Copernicus Sentinel Data Access Annual Report

Foreword

I am honoured to be introducing the 2021 Copernicus Sentinel Data Access Annual Report. This key report is produced by a Serco-led consortium in charge of the development and operations of the Sentinel Data Access System. Since the start of our operations in 2014, Serco has proudly published this annual report with the support of our consortium partners Gael Systems, NOA and GRNET.

The report provides an overview of the Sentinels Data Access System, outlining the Earth Observation data products made available through it, the demographics of users and their uptake of products, the status of agreements with collaborative and international partners, as well as the evolution of the System over the years and the outlook for the future.

The report shows the complexity of an operational scenarios coping with a constant increase of the number of users successfully accessing an ever-growing amount of data. This report therefore presents an insider perspective on the range of achievements, building on the contributions of all the teams involved in ESA's Copernicus operations.

In 2021 the overall published volume of data has exceeded 30PB (with a 7.5 PB/year stable rate of growth) while the global interest in this EU-led initiative is demonstrated by the overall users downloads: more than 86PB of data have been downloaded in this reporting year, a figure enhanced by downloads coming from the re-distribution of Sentinel data by Copernicus Participating States, via their collaborative ground segments, our international partners and by commercially oriented organisations.

It is also worth highlighting that these numbers have been reached during the transition of Data Access System from the ESA-provided network infrastructure to the ONDA, the Serco DIAS ecosystem. This year, in fact, the Data Access team successfully achieved the objective of making the Data Access System completely independent from the previous infrastructure, whilst maintaining the interfaces operated by the Data Access System without impact on services and data.

The continuous growth of the service over the years demonstrates the value and benefits of using Sentinels data to develop added value information. Serco is proud of the achievements outlined in this report as we remain committed to support ESA and the European Commission in enabling and easing access to Satellite data. Our objective is to help attract new potential consumers of space data and services.

I hope you will enjoy reading the report and will find it useful,

Gaetan Desclee
Managing Director of Serco in Europe

➔ Document Scope

A deliverable of the Sentinels Rolling Archive, Operations Maintenance and Evolution contract, this document provides an annual look at the Sentinel Data Access Service operated by the Serco Gael consortium for ESA as part of the Copernicus programme.

Written by:

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→ Documentation

Reference documents

Key	Title	link
[RD-1]	Sentinel High Level Operations Plan (HLOP)	https://sentinels.copernicus.eu/documents/247904/685154/Sentinel_High_Level_Operations_Plan

Definitions

Data Dissemination	Refers to the access and retrieval of Copernicus data by users (could be national Collaborative Ground Segments, Data Hub Relays (DHR) or user of the Open Hub etc) directly from ESA core nodes
Data Exchange	Refers to the transfer of Copernicus data from one Data Hub Relay (DHR) to another DHR
Data Ingestion	Refers to the indexing, storage and publication on the data dissemination infrastructure of the Copernicus data
Data Publication	Refers to the provision of user-level data available online for download by users
Data Relay	Refers to the transfer of Copernicus Data from a Data Hub Relay (DHR) to a national Collaborative Ground Segment
Rolling Archive	Online accessible repository of Copernicus data representing a subset of the total mission archive and regularly updated to maintain a fixed archive volume (e.g. the last months of user-level data)
Y2021	Refers to the reporting period covered in this report, from 1/12/20 - 30/11/21. Similarly, Y2020 refers to the previous reporting period: 1/12/19 - 30/11/20; Y2019 to the reporting period 1/12/18 - 30/11/29; Y2018 to the reporting period 1/12/17 - 30/11/18; Y2017 to the reporting period 01/12/16 - 30/11/17; Y2016 to reporting period 01/12/15-30/11/17; and Y2015 to the reporting period from 03/10/14 – 30/11/15.

The acronyms used in the document can be found in Annex 1: List of Acronyms.

Conventions

In this report, the following conventions have been used:

- the SI approved unit symbols KiB, MiB, GiB, TiB and PiB are used to report data volumes: 1KiB=2^{10} bytes, 1 MiB= 2^{20}bytes, 1GiB= 2^{30} bytes, 1 TiB = 2^{40} bytes and 1 PiB = 2^{50} bytes.
- unless otherwise noted, the volume figures refer to the compressed user-level data volumes as published and downloaded via the data hub access points.

