScape (<http://www.sarmap.ch/page.php?page=sarscape>) is often recommended by users. One advantage is that it supports polarimetric modes (dual-polarimetric and full-polarimetric). Another advantage is that SAR image advanced filters can be applied including

single-channel, multi-channel, and polarimetric ones. This allows efficient speckle reduction and preservation of radar reflectivity, edges, details and textural features which is important.

## Panoply

Panoply (<https://www.giss.nasa.gov/tools/panoply/>) is a cross-platform application that runs on Macintosh, Windows, Linux and other desktop computers and gives an opportunity to plot geo-referenced and other arrays from netCDF, HDF, GRIB, and other datasets. In offline mod it is one of the best GIS systems for products such as Sentinel-5p and Sentinel-3 data visualization.



## BEAT

The Basic ENVISAT Atmospheric Toolbox (BEAT)

(<https://eo4society.esa.int/resources/beat/>) project is an open source software for scientific analysis of atmospheric EO data.

The primary instruments supported by BEAT are Tropomi (Sentinel-5P), GOME-2 and IASI (MetOp), OMI, TES and MLS (Aura), GOMOS, MIPAS, and SCIAMACHY (ENVISAT), and GOME (ERS-2).

The tool consists of several components, with the main components being CODA (allows direct reading access to product data, supporting a very wide range of products), HARP (toolset for ingesting, processing and inter-comparing satellite or model data against correlative data), and VISAN (cross-platform visualization and analysis application for atmospheric data using Python). These components are made available by means of several software packages.

## Open Data Cube (ODC)

Project Open Data Cube (ODC) is an open source project was born out of the need to better manage satellite data. It has evolved to support interactive data science and scientific computing [16]. Open Data Cube Core provides an integrated gridded data analysis environment for decades of analysis ready earth observation satellite and related data from multiple satellite and other acquisition systems (<https://www.opendatacube.org/>). The objective of the ODC is:

- Minimize time and specialized knowledge required to access and prepare satellite data
- Free and open EO satellite data and application algorithms
- Open source software solutions that are advanced through community contributions
- Consistent data architectures that allow sharing of code, tools and algorithms
- Efficient time series analyses to support land change applications
- Use of multiple datasets together (e.g., interoperability and complementarity)
- Use of common GIS tools (e.g. QGIS, ArcGIS)
- Local and regional solutions that avoid commercial and internet dependence
- Sustained customer service and user support

## ESA's Sen2-Agri system

Sen2-Agri is an automated data processing system Sentinel-2 (A and B), developed during the implementation of the European Space Agency's project Sentinel-2 for Agriculture. This system allows its users to automatically download data for the target area as well as to create series of products on a regular basis both automatically and through interaction with users via a web interface (Fig. 7). Creation of predefined products [18-20] (e.g. mask of crop area, crop map) requires collection and processing of field samples.

The following products to be created:

- Atmospheric correction products based on the MACCS algorithm in automatic mode (L2A products - Bottom of Atmosphere Reflectance with snow masks, water, clouds and clouds shadows).
- Monthly cloud-free composites (Surface Reflectance), that can be created both according to the predefined schedule (specified in the configuration of the area of interest), and as per user's request (10-20 meters resolution).
- Monthly mask of cultivated cropland areas, which is being built starting from the middle of vegetation season both according to the predefined schedule (specified in the configuration of the area of interest), and as per user's request (10 meters resolution).
- Crops map with the indication of main crops twice per season (10 meters resolution).
- Field products (NDVI and LAI) showing the state of crops progress on a regular basis.

This automated system can be used free of charge as well as deployed both on the local computers and within the cloud platform in case of available funding.



