GEOESSENTIAL ERA-PLANET

Essential Variables workflows for resource efficiency and environmental management

Deliverable 1.5
Data handling guidelines

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Executive Summary

In this deliverable 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.

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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 present the available satellites that can be particularly useful in the GEOEssential project. The list of them is shown in Table 1.

Table 1. List of available satellites and specifications

Optical Satellite	Resolution	Revisit time	Coverage	Start date	Data access	Spatial resolution (m)
Landsat-8	30 m, 100 m, 15 m (pan chrome)	16 days	Whole planet	2013	Free available	30 m
Sentinel-2	10, 20, 60 m	5 days	Whole planet	2015	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
SAR Satellite	**Resolution**	**Revisit time**	**Coverage**	**Start date**	**Data access**	**Spatial resolution (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 sensors

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.

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 provides 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-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.

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] µm
- SLSTR: Sea and Land Surface Temperature Instrument. Have 9 bands [0.55-12] µm
- 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.

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.

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 µm to 14.4 µm 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 (nm)	Resolution (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

Band	Wavelength (µm)	Resolution (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

12	546–556	1000
13	662–672	1000
14	673–683	1000
15	743–753	1000
16	862–877	1000
17	890–920	1000
18	931–941	1000

31	10.780–11.280	1000
32	11.770–12.270	1000
33	13.185–13.485	1000
34	13.485–13.785	1000
35	13.785–14.085	1000
36	14.085–14.385	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

Synthetic Aperture Radar (SAR) sensors

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 incorporates 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

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

Table 5. Spectral bands for the TerraSAR-X sensors

Mode	Coverage Azimuth x Range (km2)	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.

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: www.eneon.net). 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.

