

Analytical Report n20



Analytical Report 20

COPERNICUS DATA FOR THE OPEN DATA COMMUNITY

This study has been prepared by the con.terra as part of the European Data Portal. The European Data Portal is an initiative of the European Commission, implemented with the support of a consortium led by Capgemini Invent, including Intrasoft International, Fraunhofer Fokus, con.terra, Sogeti, 52°North, Time.Lex, the Lisbon Council, and the University of Southampton. The Publications Office of the European Union is responsible for contract management of the European Data Portal.

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Luxembourg: Publications Office of the European Union, 2021

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OA-BF-21-002-EN-N

ISBN: 978-92-78-42414-5

ISSN:2600-0601

doi: 10.2830/309367



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Executive Summary

The Copernicus programme generates valuable data from satellites and in situ sensors – and makes vast amounts of earth observation data available, in line with the European Data Portal’s goal to increase the accessibility and value of open data. This analytical report aims to help open data enthusiasts with leveraging the potential of Copernicus data for earth observation applications. While earth observation professionals may have the required knowledge and tools readily available, open data users are likely to face three basic questions:

- (1) What can I do with Copernicus data?
- (2) How can I access the data?
- (3) What tools do I need for using the data?

This report will address these questions using information found on the European Data Portal, specialised catalogues, and by examining practical examples of Copernicus data applications. It first reviews some of the many possible uses of Copernicus Data such as (1) observing plastic pollution of the oceans, land change through mining activities, volcanic activities, ice loss, creation of artificial islands, and various impacts on nature, e.g., deforestation, wildfires, storms, or pests. It then further covers one example application in-depth, demonstrating how an (2) application can download data from the Copernicus Open Access Hub, and (3) process the downloaded data using specialised tools. Thus, our desk research demonstrates the practical use of the different product types provided by the Copernicus missions and highlights how the open data community can access and process Copernicus data for building applications that allow for earth observation insights.

Introduction

Copernicus Data

Copernicus is the European Union's earth observation programme, committed to being *Europe's eyes on Earth*. The European Commission is heading this initiative in partnership with organisations such as the European Space Agency (ESA). The ESA¹ states:

"Copernicus is the most ambitious Earth observation programme to date. It will provide accurate, timely and easily accessible information to improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security. [...] Copernicus will help shape the future of our planet for the benefit of all."



FIGURE 1: WHAT IS THE COPERNICUS PROGRAMME? (SCREENSHOT FROM VIDEO²)

The Copernicus missions deliver vast amounts of global data (12 terabytes per day³) from satellites and other measurement systems, as well as services based on these data sources⁴. Most of these data products and information services are freely and openly accessible to its users, in line with the European Data Portal's goal to increase the accessibility and value of open data and promoting its use.

Copernicus data is relevant to many users because of the data's high temporal resolution and the range of possible applications. Each programme's satellite mission has a different focus⁵, e.g., Sentinel-1 focuses more on emergency response, Sentinel-2 on land monitoring, Sentinel-3 and 6 on monitoring the oceans and waters, and Sentinel-4 and 5 on the atmosphere. Another benefit of Copernicus data is its *up-to-dateness*. For example, the Sentinel-2 satellites systematically revisit most land areas of the world every five days⁶.

Open data users can apply data provided by the Copernicus missions to observe, detect, or monitor a wide range of phenomena such as plastic pollution of the oceans, land change through mining activities, volcano eruptions,

¹ ESA – Overview: https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Overview3

² What is the Copernicus Programme? – YouTube: <https://www.youtube.com/watch?v=MGJss4lDaBo>

³ Accessing data – the where and how: <https://www.copernicus.eu/en/accessing-data-where-and-how>

⁴ About Copernicus: <https://www.copernicus.eu/en/about-copernicus>

⁵ Guido Leverini (ESA) about the Sentinels in the overview video¹.

⁶ User Guides - Sentinel-2 MSI - Revisit and Coverage - Sentinel (esa.int): <https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/revisit-coverage>

marine and land ice loss, the appearance of (artificial) islands, as well as impacts on nature from pests, storms, deforestation, or wildfires.

Copernicus data recently becomes an increasingly popular source for showing the bigger picture in the media. News and blog posts use Copernicus data to report on economic activity, climate change, or the COVID-19 pandemic.

Responses to the *European Data Portal Thinkathon*⁷ during the INSPIRE 2018 Conference showed that while there is high interest in Copernicus data, there seems to be some confusion on what data is available, as well as how the data can be discovered and used.

Aim of this report

This analytical report aims to help open data enthusiasts leverage the potential of Copernicus data. In contrast to Earth observation professionals who have the required knowledge and tools readily available, open data users are likely to face the following basic questions:

- (1) What can I do with Copernicus data?
- (2) How can I access the data?
- (3) What tools do I need to use the data?

This report will address these questions using information found on specialised catalogues, and by examining practical examples of Copernicus data applications.

Approach

To help users with finding answers to their basic questions, we conducted a desk research as described in the following paragraph. The results of this research first give a broad introduction to use cases and then delve deeper into one of these use cases.

The first part covers a range of potential use cases to answer the question of what can be done with Copernicus data on a general level. We drew the relation between the various use cases described in the literature and addressed in real-life applications and match them with the Copernicus programme's thematic areas, relevant instruments, and product types available.

The second part of the research focuses on one particular use case in depth. We walk through the whole process of finding suitable Copernicus data, accessing it, and processing the data for use in a real-life application. This part demonstrates how an application can periodically download data from the Copernicus Open Access Hub, process the data using specialised tools, and focus on a particular area of interest.

Thus, this analytical report highlights how the open data community can access and process Copernicus data for building applications that allow for earth observation insights.

The Copernicus Programme

The introduction so far touched on some background aspects of the topic of Copernicus data. The following provides a more in-depth background, covering background information that can be of interest to users.

The European Commission manages the programme, while its implementation involves partnerships with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies, and Mercator Océan². The website further explains Copernicus' goal to benefit all European citizens and that all data and information services are free and openly accessible. Therefore, the name *Copernicus* is an

⁷ The European Data Portal Thinkathon 2018: <https://www.europeandataportal.eu/en/highlights/european-data-portal-thinkathon-during-inspire-2018-conference>

homage to Nicolaus Copernicus, who made pioneering contributions to astronomy and geographical sciences^{8,2} from which humanity still greatly benefits.

The Copernicus programme collects data from several dedicated and contributing satellite missions as well as from in situ systems on the ground. The Sentinels are major components of the programme. They are Satellite missions, each consisting of a family of dedicated satellites, or instruments aboard other satellites, to serve different aspects of earth observation^{2, 9, 10, 11}.

- The **Sentinel-1** family is dedicated to covering weather and daylight independent monitoring of land and ocean using Synthetic Aperture Radar (SAR) instruments.
- The dedicated **Sentinel-2** satellites focus on optical land monitoring such as imagery of vegetation, soil and water cover, inland waterways, and coastal areas. Their Multi Spectral Instrument (MSI) senses light reflected from the earth in various wavelengths, including visible red, green, blue, and infrared.
- **Sentinel-3** uses optical, radar and altimetry instruments for marine and land services, and is dedicated to measuring aspects such as sea-surface topography, sea- and land-surface temperature, ocean colour, and land colour with high-end accuracy and reliability.
- The **Sentinel-4** mission (starting 2023) will provide atmospheric composition monitoring. It will monitor air quality over Europe and will orbit earth aboard EUMETSAT's Meteosat Third Generation satellites¹². It will provide data at high spatial resolution and high revisit frequency (hourly).
- **Sentinel-5** (starting 2021) will also provide atmospheric composition monitoring, delivering data on global air quality and climate-related trace gases and aerosols in the atmosphere. The Sentinel-5 instrument will orbit earth aboard EUMETSAT's Metop - Second Generation satellites¹³. While Sentinel-5 is planned, a precursor mission named Sentinel-5P is already in orbit and provides data until the start of the Sentinel-5 instrument.
- The **Sentinel-6** provides highly accurate altimetry of global sea-surface height to support, for example, oceanography and climate studies.
- The **in situ** component also plays a key role for data products provided by the Sentinels and the Copernicus programme; e.g., in situ sensors are needed for calibration and validation of the satellite data to provide robust information. Examples of in situ resources include weather balloons, sensors aboard airplanes or ships, as well as topographic maps, to add information to the satellite data that is not available from space^{14, 15}.

For further readings on the Copernicus' space and ground components users can refer to the *Copernicus in detail* page on the Copernicus website¹⁶ and the Copernicus brochure¹⁷.

The produced data can be accessed through access points provided by ESA and EUMETSAT, depending on the mission and type of data, as well as through the Data and Information Access Services (DIAS) platforms that provide (partial) mirrors of the data^{3, 18,19}. The DIAS nodes also commercially offer advanced computing services

⁸ E.g., *De revolutionibus orbium coelestium* (Copernicus, 1543)

⁹ Infrastructure Overview | Copernicus:

<https://www.copernicus.eu/en/about-copernicus/infrastructure-overview>

¹⁰ Discover our satellites | Copernicus:

<https://www.copernicus.eu/en/about-copernicus/infrastructure/discover-our-satellites>

¹¹ Sentinel series | EUMETSAT: <https://www.eumetsat.int/our-satellites/sentinel-series>

¹² Meteosat Third Generation (MTG) | EUMETSAT: <https://www.eumetsat.int/meteosat-third-generation>

¹³ Metop - Second Generation | EUMETSAT: <https://www.eumetsat.int/metop-sg>

¹⁴ Copernicus In Situ Component: <https://www.eumetsat.int/metop-sg>

¹⁵ In situ component | Copernicus:

<https://www.copernicus.eu/en/about-copernicus/infrastructure/situ-component>

¹⁶ Copernicus in detail | Copernicus: <https://www.copernicus.eu/en/about-copernicus/copernicus-detail>

¹⁷ Copernicus Brochure:

https://www.copernicus.eu/sites/default/files/Brochure_Copernicus_2019%20updated_0.pdf

¹⁸ Copernicus Open Access Hub: <https://scihub.copernicus.eu/>

¹⁹ Data and Information Access Services: <https://www.copernicus.eu/en/access-data/dias>

in addition to access to their data mirrors. Furthermore, the Copernicus Services provide higher level products for each thematic area of the programme²⁰; i.e., for Atmosphere, Marine, Climate, Emergency Management, Land, and Security²¹. These services provide products derived from the original satellite data. For example, the Global Land Service provides products such as land cover or leaf area index²². A service catalogue is available on the Copernicus website²³. Products offered by the Copernicus Services are often very specific to their domain but easier to use than the uninterpreted satellite images.