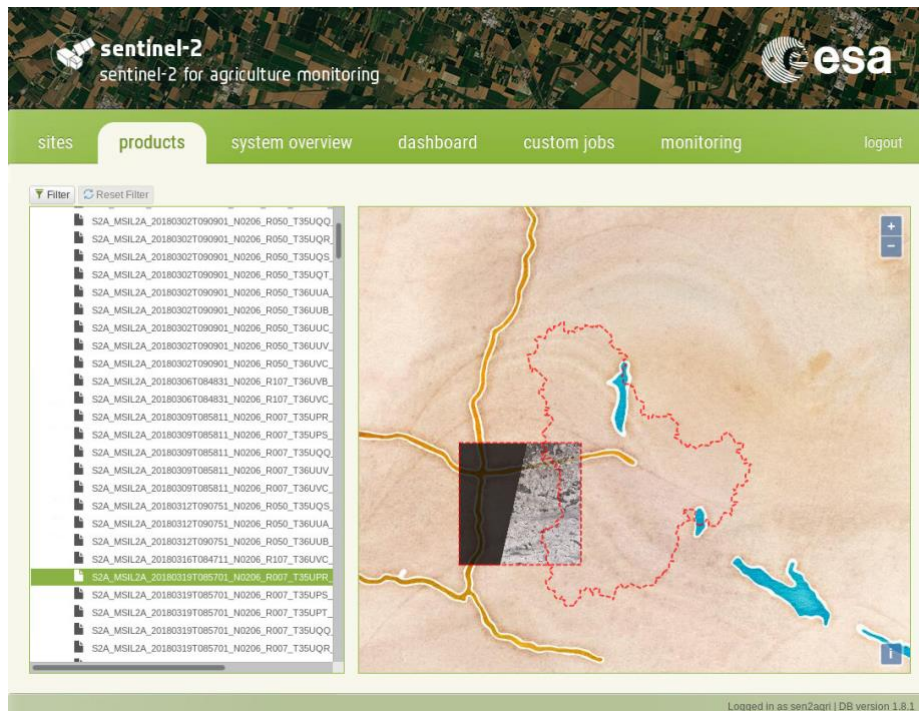


Figure 4 User web-interface of Sen2-Agri system

## Commercial software

### ENVI

An example of general purpose commercial software package is ENVI (<https://www.harrisgeospatial.com/SoftwareTechnology/ENVI.aspx>) that has special part for processing SAR data. One positive feature of ENVI is that specially designed blocks can be attached to the main body.

### ERDAS IMAGINE

ERDAS IMAGINE (<https://www.hexagongeospatial.com/products/power-portfolio/erdas-imagine>) provides true value, consolidating remote sensing, photogrammetry, LiDAR analysis, basic vector analysis, and radar processing, map and report generation and printing through the map composer, spatial modelling and analysis, terrain creation, editing, and analysis.

### eCognition

eCognition (<http://www.ecognition.com/>) offers a comprehensive collection of algorithms tailored to the different aspects of image analysis. The user can choose from a variety of segmentation algorithms such as multiresolution segmentation, quad tree or chessboard. The scope of classification algorithms ranges from sample-based nearest neighbour, fuzzy logic membership function or specialized context-driven analysis. Layer operation algorithms allow pixel-based filters such as slope, aspect, edge extraction or user defined layer arithmetic to be applied.