➔ Table of Contents

1 INTRODUCTION

Copernicus is a European Union programme which provides operational information on the world's land surfaces, oceans and atmosphere, to support environmental and security policymaking and meet the needs of citizens and service providers. Under the Space Component of the Copernicus programme, ESA has developed a family of dedicated satellites, called the Copernicus Sentinels, to serve the programme's Earth Observation requirements. The data acquired from these missions is systematically downlinked and processed to operational user level data by the Sentinel ground segments. The Copernicus Data Access System retrieves the Copernicus Sentinel-1, -2, -3 (land) and -5P user level data from the relevant ground segment and makes them available for users to download from dedicated access points, known as data hubs.

This Annual Report presents the performance of the Copernicus Data Access System operated by ESA during the year 1 December 2020 to 30 November 2021 (referred to throughout this report as 'Y2021'), and analyses the trends visible in the public uptake of Copernicus Sentinel data. This is the sixth such report released by the data access service provider, Serco Italia SpA.

The magnitude of the task which the Data Access System manages is visible throughout the Report, from the description of the extensions made to the underlying infrastructure, to the statistics about data publication and download. Whereas at the end of Y2015, 355,939 user level data had been published on the Copernicus Open Access Hub (Open Hub) and 3.38 PiB of data had been downloaded, in Y2021 the **53 millionth** user level data was published on the Open Hub and by 30 November 2021 users had downloaded nearly a massive **320 PiB** of data user level data. During the reporting period almost **33,000** user level data were published per day. Moreover, the number of registered users reached **496,349** by the end of Y2021, indicating that not only is the existing user base consolidated but also that word is spreading and more and more users are starting to engage with the potential contained in the vast stores of free and open data available through the Copernicus Data Access System.

Throughout the document the following nomenclature will be used to signify a particular reporting period:

- **Y2021**: 1 December 2020 – 30 November 2021 (this report)
- **Y2020**: 1 December 2019 – 30 November 2020 (report released on 07 September 2021)
- **Y2019**: 1 December 2018 - 30 November 2019 (report released on 25 May 2020)
- **Y2018**: 1 December 2017 – 30 November 2018 (report released on 8 May 2019)
- **Y2017**: 1 December 2016 – 30 November 2017 (report released on 18 May 2018)
- **Y2016**: 1 December 2015 – 30 November 2016 (report released on 5 April 2017)
- **Y2015**: 3 October 2014 – 30 November 2015 (report released on 27 April 2016)

1.1 Data Access System Architecture

The Copernicus Sentinel Data Access System provides different user typologies free and open access to Copernicus Sentinel user-level data. The System is developed and managed by Serco SpA with the consortium partners GAEL Systems, the National Observatory of Athens (NOA) and GRNET S.A. The service includes the management of the infrastructure, supporting applications and procedures, and expert staff who tailor publication of user-level data to the operational scenarios and respond to user enquiries.