This continuously growing pool of data is open to the public and can be downloaded and used free of charge²⁴. All data products and services provided by the Copernicus programme are publicly available (only the security service is not public). However, prior to downloading, the Copernicus license must be accepted, and one needs to be registered with the platform. Copernicus states that most of the data and services are made freely available and accessible. While Copernicus data is generally open, the European Commission's strategy also includes distributing the data via commercial platforms to support establishing a data ecosystem – i.e., data access via the DIAS nodes. These access nodes provide download mirrors but can also offer paid services for processing the data in the cloud using their infrastructure, tools, and computing power¹⁹. In contrast, the Copernicus Open Access Hub maintained by ESA does not offer computing resources, but free and open access to Copernicus data²⁵. Despite this clear commitment to free and open access, e.g., for Sentinel-2 data, users need to register and login with the Copernicus Open Access Hub. This is because ESA needs to track user data for reporting, e.g., to the European Union, and the public²⁶. Yearly reports, such as the report for 2019²⁷, include figures such as downloads per country and active users per domain. For this exhaustive reporting, it is necessary to track in which domains the data is used and should not be considered a limitation of access. The following focuses on open data use cases and will not cover paid services.

There is an ongoing integration of Copernicus Data catalogues with the European Data Portal. Making Copernicus data or services discoverable via the European Data Portal requires harvesting metadata. A metadata catalogue that is already being harvested by the European Data Portal is the EUMETSAT Product Navigator²⁸ (see Figure 2). The European Data Portal currently contains more than 600 individual collections from the EUMETSAT Product Navigator, which link to the EUMETSAT distribution systems, e.g., the ordering application where products can be selected for ordering outside of the European Data Portal. While users can find already find these datasets, the process of making Copernicus Data discoverable via the European Data Portal raises two challenges related to data representation and availability of the required metadata: Firstly, data must be represented in the European Data Portal in a meaningful way so that the users can interact with the information intuitively. Secondly, metadata must be readily available to be harvested to serve the required standards and meaningful representation. These challenges will be highlighted in the discussion section because they relate to the users' challenge of discovering relevant earth observation data products.

²⁰ Thematic Areas - Sentinel (esa.int): <https://sentinel.esa.int/web/sentinel/thematic-areas>

²¹ Copernicus Services | Copernicus: <https://www.copernicus.eu/en/copernicus-services>

²² Copernicus Global Land Service: <https://land.copernicus.eu/global/products/>

²³ Copernicus services catalogue | Copernicus: <https://www.copernicus.eu/en/accessing-data-where-and-how/copernicus-services-catalogue>

²⁴ COMMISSION DELEGATED REGULATION (EU) No 1159/2013 of 12 July 2013: http://data.europa.eu/eli/reg_del/2013/1159/oj

²⁵ Legal notice on the use of Copernicus Sentinel Data and Service Information https://sentinels.copernicus.eu/documents/247904/690755/Sentinel_Data_Legal_Notice

²⁶ Open Access Hub (copernicus.eu) – Terms and Conditions: <https://scihub.copernicus.eu/twiki/do/view/SciHubWebPortal/TermsConditions>

²⁷ Open Access Hub (copernicus.eu) – Annual Reports Archive: <https://scihub.copernicus.eu/reportsandstats/>

²⁸ EUMETSAT Product Navigator: <https://navigator.eumetsat.int/start>

The screenshot displays the EUMETSAT Product Navigator interface. At the top, there is a navigation bar with links for Newsletter, FAQ, Search, Contact, Cookies, Legal notice, and Login. A search bar is present with the text 'Search site content...'. Below the navigation bar, the breadcrumb trail reads 'European Data Portal > Catalogues > EUMETSAT Product Navigator'. The main content area is divided into several sections: a left sidebar with the European Union flag and metadata for the selected dataset, a central search bar, and a main content area showing search results. The search results section indicates '669 datasets found' and displays the first result: 'Global Sea Ice Type (GRIB) - Multimission'. The metadata for this dataset includes a description of the product, the publisher (EUMETSAT), and a table with columns for 'Created' (UNKNOWN) and 'Updated' (30.05.2017 02:00). A 'Countries' filter is visible at the bottom left, showing 'Europe' with 669 results.

FIGURE 2: METADATA FROM THE EUMETSAT PRODUCT NAVIGATOR (SCREENSHOT)

Exploring Copernicus Data Use Cases

This chapter explores potential use cases and matches them with the Copernicus' thematic areas, missions, and instruments. The results of our desk research are presented in Table 1, and Table 2.

Use Cases

Copernicus services address six thematic areas: land, marine, atmosphere, climate change, emergency management, and security. The Copernicus Services section²¹ on the Copernicus website (shown in Figure 3) links to each thematic area with a service devoted to it and a subdomain on the Copernicus website.

Other sources of inspiration for applications of Copernicus data could include a search on the internet to reveal satellite data applications²⁹. The ESA website highlights applications³⁰ and success stories³¹. For example, the Emergency Management news on the Emergency Management section of their website³². The Copernicus programme's website, too, presents *opportunities*³³, or *image of the day* posts³⁴. Users can describe their Use Case and submit it to be published on the Copernicus programme's website³⁵.

²⁹ Examples of satellite data applications found on the internet:

<https://gijn.org/2021/01/05/how-to-use-satellite-imagery-in-your-next-investigation/>

<https://www.geospatialworld.net/blogs/satellite-images-capture-major-events-of-2020/>

³⁰ ESA – Applications/Observing_the_Earth/Copernicus/Overview3:

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Overview3

³¹ Sentinel Success Stories - News - Sentinel (esa.int): <https://sentinel.esa.int/web/sentinel/news/success-stories>

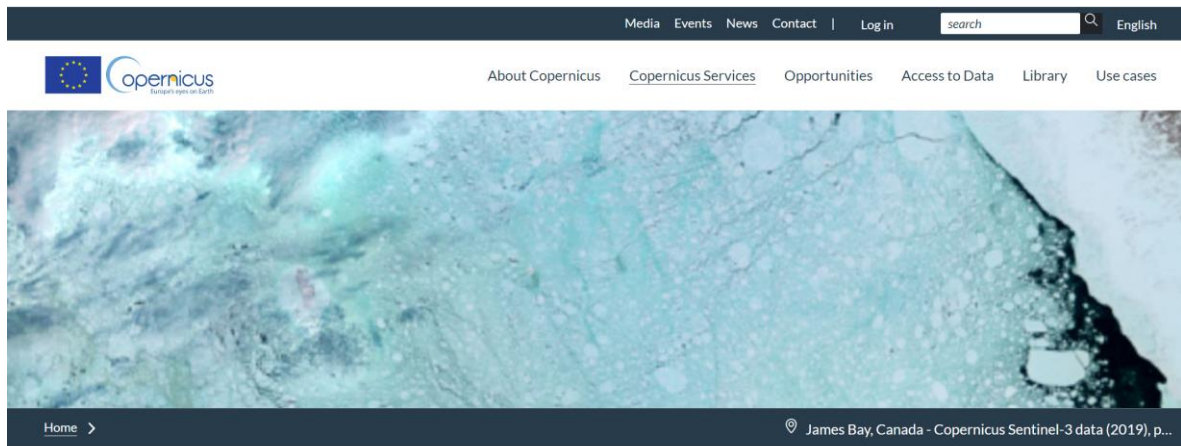
³² Thematic Areas - Emergency Management - Sentinel (esa.int):

<https://sentinel.esa.int/web/sentinel/thematic-areas/emergency-management>

³³ Opportunities | Copernicus: <https://www.copernicus.eu/en/opportunities>

³⁴ Image of the day | Copernicus: <https://www.copernicus.eu/en/media/image-day>

³⁵ Use cases | Copernicus: <https://www.copernicus.eu/en/use-cases>



Copernicus Services



FIGURE 3: COPERNICUS SERVICES SECTION ON THE PROGRAMME'S WEBSITE (SCREENSHOT)

Table 1 lists use cases we selected from these and other sources to address some of the many potential application areas. Listed are use cases from different sources to allow for a broader impression. The table matches the selected use cases with the Copernicus thematic areas, and with the tools reported.

TABLE 1: USE CASES MATCHED WITH USED DATA PRODUCTS AND TOOLS

Use Case	Copernicus Thematic Areas	Instruments, Data Products, and Tools
Land cover classification: https://land.copernicus.eu/global/products/lc	Land	Copernicus Land Monitoring Service
UV index forecasting: https://atmosphere.copernicus.eu/charts/cams/uvindex-forecasts	Atmosphere	Copernicus Atmosphere Monitoring Service
Sea ice berg concentration and individual icebergs: https://resources.marine.copernicus.eu/?option=com_cs_w&view=details&product_id=SEAICE_ARC_SEAICE_L4_NRT_OBSERVATIONS_011_007	Marine	Copernicus Marine Environment Monitoring Service
Monthly climate bulletin explorer (mapping ground temperature anomalies): https://cds.climate.copernicus.eu/cdsapp#!/software/app-c3s-monthly-climate-bulletin-explorer	Climate Change	Copernicus Climate Change Service

Mapping disasters or risks; Copernicus Emergency Management Service – Mapping https://emergency.copernicus.eu/mapping/copernicus-emergency-management-service	Emergency	Copernicus Emergency Management Service
Coral bleaching of the Great Barrier Reef: http://www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-2/Sentinel-2_captures_coral_bleaching_of_Great_Barrier_Reef	Marine	Sentinel-2 MSI
Rapid Action on Coronavirus and EO (RACE): https://race.esa.int/	Marine, Atmosphere, Land, Climate Change, Emergency	Sentinel-2 MSI, in situ data from other sources
Prozessierung von Sentinel-5P-Daten in der ArcGIS-Plattform: https://storymaps.arcgis.com/stories/ffb2678bf09f466b9744d30c5fb902a2	Atmosphere	Sentinel-5P TROPOMI, S5P_L2_NO2___R, ArcGIS Pro
SenSituMon (flood mapping): https://www.sensitumon.eu/	Emergency, Land	Sentinel-1 SAR, and in situ data from other sources
Inspecting active volcanoes: https://medium.com/sentinel-hub/active-volcanoes-as-seen-from-space-9d1de0133733	Emergency, Land, Atmosphere	Sentinel-1 SAR, Sentinel-2 MSI, Sentinel-5P, EO Browser/Volcano Theme, band combination
Corradino, C.; Ganci, G.; Cappello, A.; Bilotta, G.; Hérault, A.; Del Negro, C. Mapping Recent Lava Flows at Mount Etna Using Multispectral Sentinel-2 Images and Machine Learning Techniques. <i>Remote Sens.</i> 2019, 11, 1916. https://www.mdpi.com/2072-4292/11/16/1916	Emergency, Land	Sentinel-2 MSI, machine learning, in situ / ground-based measurements for validation
Biermann, L., Clewley, D., Martinez-Vicente, V. et al. Finding Plastic Patches in Coastal Waters using Optical Satellite Data. <i>Sci Rep</i> 10, 5364 (2020). https://www.nature.com/articles/s41598-020-62298-z	Marine	Sentinel-2 MSI, machine learning, custom in situ data for validation
Ban, Y., Zhang, P., Nascetti, A. et al. Near Real-Time Wildfire Progression Monitoring with Sentinel-1 SAR Time Series and Deep Learning. <i>Sci Rep</i> 10, 1322 (2020). https://www.nature.com/articles/s41598-019-56967-x	Emergency (also related to Land, Atmosphere, Climate Change)	Sentinel-1 SAR, machine learning, in situ data from on-site inspection with drones

One of the use cases from Table 1 will be covered as the example in chapter *Finding and Using Copernicus Data: Copernicus Emergency Management Service – Mapping of the Copernicus Emergency Management Service* which deals with mapping events related to (possible) disasters such as the latest event *Etna Volcano eruption in Sicily, Italy*^{36,37}. The instruments listed in Table 1 are usually specific to a few thematic areas. However, this does not mean that usage of data from certain instruments would be limited to the originally intended use cases or thematic areas. For example, Biermann et al. used Sentinel-2 data and machine learning techniques for detecting

³⁶ An article about the volcanic eruption mapping event in the EMS:

<https://emergency.copernicus.eu/mapping/ems/copernicus-ems-monitors-volcanic-eruption-and-earthquakes-italy>

³⁷ The mapped EMS event for the Etna eruption – Event Time (UTC): 2018-12-24 06:00:

<https://emergency.copernicus.eu/mapping/list-of-components/EMSR336>

plastics in coastal waters. The authors used Sentinel-2 data, which is originally focused on land observation. However, the data proved useful for their marine application too.