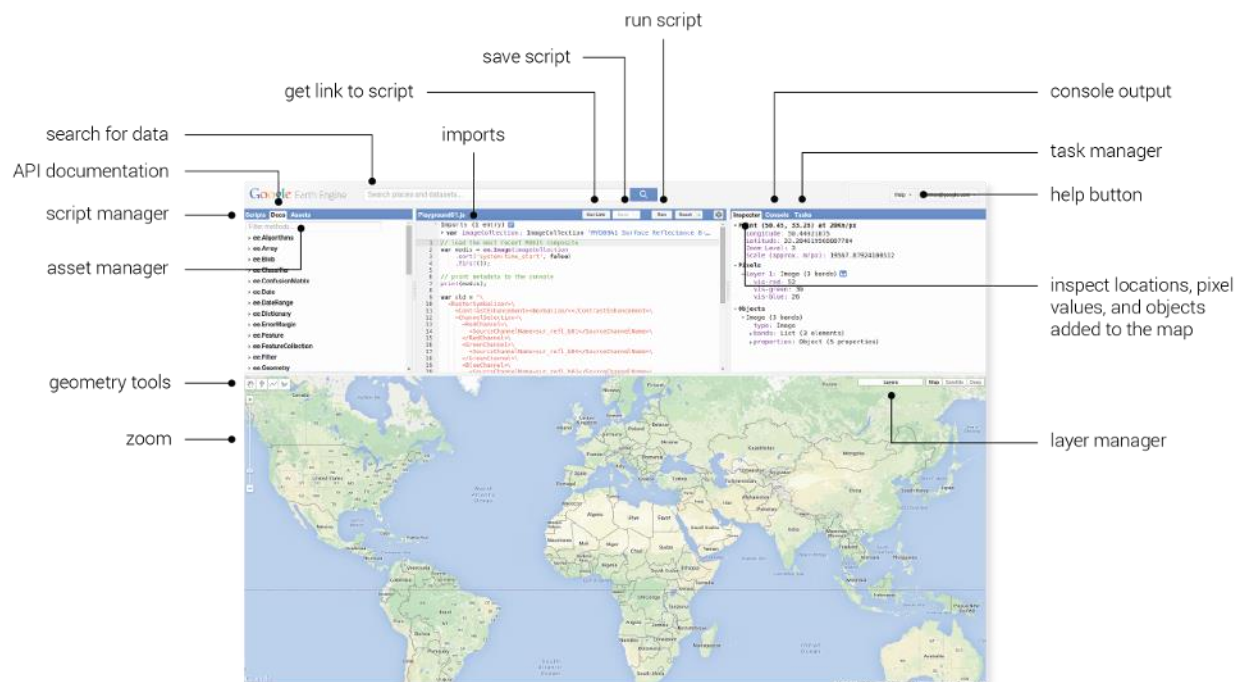
# Platforms

## Open-source solutions

### Google Earth Engine

Google Earth Engine is a computing platform that allows users to run geospatial analysis on Google's infrastructure. There are several ways to interact with the platform. The Code Editor is a web-based IDE for writing and running scripts. The Explorer is a lightweight web app for exploring our data catalogue and running simple analyses. The client libraries provide Python and JavaScript wrappers around our web API. Continue reading for an overview of each of these, or visit the Earth Engine's Developer Guide for an in-depth guide.

The Earth Engine Code Editor at [code.earthengine.google.com](https://code.earthengine.google.com) is a web-based IDE for the Earth Engine JavaScript API. It requires log in with a Google Account that's been enabled for Earth Engine access. Code Editor [17] features are designed to make developing complex geospatial workflows fast and easy. The Code Editor has the following elements (Fig.5).



*Figure 5 User interface of Google Earth Engine*

The client libraries provide JavaScript and Python wrapper functions for the Earth Engine API. You can use them to build custom applications and to develop Earth Engine code locally using a JavaScript or Python interpreter. The repository on GitHub includes a number of demos illustrating how to use the client libraries.

## Commercial solutions

### DIAS

To facilitate and standardize access to data, the European Commission has funded the deployment of five cloud-based platforms providing centralized access to Copernicus data and information, as well as to processing tools. These platforms are known as the DIAS, or *Data and Information Access Services*

([https://www.copernicus.eu/sites/default/files/Copernicus\\_DIAS\\_Factsheet\\_June2018.pdf](https://www.copernicus.eu/sites/default/files/Copernicus_DIAS_Factsheet_June2018.pdf)).

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 Copernicus' six operational services, together with cloud-based tools (open source and/or on a pay-per-use basis).

Each of the five DIAS platforms (Fig. 6) also provides access to additional commercial satellite or non-space data sets as well as premium offers in terms of support or priority. DIAS allows the users to develop and host their own applications in the cloud, while removing the need to download bulky files from several access points and process them locally.