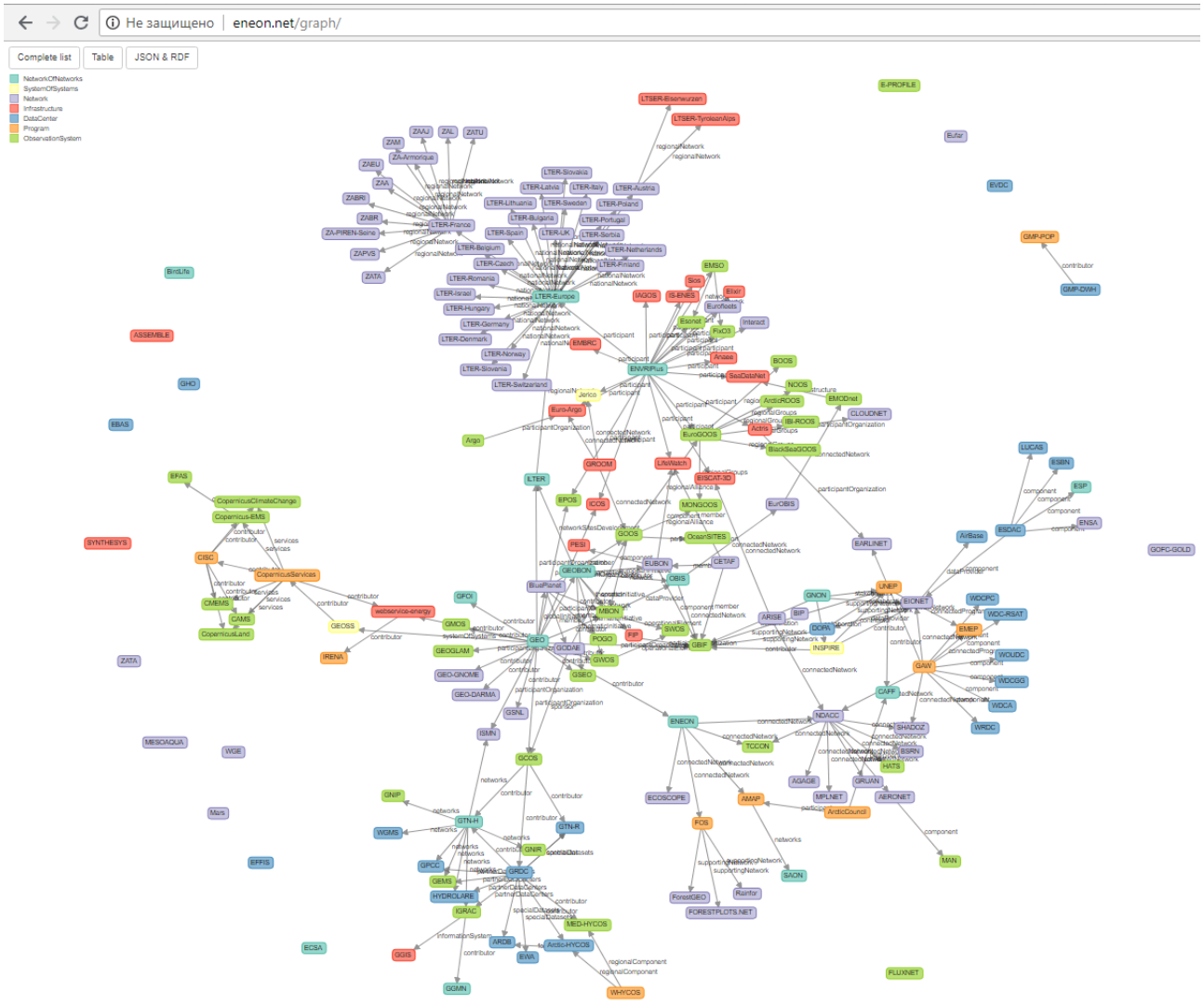

Figure 1 Dynamic graph on existing European EO networks (ENEON)

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).

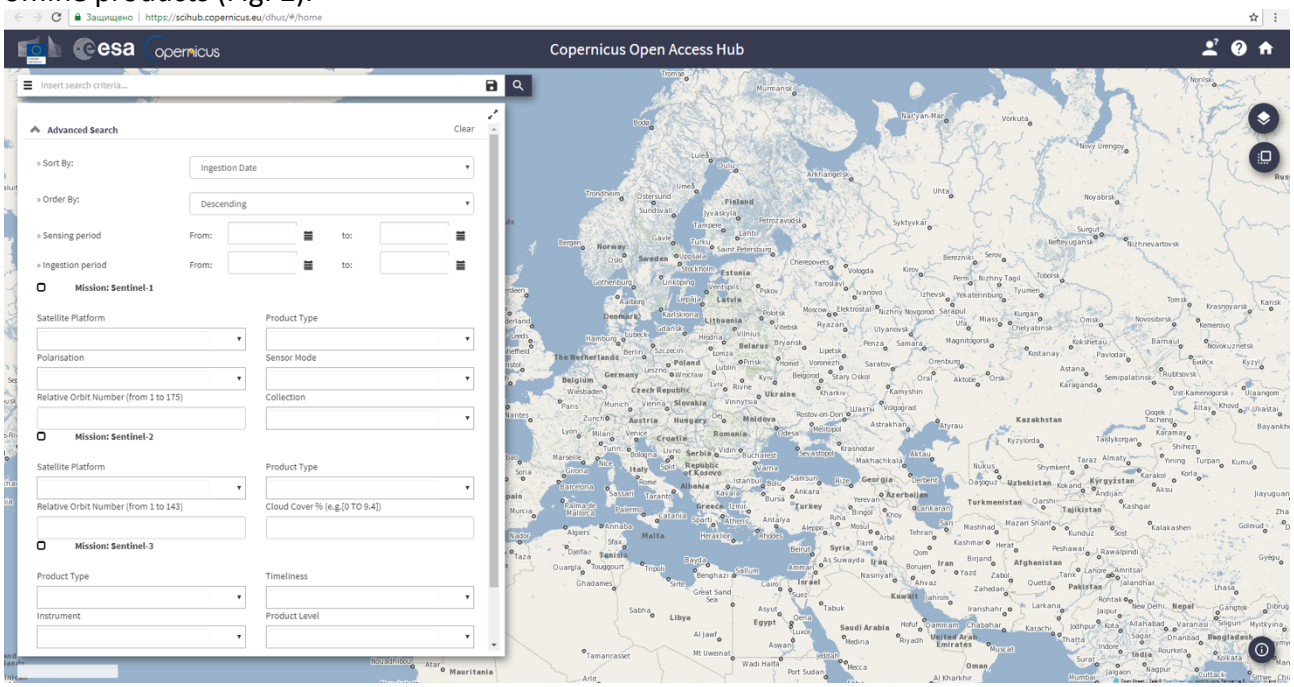

Figure 2 User interface of Copernicus Open Access Hub

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).