Many applications rely on or use additional in situ data, e.g., indirectly when data products are improved based on in situ data or directly when incorporating in situ data. For example, Biermann et al. and Ban et al. used ground truth data in their research. Another example is the SenSituMon project, which aims to harness the potential of Copernicus data (i.e., high frequency and large area coverage), in addition to using in situ data such as from water level sensors, which are fixed to one location. This data is used to gather information on flooding events for applications for the insurance industry and agriculture.

Currently impacts of the COVID-19 pandemic are often shown in the news or in blog posts using data from the Sentinel-2 mission such as footage of parking cruise ships³⁸ or aeroplanes³⁹. The Rapid Action on Coronavirus and EO (RACE) application makes such information available (see Table 1). Figure 4 shows a screenshot from RACE depicting the impact of the pandemic on the airport Fraport in Germany. The application shows the airport on January 20, 2020, when it operated normally, and on April 4, 2020, during the lockdown. The automatic detection of aeroplanes by the application clearly shows (yellow bounding boxes in the image) the unused, parking aeroplanes on the north western runway. The application is described in detail by Sara Aparício on medium.com⁴⁰.

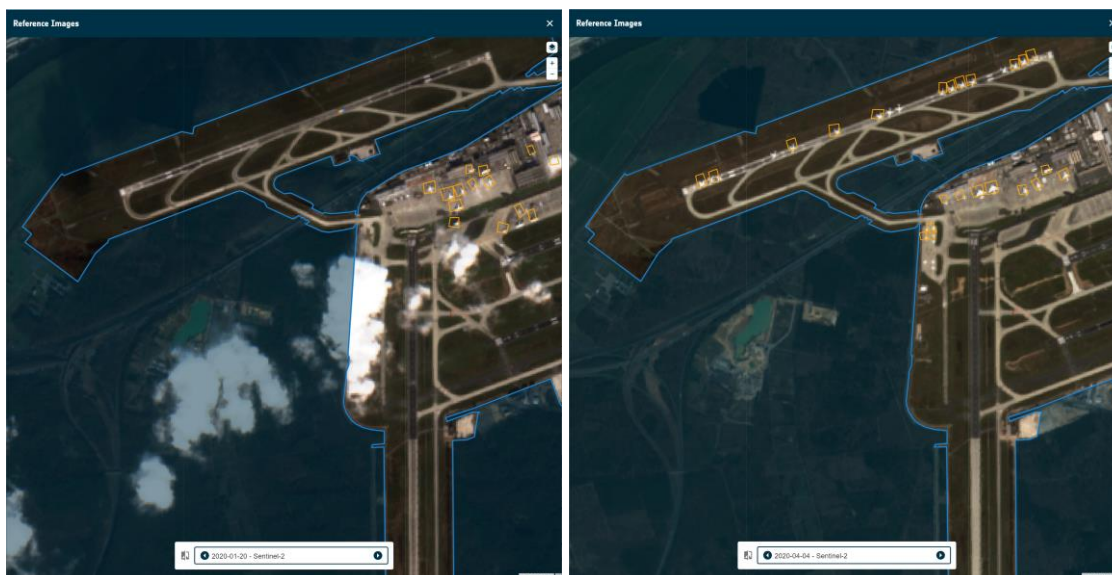


FIGURE 4: SENTINEL-2 SCENES OF FRAPORT'S NORTH WESTERN RUNWAY, BEFORE (LEFT) AND DURING LOCKDOWN (RIGHT) – SCREENSHOTS OF USING THE RACE DASHBOARD.

Understanding the data

This report so far provides an initial overview, ideas, and insights into applications of Copernicus data from industry, education, and research domains. It points out some important details for applications, including methods applications can use and instruments that example applications can get suitable data from.

³⁸ Locked down afloat: why dozens of cruise ships ended up stranded in Manila Bay | The Guardian: <https://www.theguardian.com/environment/2020/jun/02/locked-down-afloat-why-dozens-of-cruise-ships-ended-up-stranded-in-manila-bay>

³⁹ Parking in a Pandemic: Where Are All the Airplanes and Cruise Ships During COVID-19? (scitechdaily.com): <https://scitechdaily.com/parking-in-a-pandemic-where-are-all-the-airplanes-and-cruise-ships-during-covid-19/>

⁴⁰ The pandemic disruption of air traffic — as seen from Space | by Sara Aparício | Euro Data Cube | Medium: <https://medium.com/euro-data-cube/the-pandemic-disruption-of-air-traffic-as-seen-from-space-6dad64201b9a>

To decide which data is suitable for a specific use case, some additional knowledge is needed on data products offered by the different missions and what data the individual instruments will deliver. This part of the report is meant to provide an overview and a starting point for gaining further information.

The full background and specifications about the missions, the instruments used to gather the data, and data products are provided in the respective user guides (see links in Table 2). To provide an overview and entry point, Table 2 matches the different instruments and thematic areas as they are listed in the respective user guides. The table also links to the respective user and technical guides for reference. This structured overview can help users to find out how their envisioned application might relate to the Copernicus missions and where to find more information. The user guide can then help to get started with using a data product, and the technical guide provides instrument specification. The next chapter covers one of these instruments by showing how to download and use Sentinel-2 data for a particular use case.

TABLE 2: OVERVIEW OF INSTRUMENTS AND THEMATIC AREAS COMPILED FROM THE INDIVIDUAL USER GUIDES LISTED

Instrument	Applications and links to the guides
Sentinel-1 SAR	Maritime Monitoring, Land Monitoring, Emergency Management User Guides - Sentinel-1 SAR - Applications - Sentinel Online - Sentinel (esa.int) Sentinel-1 SAR - Technical Guide - Sentinel Online - Sentinel (esa.int)
Sentinel-2 MSI	Land Monitoring, Emergency Management, Security User Guides - Sentinel-2 MSI - Applications - Sentinel Online - Sentinel (esa.int) Sentinel-2 MSI - Technical Guide - Sentinel Online - Sentinel (esa.int)
Sentinel-3 OLCI	Maritime Monitoring, Land Monitoring, Atmospheric Monitoring, Climate Change Monitoring User Guides - Sentinel-3 OLCI - Applications - Sentinel Online - Sentinel (esa.int) Sentinel-3 OLCI - Technical Guide - Sentinel Online - Sentinel (esa.int)
Sentinel-3 SLSTR	Maritime Monitoring, Land Monitoring, Atmospheric Monitoring, Climate Change Monitoring User Guides - Sentinel-3 SLSTR - Applications - Sentinel Online - Sentinel (esa.int) Sentinel-3 SLSTR - Technical Guide - Sentinel Online - Sentinel (esa.int)
Sentinel-3 Synergy	Land Monitoring, Security, Climate Change Monitoring User Guides - Sentinel-3 Synergy - Applications - Sentinel Online - Sentinel (esa.int) Sentinel-3 Synergy - Technical Guide - Sentinel Online - Sentinel (esa.int)
Sentinel-3 Altimetry	Oceanography, Coastal Zones, Ice and Sea-Ice, Inland Waters and Land, Climate, Geodesy and Geophysics User Guides - Sentinel-3 Altimetry - Applications - Sentinel Online - Sentinel (esa.int) Sentinel-3 Altimetry - Technical Guide - Sentinel Online - Sentinel (esa.int)

**Sentinel-5P
TROPOMI**

Air Quality, Stratospheric Ozone Layer and Climate Change Monitoring, and Forecasting Applications – Sentinel-5P TROPOMI User Guide – Sentinel Online - Sentinel (esa.int)
 Products and Algorithms - Sentinel-5P Technical Guide - Sentinel Online - Sentinel (esa.int)

The next chapter will cover how to download the appropriate Copernicus data and build applications with it. The entry point for this is the Copernicus website, which provides an overview of how to access the data, including a brief description of the conventional data access points and links⁴¹. Using the information from Table 2 users can determine which instrument is likely to provide the data needed. In our example this is Sentinel-2 MSI. Users will need to look for a suitable access point for a particular product type of interest. Please refer to *Appendix A: Data Access Platforms*, for a list of access points. For our example, Sentinel-2 data products can be downloaded from the Copernicus Open Access Hub: <https://scihub.copernicus.eu/>, which is based on the Data Hub Software (DHuS)⁴² software. The access point provides a web-based data finder and well-written documentation⁴³. While its web frontend allows users to search for relevant scenes and download them manually, programmers can also use the API for automated searching and downloading.

Finding and Using Copernicus Data

After having covered a range of potential use cases to answer the question of what can be done with Copernicus data on a general level, this chapter focuses on one particular use case in depth: Mapping of lava flow from the Etna volcano using data from the Copernicus Emergency Management Service.

This use case was chosen because of the obvious need for monitoring the impact of volcanic activities on nature and urban areas. This chapter focuses on the Etna volcano, and events in December 2020 and December 2018 for a “hands on” example on how to work with Copernicus data. It first demonstrates how to search and download data for this area of interest. It will feature downloading and using Sentinel-2 products from the Copernicus Open Access Hub. It then demonstrates the use of the ESA Sentinel Application Platform (SNAP)⁴⁴ tool to view lava flow. At the end of this chapter some insights into automating the workflow with the Open Access Hub API and the SNAP graph tool are provided.

Downloading Sentinel-2 Data Products

The Copernicus Open Access Hub is used to download Sentinel-2 products which can be processed and used as true colour photographs from space. Figure 5 shows the necessary steps for searching and downloading Sentinel-2 scenes from the Copernicus Open Access Hub. In the first step, the user navigates to the area of interest, which they can draw on the map for the search. Filter options are shown in the second step, including the sensing period and the checkbox for Sentinel-2 data products. Other parameters and the product names in the results will become apparent in the following. The search result appears as a list of matching scenes and a preview of the results’ spatial extents on the map. After the search, the third step is to select and download the relevant scenes.