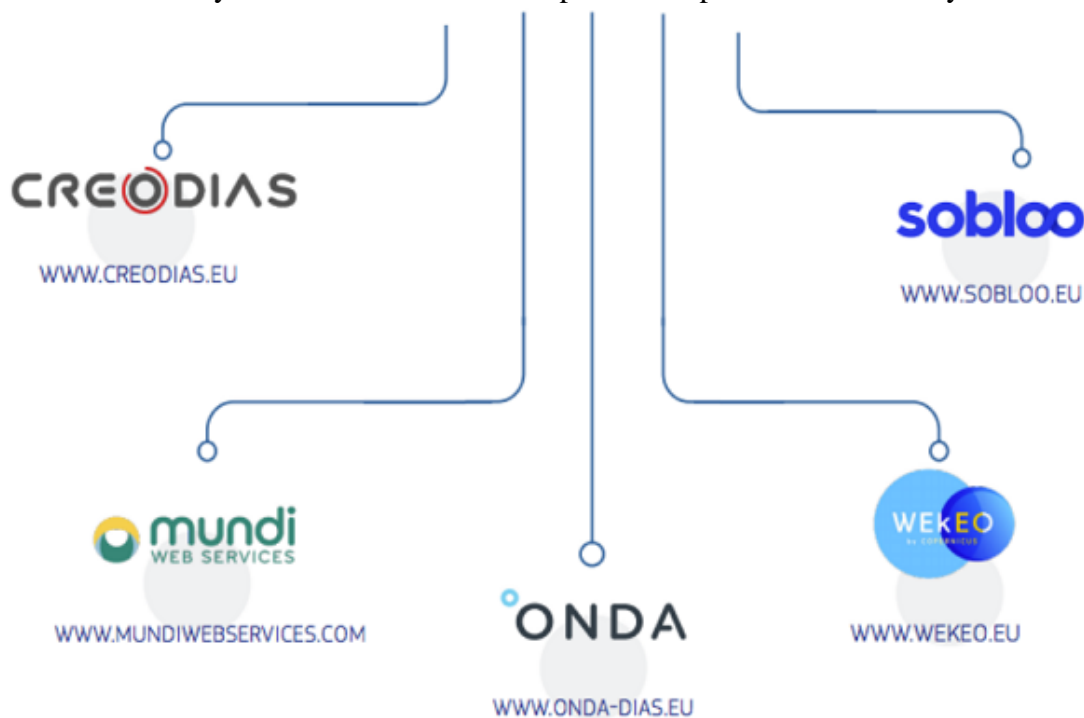


Figure 6 DIAS platforms

**Creodias** (<https://creodias.eu>) provides functionality for main data access operations (data discovery, search and download) via Object Data Access API (SWIFT/S3), file system Interface and EO Data Processing/Access HUB. *Main tools* available for users include EO Browser, EO Finder, Cloud Dashboard and JupyterHub (Jupyter Notebooks for EO data processing).

The *list of data collections* that are available for Creodias users includes Sentinel-1A & Sentinel-1B, Sentinel-2A & Sentinel-2B, Sentinel-3A & Sentinel-3B, Sentinel-5P, Landsat-5, Landsat-7, Landsat-8, Envisat with several levels of data processing. DEM and Jason-3 datasets also available for users. Full list - <https://discovery.creodias.eu/dataset>.



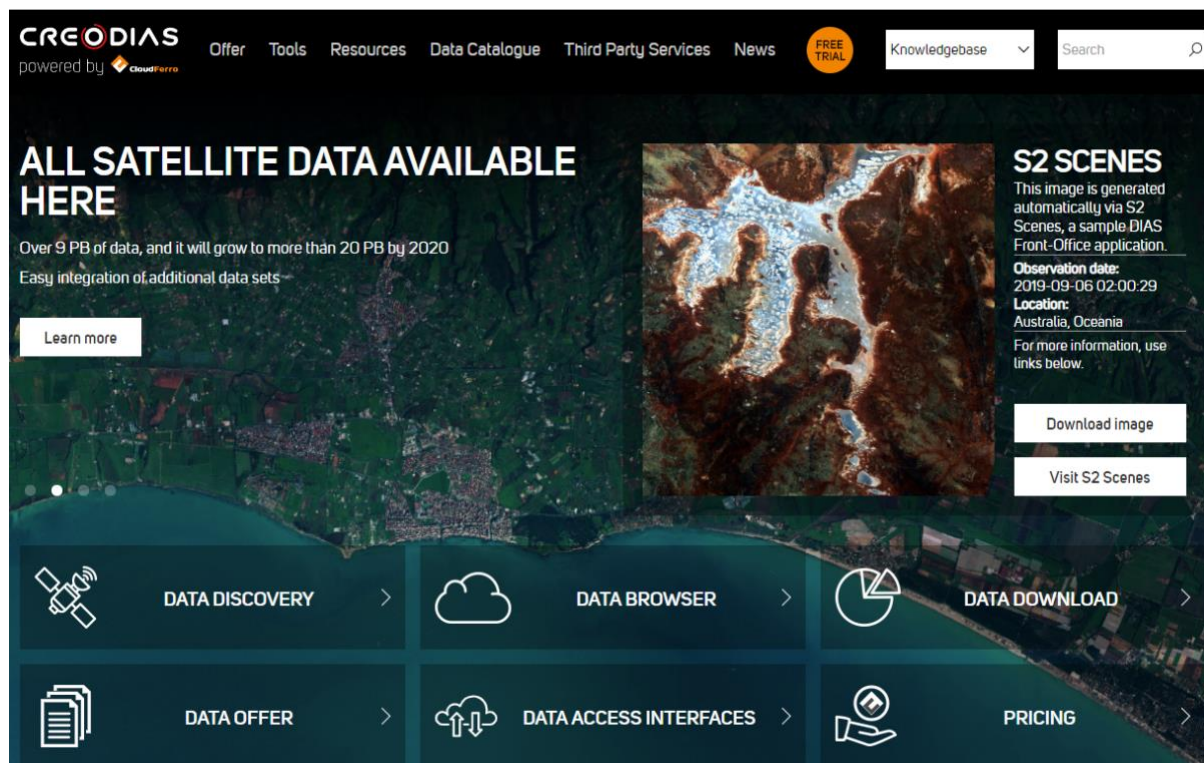


Figure 7 CREODIAS platform

**Mundi web services** (<https://mundiwebservices.com/>) provide to end users access to such *data collections* as Sentinel-1, Sentinel-2, Sentinel-3, Landsat-8 with several levels of data processing as well as to Copernicus services data. Roadmap for further data collection development includes integration of Cosmo-Skymed, IRS P5, Sentinel 3, Sentinel 5P data. Full list - <https://mundiwebservices.com/data>.