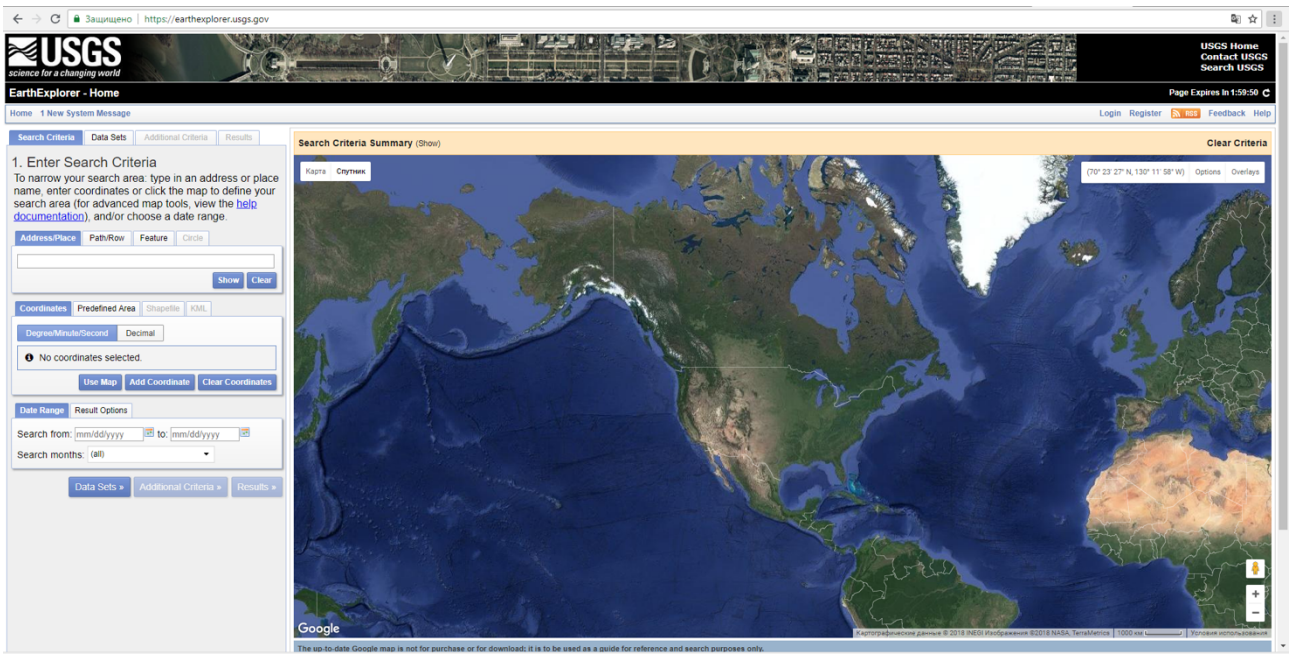

Figure 3 User interface of Earth Explorer

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 a 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.

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.

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

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 catalog 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 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.4).