Figure 6 illustrates the necessary steps for downloading older data products. This process is needed because the ESA maintains data storage for data products that are older than 12 months in an *offline fashion* called long term archive (LTA)⁴⁵. As shown in the first step, such archived data products are presented on a grey background in the search results. Users can trigger retrieval from the LTA for temporary online access via the normal download link. Scenes that were retrieved from the LTA change their status and can be downloaded. As seen in the figure,

⁴¹ Conventional Data Access Hubs | Copernicus: <https://www.copernicus.eu/en/accessing-data-where-and-how/conventional-data-access-hubs>

⁴² DHuS Open Source Portal (sentineldatahub.github.io): <http://sentineldatahub.github.io/DataHubSystem/>

⁴³ Open Access Hub (copernicus.eu): <https://scihub.copernicus.eu/userguide/WebHome>

⁴⁴ The Sentinel Application Platform (SNAP): <https://step.esa.int/main/toolboxes/snap/>

⁴⁵ Open Access Hub (copernicus.eu) – LTA: <https://scihub.copernicus.eu/userguide/LongTermArchive>

in the next steps, the *shopping cart* widget of the data hub web interface is particularly helpful for tracking the requested products because the retrieval can take many hours.

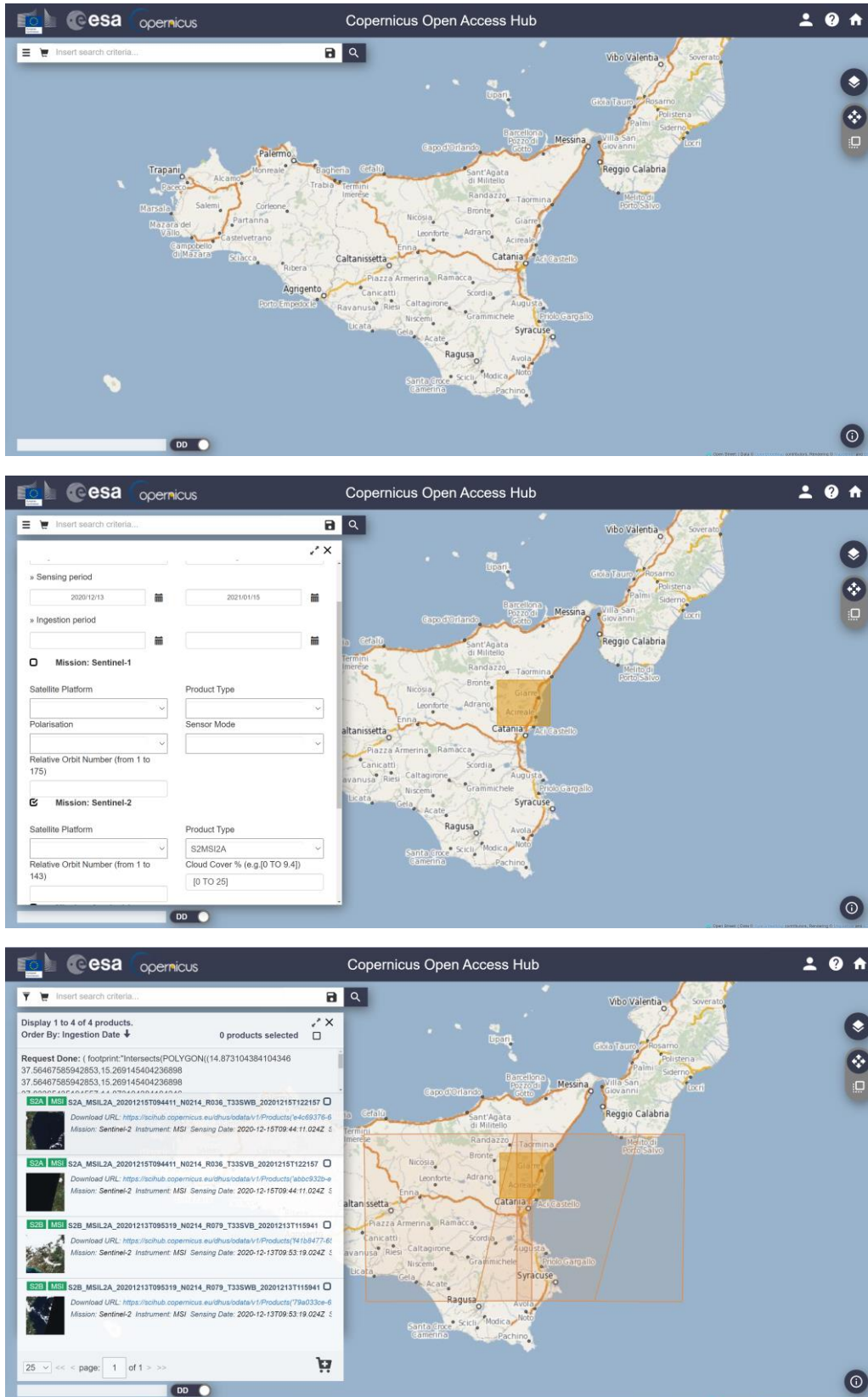


FIGURE 5: SEARCHING AND DOWNLOADING SENTINEL-2 SCENES FROM THE COPERNICUS OPEN ACCESS HUB – SCREENSHOTS FROM SCIHUB.COPERNICUS.EU/DHUS/

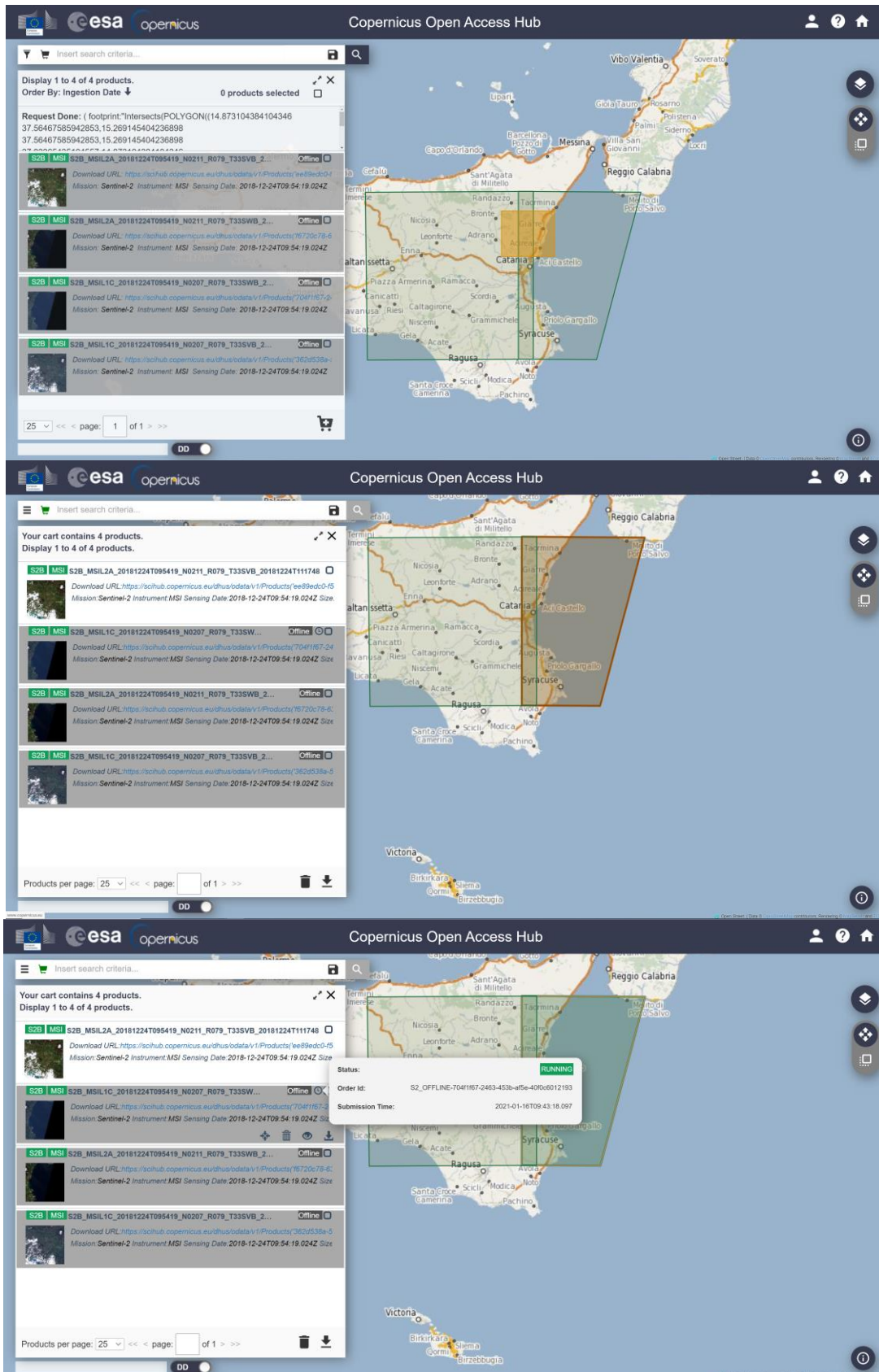


FIGURE 6: DOWNLOADING SCENES FROM THE LONG TERM ARCHIVE (LTA) – SCREENSHOTS FROM SCIHUB.COPERNICUS.EU/DHUS/

Users will need to understand two things about the search results: Firstly, the tiles of the scenes are overlapping as one can see after the search. This overlap can be useful if a small area of interest lies directly on the border of two tiles as one does not need to download both and stitch them together. Secondly, images for a tile can have large black areas such as in Figure 9; or in the preview of the found data products in Figure 5, and Figure 6. This missing coverage of a tile can happen because the instrument's field of view is limited, and the satellites' orbit is not aligned with the fixed tile grid. Therefore, tiles can be either completely covered or only partly during a revisit.

To understand the search parameters and to prepare for working with the data products, the user needs to be familiar with the missions' instrument and its data formats. The following section will cover an introduction to the Sentinel-2 mission, to gain an understanding of the data needed to be able to work with it. Further information about the mission can be found in the Sentinel-2 handbook⁴⁶. Other data products and different Copernicus missions are each described in the corresponding mission section and user guide.

The Sentinel-2 mission features two satellites, S2A and S2B. The satellites' Multi Spectral Instrument (MSI) covers 13 different ranges of the electromagnetic spectrum called bands⁴⁷. These include wavelengths centred about 492nm, 559nm, and 664nm in the bands 2, 3, and 4 respectively, which correspond to the blue, green, and red visible components of the light. While these bands have a spatial resolution of 10m, other bands have lower resolutions such as the narrow near infrared ranged band 8a, which has a spatial resolution of 20m.