*Free tools* available for users include *Discovery* to Search, view and select data in area of interest, *download* selected data and *access to the service catalogue* to explore and select different data source.

Advanced tools include *WPS Processing* (WPS can describe any calculation (i.e. process) including all of its inputs and outputs, and trigger its execution as a web service), *Time series analysis* to detect temporal variations, *Geometry control*, *Automatic functions to scripting* industrial processing, *Thematic Algorithms and pipelines* ready to use.

*Open source advanced tools* include Orfeo Toolbox and ESA SNAP software over cloud infrastructure.

Mundi cloud provides following functionality:

- Compute with virtual computing servers (Elastic Cloud Server - ECS) through virtual network computing console (VNC)
- Storage in block level storage capacities (Elastic Volume Service - EVS) or in Object Storage Service that offer a highly simplified access mechanism and a high level of scalability
- Load balancing for distribute traffic on multiple ECS and balances loads
- Big Data functions (Map Reduce Service) offers a range of tools that allows for big data analysis like Hadoop, HBase, Spark, Hue, Loader, Kafka, Storm etc.

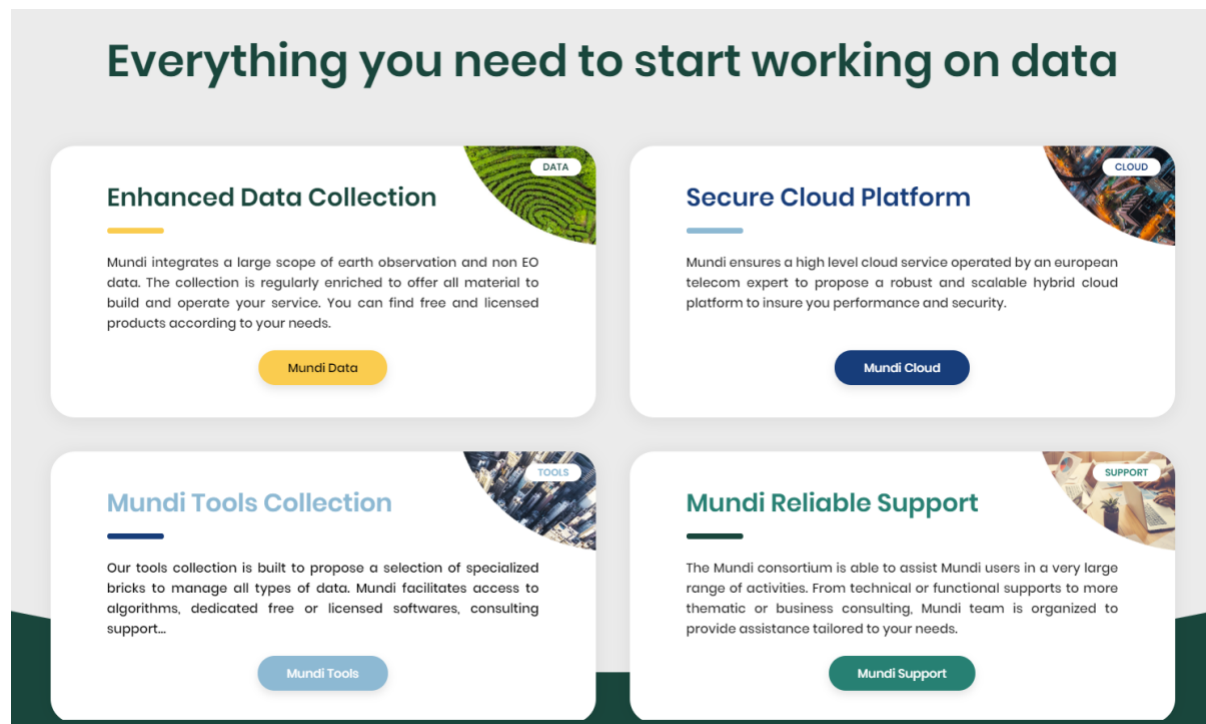


Figure 8 Mundi web services

**ONDA-DIAS** (<https://www.onda-dias.eu>) provides to end-users various services. The list of services includes:

- Data discovery
- Data View with use of standard Web Map Services (WMS) protocol
- Data Download
- Sentinel planned acquisition view
- Advanced API for access any low-level component of the product through ENS (Elastic Node Server) without the need for a full download
- Access to virtual servers over cloud infrastructure
- Custom Environments on demand