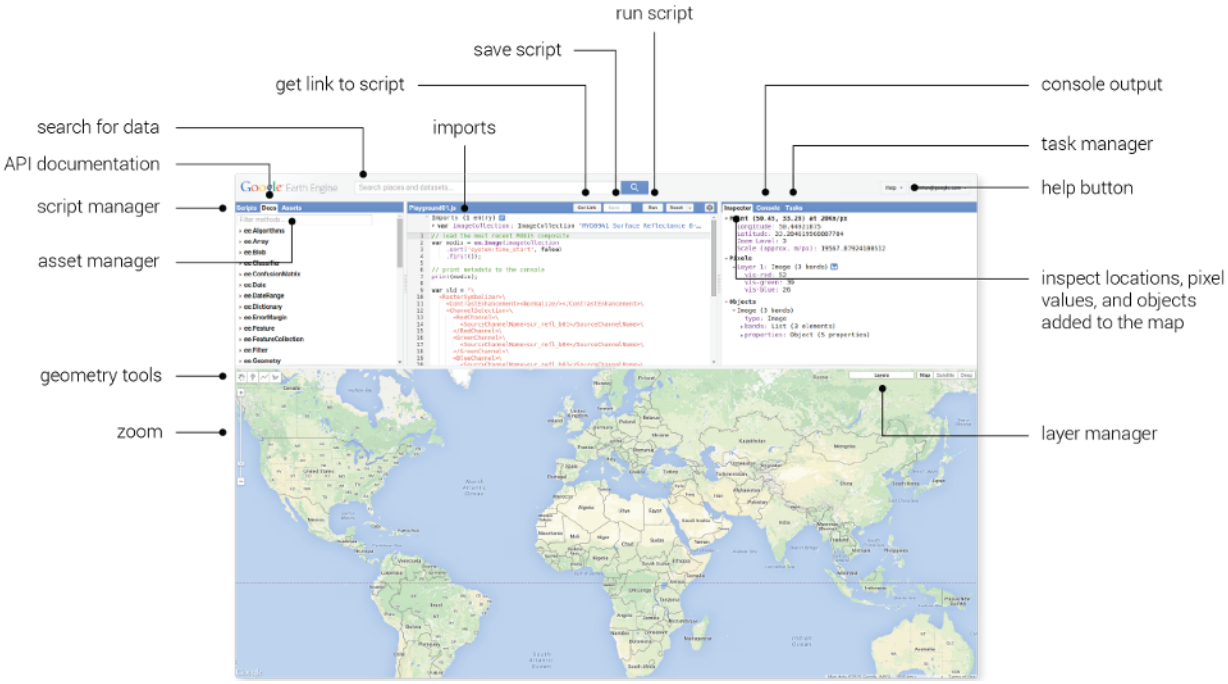

Figure 4 User interface of Google Earth Engine

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.

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. 5). 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.

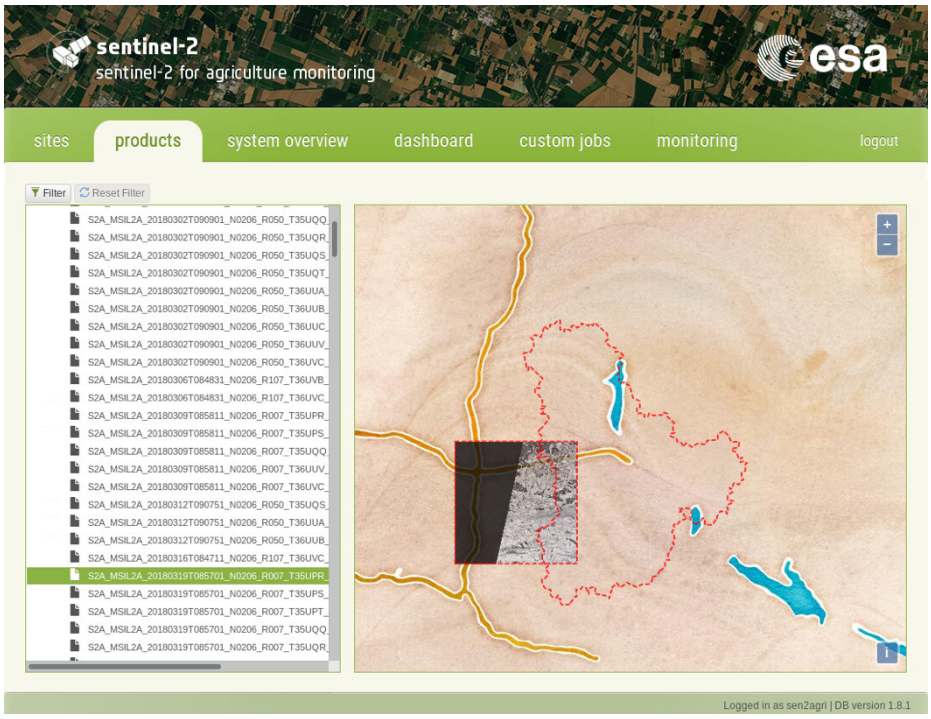

Figure 5 User web-interface of Sen2-Agri system

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 modeling 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 range from sample-based nearest

neighbor, 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.