Sentinel-2 data products are images of fixed 100km x 100km granules, which are also called tiles. These ortho-images are in UTM/WGS84 projection and the Sentinel-2 tiling grid of the earth is available for download as a *.kml* file⁴⁶. Products are either Level 1 (L1), Top of Atmosphere (TOA), or Level 2 (L2), Bottom of Atmosphere (BOA) reflectance⁴⁶ – meaning that users can either download L2 data products, which are already processed by the Copernicus ground segment, including correction of atmospheric distortions; or L1 data products, which may be available sooner after acquisition by the satellite. Alternatively, users can also download L1 data products and build the L2 products locally using the SNAP tool.

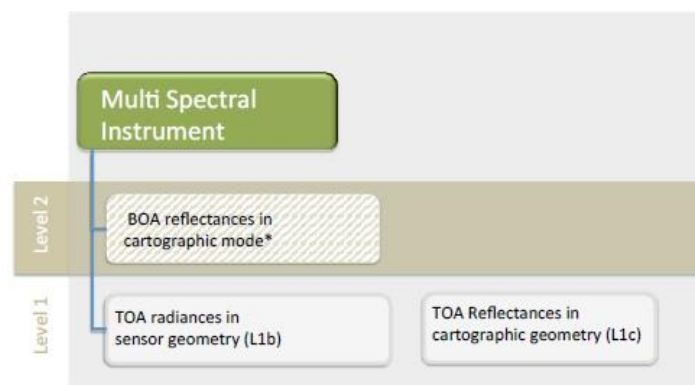


FIGURE 7: GRAPHICAL REPRESENTATION OF SENTINEL-2 CORE PRODUCTS (SOURCE: ESA'S SENTINEL-2 DATA PRODUCT DESCRIPTION⁴⁶; EUROPEAN SPACE AGENCY - ESA)

The data format of a particular product type is described by ESA in the corresponding user guide⁴⁸. Downloaded Sentinel-2 scenes are contained in a *.zip*-file, which contains a *.safe* folder⁴⁹, and its name reflects on the above described details. For example, the scene downloaded and processed below is named S2A_MSIL2A_20210114T094341_N0214_R036_T33SVB_20210114T123758.SAFE, and reflects on the satellite (S2A), instrument (MSI), processing level (L2A), data take time (20210114T094341, processing baseline (N0214),

⁴⁶ Sentinel-2 - Data Products - Sentinel Handbook - Sentinel (esa.int):

<https://sentinel.esa.int/web/sentinel/missions/sentinel-2/data-products>

⁴⁷ MSI Instrument – Sentinel-2 MSI Technical Guide – Sentinel Online - Sentinel (esa.int):

<https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-2-msi/msi-instrument>

⁴⁸ User Guides - Sentinel (esa.int): <https://sentinel.esa.int/web/sentinel/user-guides>

⁴⁹ Sentinel-2 MSI - Naming Convention:

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/naming-convention>

orbit (R036), tile (T33SVB), and processing time (20210114T123758). The contents of a Sentinel-2 product's *.safe* folder are shown in Figure 8.

The product metadata file is of particular interest as it is needed for working with the scene using the SNAP tool. Users can open this file in SNAP to start working with it. The IMG folder in a granule folder contains the actual data, a *.JPEG2000* (pixel or raster-based) file for each band.

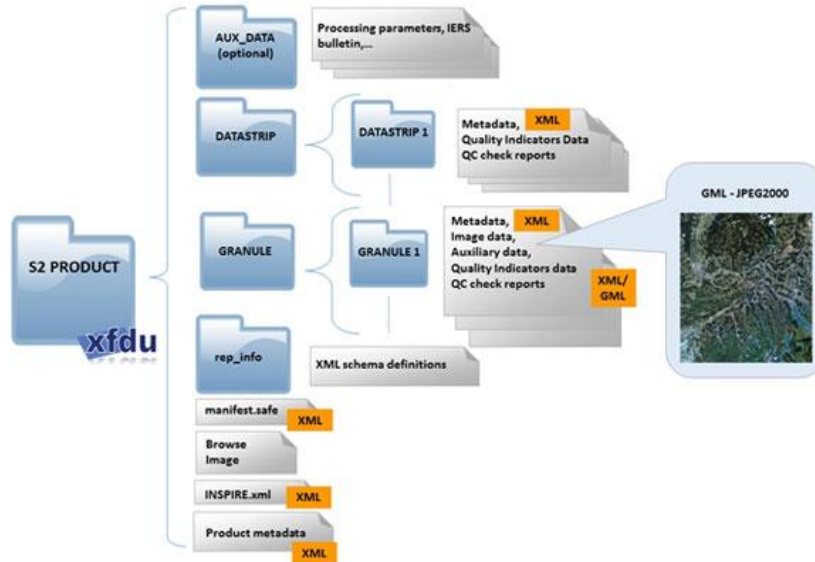


FIGURE 8: SENTINEL-2 PRODUCT FILES (SOURCE: ESA USER GUIDE⁵⁰; EUROPEAN SPACE AGENCY - ESA)

Processing with SNAP

To get a first view of a Sentinel-2 scene, users can view it as an image from space by assigning the red, green, and blue (true image) bands to the three colour channels their viewer software. Options for tools that can be used for this procedure include commercial software such as ArcGIS Pro⁵¹, free GIS tools such as QGIS⁵², open-source processing tools such as SNAP, or programming libraries such as GDAL⁵³ (e.g., via the python library rasterio⁵⁴).

To get a preview in SNAP the user needs to open a scene, use its context menu under *Open RGB Image Window*, and assign the *Sentinel 2 MSI Natural Colors* as shown in Figure 9. For the illustrated image, the B04, B03, B02 bands from the Granule/Img folder are interpreted as input. This process of assigning bands to the viewer's colours is called band combination and executed in the following step. While here only three bands are assigned to show the scene as a true colour image, the next steps will use other bands to visualise information from the MSI instrument that are not in the visible area of the electromagnetic spectrum.

⁵⁰ Data Formats - User Guides - Sentinel-2 MSI - Sentinel (esa.int):

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/data-formats>

⁵¹ ArcGIS Pro: <https://pro.arcgis.com/>

⁵² QGIS: <https://www.qgis.org/>

⁵³ GDAL — GDAL documentation: <https://gdal.org/>

⁵⁴ GitHub - mapbox/rasterio: <https://github.com/mapbox/rasterio>

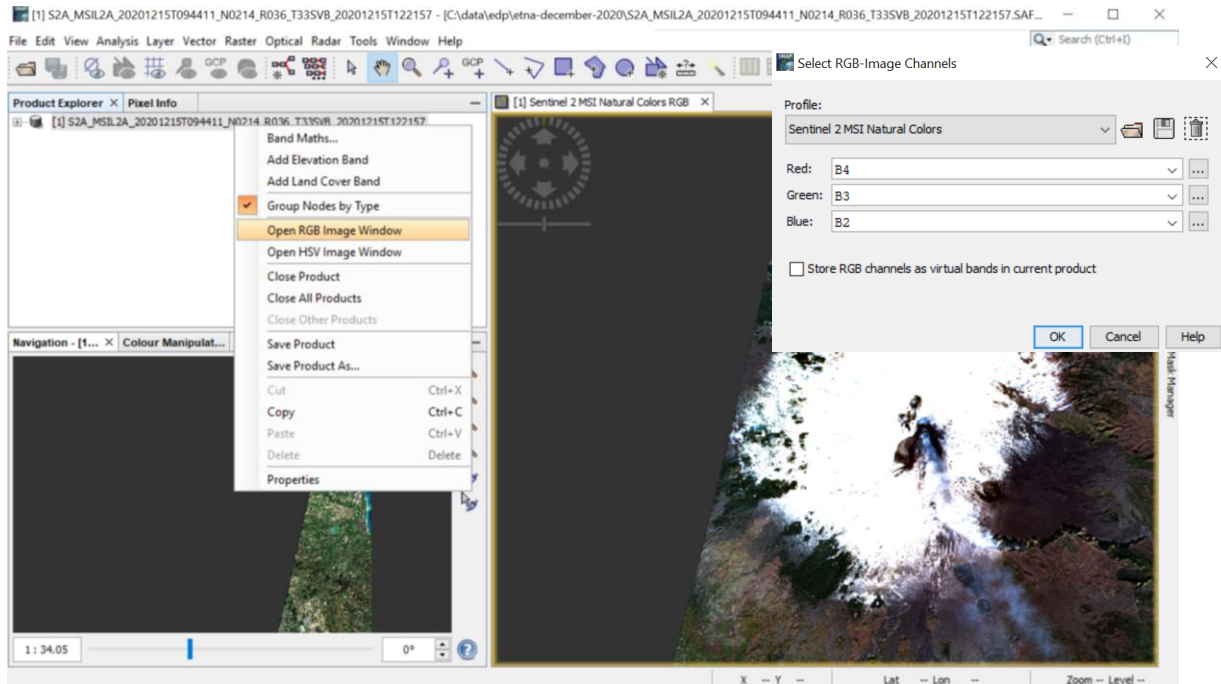


FIGURE 9: VIEWING A SENTINEL-2 SCENE AS A TRUE RGB IMAGE IN SNAP BY SELECTING THE BANDS B4 (RED), B3 (GREEN), AND B2 (BLUE) BANDS.

Users may need to reduce the data size, e.g., when working with true image data or a small area of interest only. Figure 10 shows the raster/subset tool in SNAP and some of its options, including for selecting a subset of the scene or bands. Here, the volcano crater is of interest and thus selected and clipped. The result is a subset of the original scene that can be used in further steps as a normal scene.