The *list of data collections* that are available for ONDA-DIAS users includes Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, Envisat, Landsat-8, Copernicus services CMEMS, CLMS and CAMS. Data roadmap includes integration of Very High Resolution (up-to-40 cm) Optical / SAR commercial data. Full list - <https://www.onda-dias.eu/cms/data/catalogue/>



Figure 9 ONDA-DIAS

**WEKEO** (<https://www.wekeo.eu>) provides to end-users following services:

- Usage of Virtual Machines
- Jupyter Notebooks Workspace
- Accessing satellite data via REST API
- Earth Observation Workbench platform (search datasets, select data and view data, process data using GUI applications like SNAP/Sentinel toolbox or using one of the available processing service and download the outputs)

Main datasets include Sentinel-2 and Sentinel-3, sea level data, datasets for global ocean physics analysis and other environmental datasets. Full list - <https://www.wekeo.eu/dataset-navigator/search?query=>

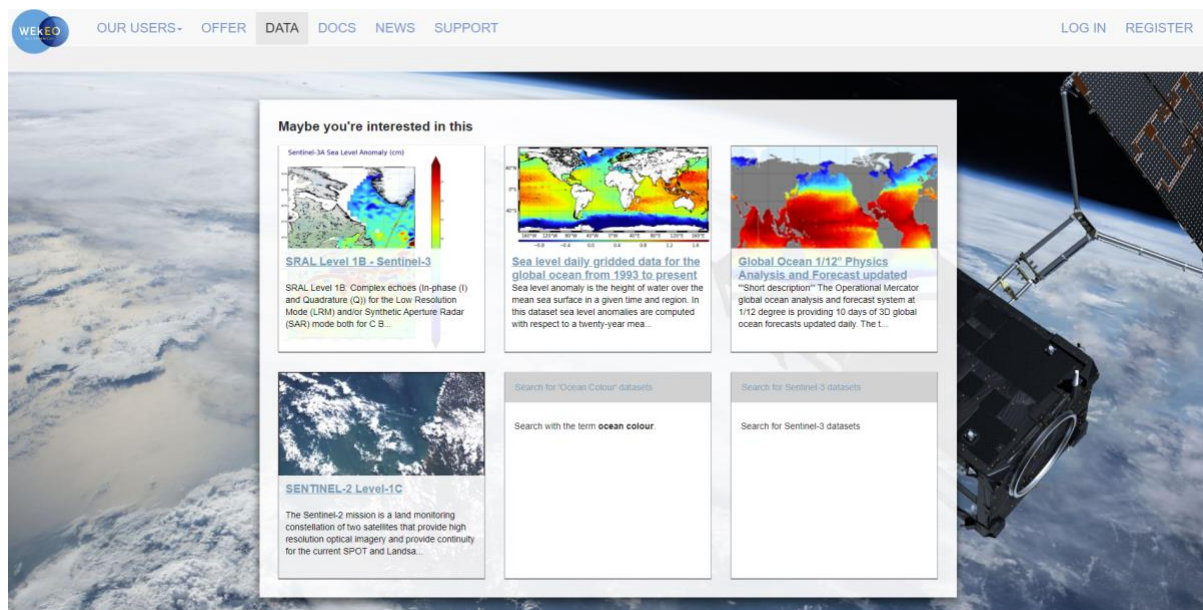


Figure 10 WEKEO

**Sobloo** (<https://sobloo.eu/>) provides following services to end-users:

- Infrastructure as a Service solution for managing computational resources with elastic scaling
- Load-balancing with use of multiple datacenters distributed all over the world
- Scalable Storage Services compatible with Amazon Simple Storage S3

The *list of data collections* that are available for Sobloo users includes Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, Copernicus core services (namely CMEMS, CLMS, CAMS, CEMS and C3S). Thematic products include MUSCATE and SOCAP products (<https://sobloo.eu/data/thematic-products>)



Figure 11 Sobloo public dashboard



## TEP

With the growing volume of environmental data from space and urgent necessity to solve a major challenge of big data exploitation, European Space Agency (ESA) has started in 2014 the EO Exploitation Platforms (EPs) initiative (<https://tep.eo.esa.int>). This initiative targets to create an ecosystem of interconnected *Thematic Exploitation Platforms* (TEPs) addressing *Coastal, Forestry, Hydrology, Geohazards, Polar, Urban themes* and *Food Security* (<https://tep.eo.esa.int/about-tep>).