ESA Thematic Exploitation Platforms

With the Thematic Exploitation Platforms ESA is bringing a new operation concept that aims at bringing the users to where the large size data is stored by providing a platform where data, tools and resources are shared. The platform is managed by a community of interest that was defined by ESA in seven areas (Fig.6), of which three are particularly interesting for GEOEssential: Forestry, Hydrology and Food Security.

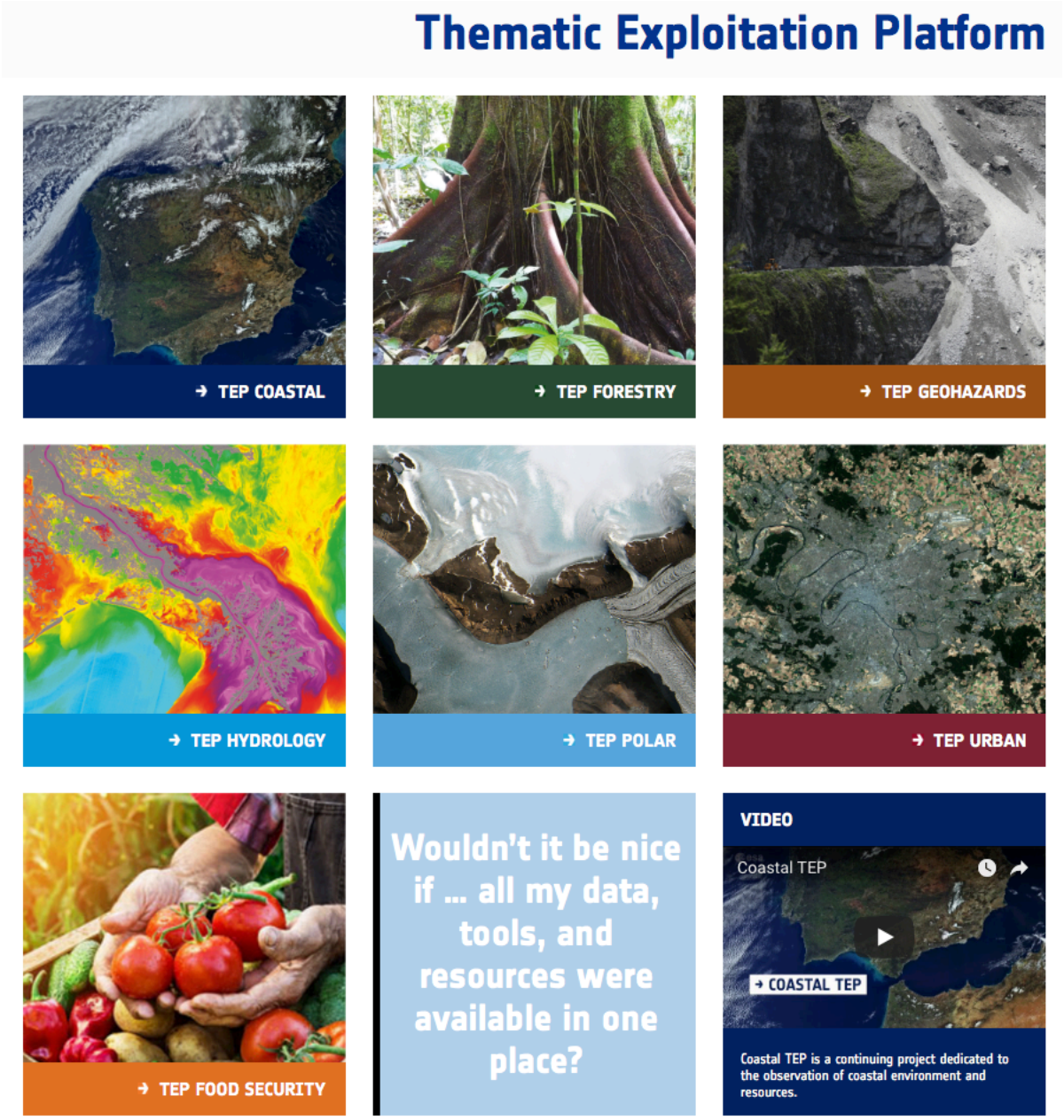

Figure 6 ESA Thematic Exploitation Platform (https://tep.eo.esa.int/about-tep)

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 date fusion with other data sources.

There 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 ones. We could to investigate only some specific domains of in-situ data for concrete applications.

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