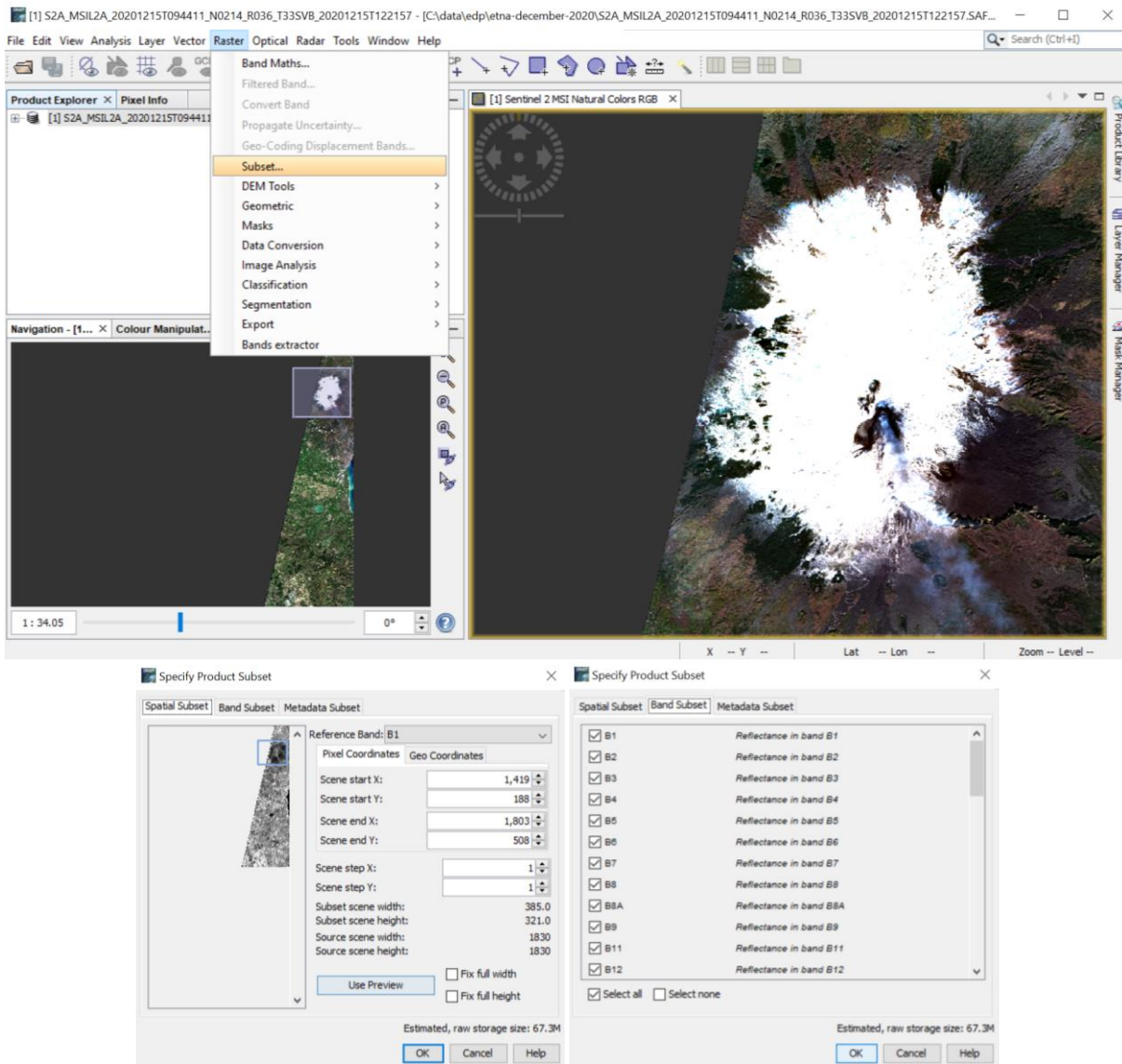


FIGURE 10: CREATING A SUBSET OF A SCENE IN SNAP WITH OPTIONS FOR SELECTING AN AREA, BANDS, AND METADATA.

Another basic processing step is the resampling of the needed bands to a common resolution. This step is often necessary because the different bands of the MSI instrument deliver data of different resolution. For example, the RGB Image Window in Figure 9 offers only combinations for bands with the same resolution. If users want to combine differing bands in a processing step (or for visualising lower resolution bands), the resampling operation in SNAP and some of its options are shown in Figure 11.

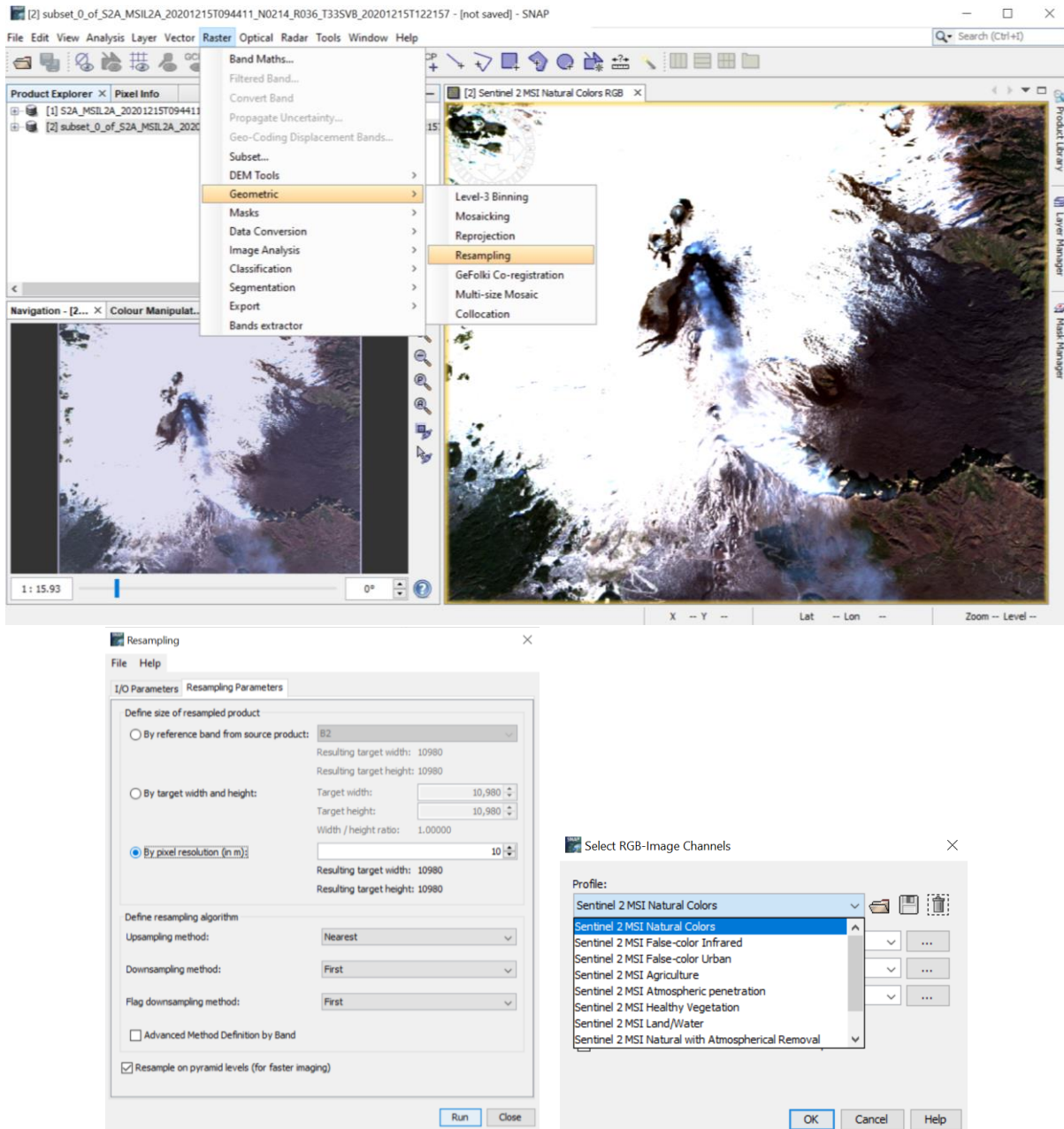


FIGURE 11: RESAMPLING BANDS TO A COMMON RESOLUTION IN SNAP RESULTS IN MORE PREDEFINED BAND COMBINATIONS IN THE VIEWER.

The natural colours combination of bands introduced before is just one option to view an area of interest of a Sentinel-2 scene. After resampling a scene, the RGB Image Window offers a larger set of predefined combinations as illustrated in Figure 11.

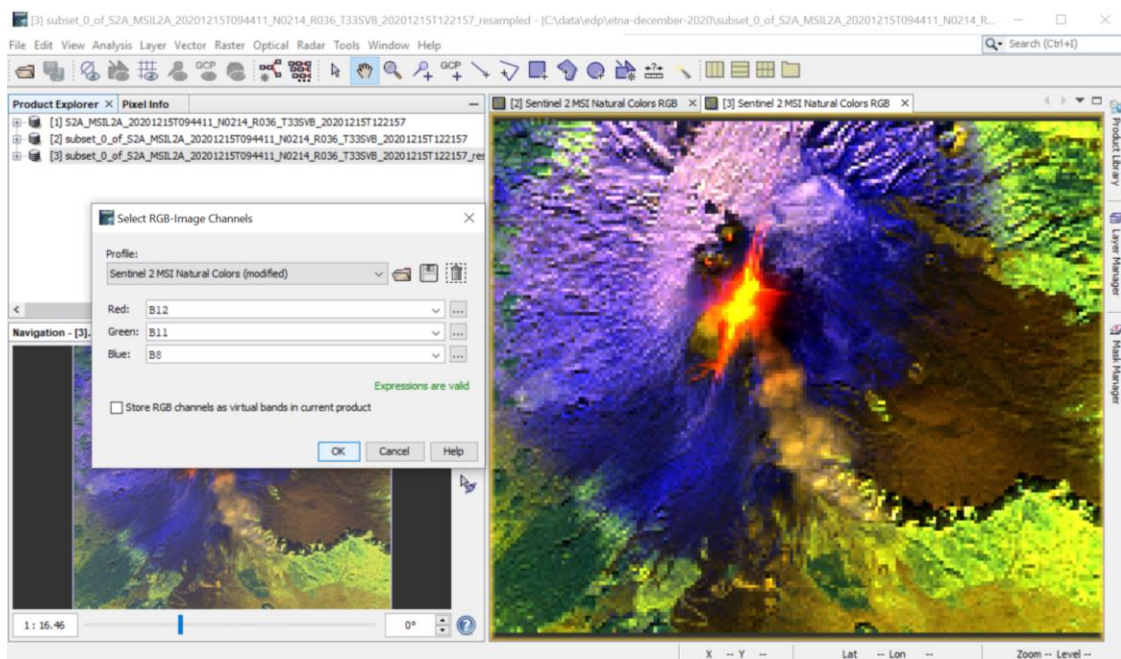


FIGURE 12: A CUSTOM BAND COMBINATION FROM ⁵⁵ IN SNAP FOR INSPECTING A VOLCANO.

Users can also enter custom combinations as illustrated in Figure 12, which adopts a combination described in an article by Sabina Dolenc on medium.com⁵⁵. SNAP also offers a function called band maths, which is used in Figure 13 to define new bands for the viewer and which can be used to define bands for assessing lava, which is otherwise black and not visible in a true colour image⁵⁵.