In general, TEP is a virtual infrastructure that deals with users (organized into communities), tools, processors, and computational resources required to work with them, through one coherent interface. As such the EP may be seen as a new ground segments operations approach, complementary to the traditional operations concept.

**The fundamental principle** of the EP operations concept is to move the user to the data and tools. Users access a platform work environment providing the data, tools, and resources required, as opposed to downloading, replicating, and exploiting data ‘at home’.

The user community is present and visible in the platform, involved in its governance and invited (and enabled) to share and collaborate. This virtual workplace typically provides access to:

- **Relevant EO and non-EO data**
- **Scalable network**, computing resources and hosted processing (Infrastructure as a Service - IaaS)
- A **platform environment** (Platform as a Service - PaaS), allowing users to integrate, test, run, and manage applications (i.e. processors) without the complexity of building and maintaining their own infrastructure, and providing access to standard platform services and functions such as collaborative tools, data mining and visualization applications, the most relevant development tools (such as Python, IDL etc.), communication tools (social network) and documentation, accounting and reporting tools to manage resource utilization.
- **Application repositories or stores** (Software as a Service, SaaS) providing access to relevant advanced processing applications (for example InSAR processors and the Sentinel Toolboxes)

The ESA EPs are furthermore implemented according to the following **principles**:

- **Develop and employ open-source and freeware** to the extent possible – to ensure reuse, avoid vendor lock-in, contain costs, and ensure openness
- **Implement standards** – to ensure interoperability
- **Implement infrastructure independence** – to ensure cost effective infrastructure sourcing, avoid vendor lock-in, and allow reuse of public and commercially available ICT
- **Implement pay-per-use** – to avoid capital investment, contain costs, and allow for cost-sharing
- **Cater also to commercial providers** – to allow (affordable) access to commercial software, data, and infrastructure when required
- **Secure IPR** – to ensure that users retain their own intellectual property rights
- **Be Community and impact driven** – implement with deep participation of the scientific and application communities, to ensure user buy-in

- **Enable sustainability** – propose funding and revenue models and sources to maximize the probability of economic sustainability of the platforms in operations phase.

In particular, Food Security Platform provides the following services:

- Cloud platform with direct access to key satellite products and derived data, backed up by a scalable processing infrastructure;
- Access to tools for computing basic key indices (vegetation and water content indices from Sentinel-2 data, as well as chlorophyll, soil and red edge indices) on the fly, and for visualising and manipulating them;
- Provision of biophysical parameters (Leaf Area, fAPAR, fCOVER, NDVI) and global land cover maps;
- EO products for Service Pilot regions are available in product collections on the platform and can be discovered using the Food Security TEP Analyst (Fig. 12)