⁵⁵ Active Volcanoes as Seen from Space | by Sabina Dolenc | Sentinel Hub Blog | Medium: <https://medium.com/sentinel-hub/active-volcanoes-as-seen-from-space-9d1de0133733>

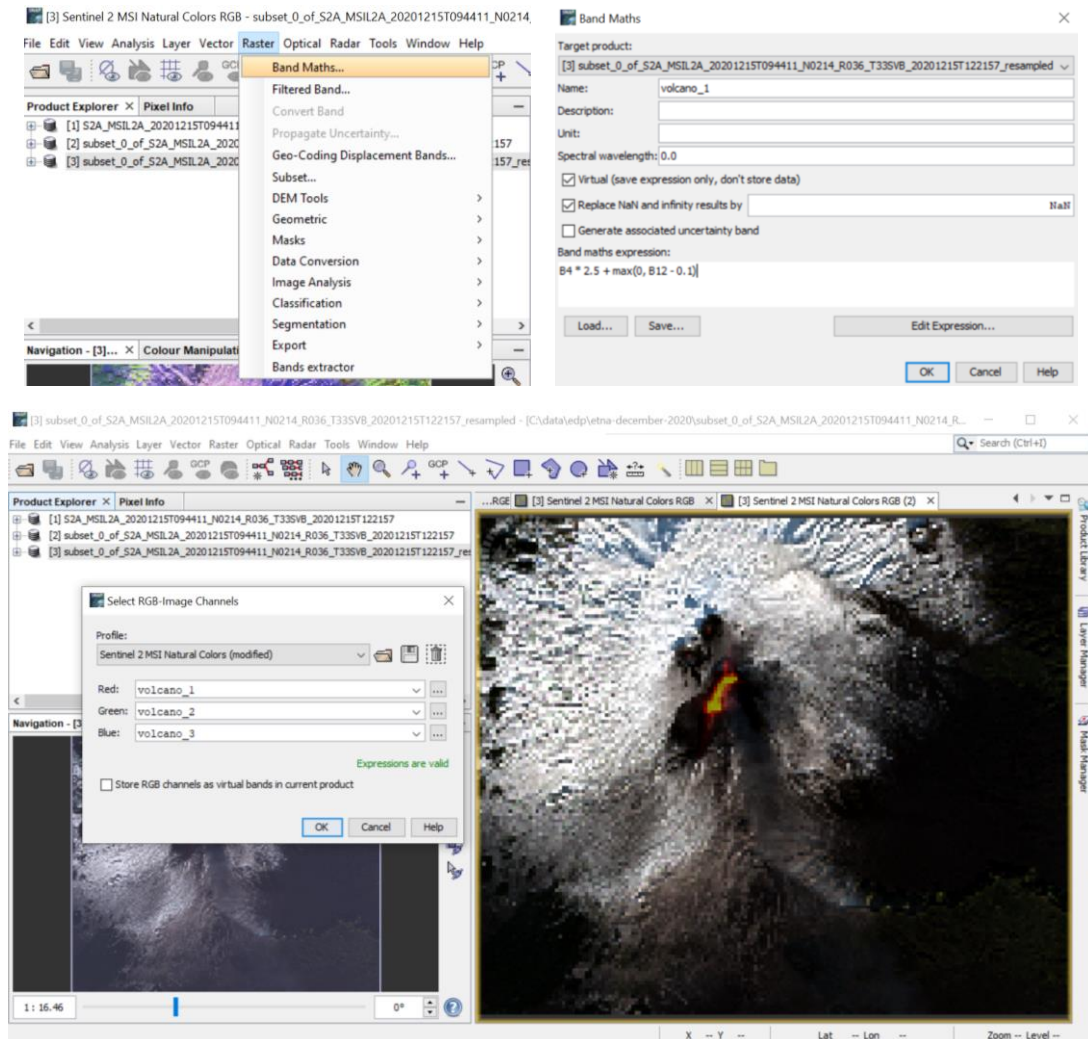


FIGURE 13: CUSTOM BAND DEFINITIONS USING THE BAND MATH FUNCTION IN SNAP. BANDS AND COMBINATION FROM 55.

While the *.jp2* files in the *.safe* format represent the individual bands, users can generate a single *.tif* file as shown in Figure 14, which is often easier to handle, or even needed for use with other GIS tools. The export as *.tif* means that the bands are composed in one file, which does not mean that the bands are tied to those of a viewer in a fixed manner. A scene requires the included bands to be of the same resolution. Users may need to apply resampling first. Because upsampling and exporting full scenes with all bands often results in files of multiple gigabytes, it can be useful to pre-process a scene before exporting so that it contains only the needed subset of the 13 Sentinel-2 MSI bands or to clip it to a smaller area of interest.

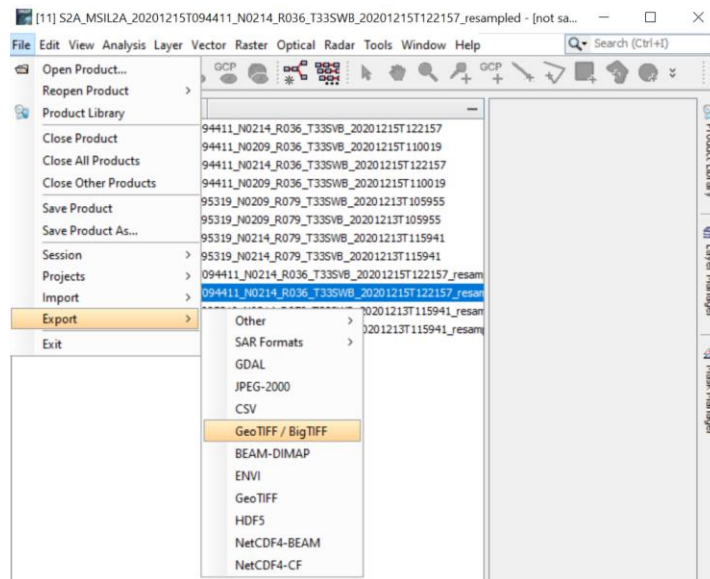


FIGURE 14: EXPORTING A SCENE AS GEOTIFF / BIGTIFF IN SNAP

After processing the scene with these steps, the image can be opened and viewed in a GIS tool or even with a normal photo viewer as shown in Figure 15. The described steps can be automated as described in the following section.

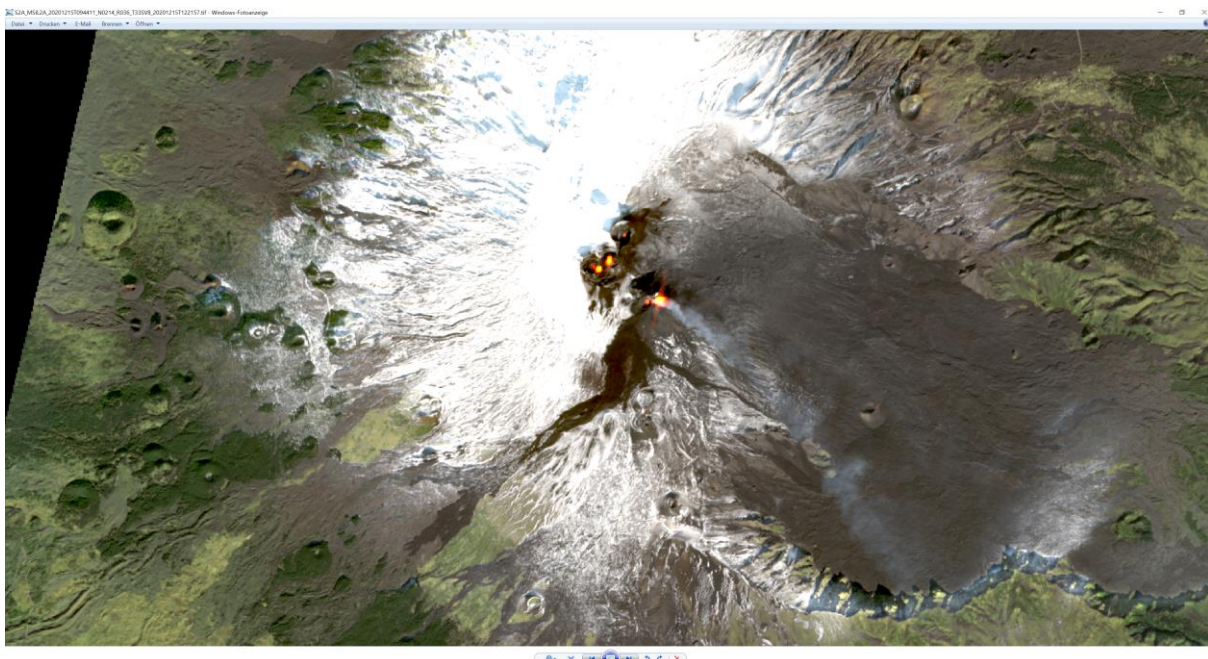


FIGURE 15: THE PROCESSED SCENE OPENED IN A PHOTO VIEWER

More information can be found in the tutorials on the SNAP tool on the ESA website⁵⁶, including, e.g., mosaicking – the process of stitching multiple scenes together.

⁵⁶ SNAP Tutorials – STEP (esa.int): <https://step.esa.int/main/doc/tutorials/snap-tutorials/>

Automatic Downloading and Processing

Figure 16 shows the process comprising the above steps implemented in SNAP's Graph Processing Tool (gpt). Users can store such created graphs and edit the .xml definition in a text editor of choice. Editing makes sense, for example when one wants to implement parameters or for reusing parts of the process. Appendix B: *Processing workflow for use with SNAP/GDP*, shows the edited process. The processing graph can be executed via the command line by first navigating to the working directory and then executing it via SNAP's gpt programme as shown below.

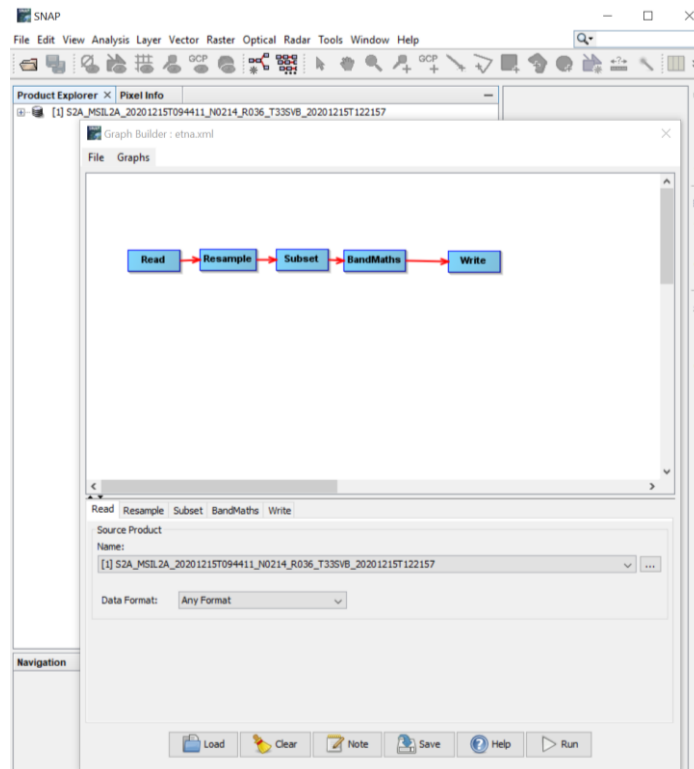


FIGURE 16: AUTOMATION OF THE WORKFLOW USING THE GRAPH BUILDER IN SNAP AND THE IMAGE OPENED IN A VIEWER

The ambitious user can now create a programme or script that searches for, downloads, and processes new Etna volcano scenes, e.g., daily; in three steps.

The first step is the implementation of the search via the Open Access Hub API. An example of a search URL looks as follows:

```
https://scihub.copernicus.eu/dhus/api/stub/products?filter=(%20footprint:%22Intersects(POLYGON((14.855741003796286%2037.640483194408375,15.099451859023652%2037.640483194408375,15.099451859023652%2037.82494043411195,14.855741003796286%2037.82494043411195,14.855741003796286%2037.640483194408375)))%22%20)%20AND%20(%20beginPosition:[2021-01-14T00:00:00.000Z%20TO%202021-01-19T23:59:59.999Z]%20AND%20endPosition:[2021-01-14T00:00:00.000Z%20TO%202021-01-19T23:59:59.999Z]%20)%20AND%20(%20(platformname:Sentinel-2%20AND%20producttype:S2MSI2A%20AND%20cloudcoverpercentage:[0%20TO%2010]))&offset=0&limit=25&sortedby=ingestiondate&order=desc
```

The second step is then to select the scene identifier from each search result and to execute the download. An example of a download URL looks as follows:

```
https://scihub.copernicus.eu/dhus/odata/v1/Products('89bb7585-47d7-434c-b9d7-2ce44d5a6948')/$value
```

Ideally, the search targets only the T33SVB tile (see Figure 5), so that the script needs to check few search results only. The programme then only needs to check if the scene was downloaded before. In other use cases, the

programme may also need to check if the area of was downloaded and processed before with an overlapping scene.

In the third step, after downloading the scene, the processing of the new scene can be achieved by running the gpt processing with the newly downloaded scene as the read argument:

```
> CD C:\data\edp\  
> C:\Program Files\snap\bin\gpt etna.xml -  
Pread=". \S2A_MSIL2A_20210114T094341_N0214_R036_T33SVB_20210114T123758.SAFE" -  
Pwrite=". \out\S2A_MSIL2A_20201215T094411_N0214_R036_T33SVB_20201215T122157.tif"
```

Conclusion and Recommendations

The usefulness of Copernicus data

This analytical report has focused on the platforms and tools concerned with the ecosystem around the Copernicus programme. It became apparent that the extent to which open data users can leverage Copernicus data is only limited by the extent to which users are willing and able to familiarise themselves with the involved platforms and needed tools. While using Copernicus data may not be considered a straightforward or easy process, this analytical report shows that the necessary tools and resources are readily available. For example, the volcano monitoring use case exercised in the final chapter used information from tutorials and blog entries to make lava flows visible in Sentinel-2 images. This analytical report can thus serve as a blueprint and guide open data users who want to use Copernicus data.

The need for in situ data

This analytical report showed that Copernicus data can enable many applications to deliver the bigger picture using Copernicus data. This report guides users with little background in earth observation so they can realise, e.g., volcano monitoring or capturing the impact of COVID-19 on economy. However, users should be aware that reliable in situ data will be required at some point for most use cases. The Copernicus programme itself uses data from sensors on earth, e.g., for calibration and validation of their satellite data products, as well as for the delivery of the Copernicus services. Other users may rely on orthophotos at very high resolution taken from aeroplanes, which are perhaps only available every five years. To complete the big picture Sentinel-2 imagery can potentially fill this gap, when a lower resolution can be acceptable until the next in situ measurement. In general, applications ultimately rely on in situ data. For example, while remote sensing can add a new dimension to monitoring waters, water level sensors can only be implemented in situ. For users looking for in situ data for their own projects, the European Data Portal can be one future starting point.

Finding Copernicus Data on the European Data Portal

It would be worthwhile to discuss making more Copernicus data discoverable through the European Data Portal. While it would be possible to display each product as an individual search result, this is not the best approach from a user perspective because the different product types would look very similar in the search results. Without further options to explore and compare products, such as with the Copernicus Open Access Hub, it would be very difficult for the users to identify the products relevant to them. Furthermore, the total number of available datasets would increase significantly possibly reducing the impact/discoverability of the already existing datasets. For example, a user using the European Data Portal's gazetteer to search available datasets by a specific location might result in large number of Sentinel datasets that are all relatively similar, while other unique datasets are only shown at the very end of the list. A better approach would be to reduce the number of search results by harvesting only the high-level collection metadata and then link to the corresponding catalogue application, preferably with predefined search parameters. This way a user looking for SAR data would only find one result for the collection of Sentinel-1 data instead of all the Sentinel-1 products that have been collected since the start of the programme. Besides the actual satellite images collected by the Copernicus Program, also the products derived from them should be taken into consideration. Integrating these products may be especially interesting for users with less experience with earth observation data. While satellite images often require additional processing steps or special knowledge to be used, the products of the Copernicus Services are already processed to serve specific use cases. They also provide very descriptive metadata that can already be harvested

with the existing geo harvester. Harvesting them would add a few very interesting datasets to the European Data Portal while the total number of products will remain manageable.

References

The references are provided in the footnotes.

Appendix A: Data Access Platforms

Conventional Data Access Points

ESA Copernicus Open Access Hub	https://scihub.copernicus.eu/
Copernicus Space Component Data Access (CSCDA)	https://spacedata.copernicus.eu/web/cscda/home
EUMETSAT EUMETCast	https://www.eumetsat.int/eumetcast
EUMETSAT Copernicus Online Data Access (CODA)	https://eoportal.eumetsat.int/cas/login

Data and Information Access Services (DIAS)

Sobloo	
URL	https://sobloo.eu
APIs	<p>Collections: https://sobloo.eu/api/v1/services/explore/ogc/csw Example GetRecords-Request</p> <p>OpenSearch: https://sobloo.eu/api/v1/services/opensearch/ List of search template URLs https://sobloo.eu/api/v1/services/explore/collections/catalog-sentinel-3</p>
ONDA	
URL	https://www.onda-dias.eu/cms/
APIs	<p>Documentation Discovery API: https://www.onda-dias.eu/cms/de/services/catalogues/discovery/</p> <p>OData interface: https://catalogue.onda-dias.eu/dias-catalogue/Products</p> <p>OpenSearch: https://catalogue.onda-dias.eu/opensearch/OpenSearchDescription</p>
mundiwebservices	
URL	https://mundiwebservices.com
APIs	<p>CSW Collections: https://mundiwebservices.com/acdc/catalog/proxy/search/collections/csw</p> <p>CSW Products (e.g., Sentinel-1): https://mundiwebservices.com/acdc/catalog/proxy/search/Sentinel1/csw</p> <p>OpenSearch Collections: https://mundiwebservices.com/acdc/catalog/proxy/search/collections/opensearch/description.xml</p> <p>OpenSearch Products (e.g., Sentinel-1): https://mundiwebservices.com/acdc/catalog/proxy/search/Sentinel1/opensearch/description.xml</p>
CREAODIAS (formerly called EO CLOUD)	
URL	https://creodias.eu/
APIs	<p>CSW URL: http://catalogue.creodias.eu/srv/en/csw?request=GetCapabilities&service=CSW&version=2.0.2</p>
WEKEO	
URL	https://www.wekeo.eu/
APIs	<p>CSW URL: https://www.wekeo.eu/elastic-csw/service?request=GetCapabilities&service=CSW</p>

Appendix B: Processing workflow for use with SNAP/GDP

Example of the processing graph for SNAP described in *Automatic Downloading and Processing*

```

<graph id="Graph">
  <version>1.0</version>
  <node id="Read">
    <operator>Read</operator>
    <sources/>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <!--<file>C:\data\edp\etna-december-
      2020\S2A_MSIL2A_20201215T094411_N0214_R036_T33SVB_20201215T122157.SAFE\MTD_
      MSIL2A.xml</file-->
      <file>${read}</file>
    </parameters>
  </node>
  <node id="Resample">
    <operator>Resample</operator>
    <sources>
      <sourceProduct refid="Read"/>
    </sources>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <referenceBand/>
      <targetWidth/>
      <targetHeight/>
      <targetResolution>10</targetResolution>
      <upsampling>Nearest</upsampling>
      <downsampling>First</downsampling>
      <flagDownsampling>First</flagDownsampling>
      <resamplingPreset/>
      <bandResamplings/>
      <resampleOnPyramidLevels>true</resampleOnPyramidLevels>
    </parameters>
  </node>
  <node id="Subset">
    <operator>Subset</operator>
    <sources>
      <sourceProduct refid="Resample"/>
    </sources>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <sourceBands>B1,B2,B3,B4,B5,B6,B7,B8,B8A,B9,B11,B12</sourceBands>
      <region>0,0,0,0</region>
      <referenceBand/>
      <geoRegion>POLYGON ((14.855740547180176 37.64048385620117,
      15.099452018737793 37.64048385620117, 15.099452018737793 37.8249397277832,
      14.855740547180176 37.8249397277832, 14.855740547180176 37.64048385620117,
      14.855740547180176 37.64048385620117))</geoRegion>
      <subSamplingX>1</subSamplingX>
      <subSamplingY>1</subSamplingY>
      <fullSwath>false</fullSwath>
      <tiePointGridNames/>
      <copyMetadata>true</copyMetadata>
    </parameters>
  </node>
  <node id="BandMaths">
    <operator>BandMaths</operator>
    <sources>
      <sourceProduct refid="Subset"/>
    </sources>
    <parameters class="com.bc.ceres.binding.dom.XppDomElement">
      <targetBands>

```

```

<targetBand>
  <name>volcano_1</name>
  <type>float32</type>
  <expression>B4 * 2.5 + max(0, B12 - 0.1)</expression>
  <description/>
  <unit/>
  <noDataValue>0.0</noDataValue>
</targetBand>
<targetBand>
  <name>volcano_2</name>
  <type>float32</type>
  <expression>B3 * 2.5 + max(0, B11 - 0.1)</expression>
  <description/>
  <unit/>
  <noDataValue>0.0</noDataValue>
</targetBand>
<targetBand>
  <name>volcano_3</name>
  <type>float32</type>
  <expression>B2 * 2.5</expression>
  <description/>
  <unit/>
  <noDataValue>0.0</noDataValue>
</targetBand>
</targetBands>
<variables/>
</parameters>
</node>
<node id="Write">
  <operator>Write</operator>
  <sources>
    <sourceProduct refid="BandMaths"/>
  </sources>
  <parameters class="com.bc.ceres.binding.dom.XppDomElement">
<!--<file>C:\data\edp\Subset_S2A_MSIL2A_20201215T094411_N0214_R036_
T33SVB_20201215T122157_resampled_BandMath.tif</file>-->
    <file>${write}</file>
    <formatName>GeoTIFF-BigTIFF</formatName>
  </parameters>
</node>
<applicationData id="Presentation">
  <Description/>
  <node id="Read"><displayPosition x="47.0" y="87.0"/></node>
  <node id="Resample"><displayPosition x="129.0" y="86.0"/></node>
  <node id="Subset"><displayPosition x="216.0" y="86.0"/></node>
  <node id="BandMaths"><displayPosition x="293.0" y="87.0"/></node>
  <node id="BandMaths (2)"><displayPosition x="293.0" y="120.0"/></node>
  <node id="BandMaths (3)"><displayPosition x="294.0" y="158.0"/></node>
  <node id="Write"><displayPosition x="412.0" y="88.0"/></node>
</applicationData>
</graph>

```