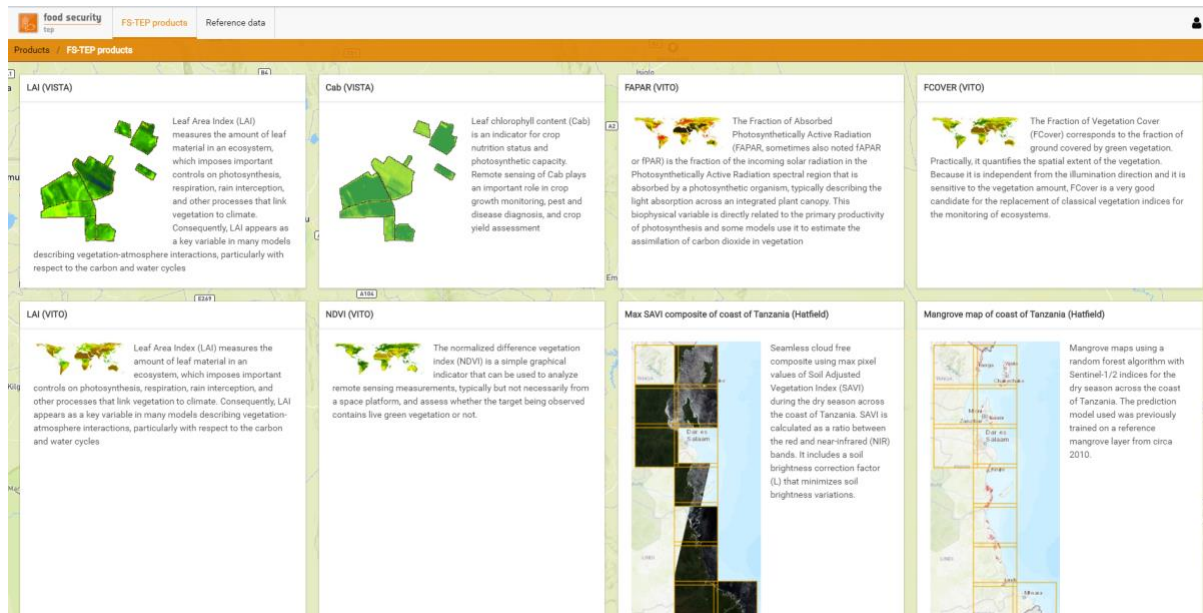


Figure 12 Food Security TEP Analyst interface

## Conclusion

In this deliverable 8 satellites (5 optical and 3 radar) are summarized, 2 of them are commercial, as well as 4 product services that are directly related to SDGs and EVs. Also, the list of the most popular satellite image processing software is provided within this deliverable, the functionality of mentioned products can be used to build optimized computing systems for the big data processing.

Data and services were analyzed not only in terms of optimized big data processing but also in terms of usability, accessibility, most of the services are easy in data access and data are well indexed and visualized. With use of data access links from this deliverable it is

possible to get both raw data for further processing and data with different processing levels or to perform further data fusion with other data sources.

There are a lot of different networks of in-situ data, that are mentioned in corresponding section of deliverable. However, it should be mentioned that all of them have different nature and it is impossible to work with them at once. We could investigate only some specific domains of in-situ data for concrete applications.

## References

- [1] Sentinel 2. Earth Online. European Space Agency. Available from: <https://sentinel.esa.int/web/sentinel/missions/sentinel-2/>
- [2] Drusch, M., et al. "Sentinel-2: ESA's optical high-resolution mission for GMES operational services." *Remote Sensing of Environment* 120 (2012): 25-36.
- [3] ESA Special Publication. Sentinel-3: ESA's global land and ocean mission for GMES operational services. ESA communications, 2012.
- [4] MODIS website. National Aeronautic and Space Administration. Available from: <https://modis.gsfc.nasa.gov/about/>
- [5] Curlander, John C., and Robert N. McDonough. "Synthetic aperture radar". Vol. 396. New York, NY, USA: John Wiley & Sons, 1991.
- [6] ESA Special Publication. Sentinel-1: ESA's Radar Observatory Mission for GMES operational services. ESA communications, 2012.
- [7] Radarsat-2. Canadian Space Agency. Available from: <http://www.asc-csa.gc.ca/eng/satellites/radarsat2/Default.asp>
- [8] Coordinating an Observation Network of Networks EnCompassing satellite and In-situ to fill the Gaps in European Observations. Available from: [https://cordis.europa.eu/result/rcn/186671\\_fr.html](https://cordis.europa.eu/result/rcn/186671_fr.html)
- [9] European Network of Earth Observation Networks. Available from: <http://www.eneon.net/>
- [10] Joint Experiment of Crop Assessment and Monitoring. Available from: <http://www.jecam.org/>
- [11] The Committee on Earth Observation Satellites. Available from: <http://ceos.org/>
- [12] CEOS Cal/Val portal. Available from: <http://calvalportal.ceos.org>
- [13] Manakos, Ioannis, and Samantha Lavender. "Remote Sensing in Support of the Geo-information in Europe." *Land Use and Land Cover Mapping in Europe*. Springer, Dordrecht, 2014. 3-10.
- [14] Schroedter-Homscheidt, Marion, et al. "The Copernicus Atmosphere Monitoring Service (CAMS) Radiation Service in a nutshell." *DLR, Service Contract No* (2015).
- [15] Gitas, Ioannis. "Copernicus Land Monitoring Service." 10442/15383 (2016): 00-34.
- [16] Augustin, Hannah, et al. "A Semantic Earth Observation Data Cube for Monitoring Environmental Changes during the Syrian Conflict." *GI\_Forum* 2018, 1 (2018): 214-227.
- [17] Shelestov, Andrii, et al. "Exploring Google earth engine platform for Big Data Processing: Classification of multi-temporal satellite imagery for crop mapping." *Frontiers in Earth Science* 5 (2017): 17.
- [18] Kussul, Nataliia, Andrii Shelestov, and Andrii Kolotii. "Sen2-Agri: Deployment of National Sentinel-2 product's distribution Center in Ukraine." (2016).
- [19] Kussul, Nataliia, et al. "Sen2-Agri: Leaf Area Index mapping for the territory of Ukraine." (2016).

[20] Kolotii, PhD Andrii, et al. "Sen2-Agri country level demonstration for Ukraine." 2016 Fall Meeting. 2016.