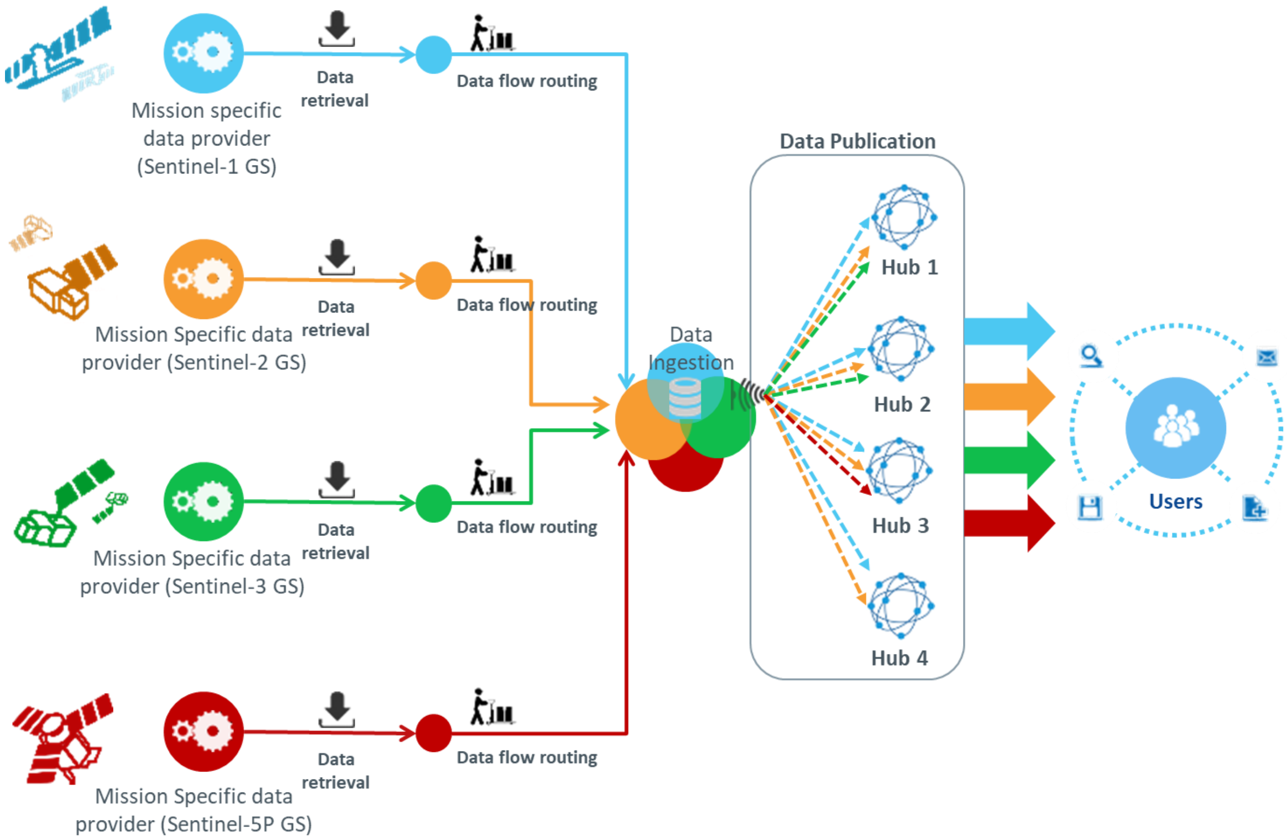

Figure 1: Copernicus Sentinel Data Access System Model

As its general functionality, the Data Access System automatically retrieves user-level data from ESA's Sentinel ground segments and publishes them online, on a series of dissemination points known as hubs. Accessing these hubs, users are able to explore the data collections and download user-level data, either through an interactive graphical web interface (GUI) or automatically, using a scripting interface (API). The figure above illustrates the flow of data through the system.

Due to the flexible architecture on which the Data Access System is based, the consortium is able to expand the hub configuration to accommodate the ever-widening user base and the different operational data access requirements of the various stakeholders involved in Copernicus.

Since the end of Y2016, the system has operated a total of four main hub services through which users can access the user-level data. Each of these hubs has been configured to meet the needs of its target community of users, as shown in Figure 1. Each is described in more detail below.

Figure 2: The Sentinel Data Access System Configuration at the end of Y2021

The **Copernicus Open Access Hub (the Open Hub)** is the hub which offers to all users free, full and open access to Copernicus Sentinel data on the basis of self-registration. Accordingly, there are no restrictions on who can register to download data. The Open Hub is composed of two nodes: the SciHub – accessed by graphical user interface – and the APIHub – accessed via user-defined scripts.

Due to the high number of users active on the Open Hub at any one time, and the need to ensure bandwidth remains available for all users, the number of concurrent downloads which users are entitled to make is configured to two.

The Open Hub provides access to all user-level data which have been published on the Copernicus Sentinel Data Access System since the start of operations, via the same catalogue.

Since .30 November 2020, all data are managed within cloud storage systems. The fresh data are made available for immediate access, whereas older (less used) data are available from DIAS cloud archives for asynchronous access. The current configuration is that the latest six months of data available for the immediate access, all other data since the qualification of the user level data are available within the cloud archive and are generally made available for download within 60 minutes from request (even less, depending on the size of the data). Further details of the configuration and performances are outlined in section 2.3.4.

The Open Hub user information pages are kept up-to-date with the latest information about the rollout of the data and the current status of the data (see e.g. https://scihub.copernicus.eu/userguide).

The Open Hub is generally the first hub on which user-level data from a new mission are published. During the satellite commissioning phase, and in the support of introduction of new user level data types the access to the first data is restricted to mission experts, to enable them to carry out the calibration and validation activities required to qualify the user-level data. This initial release is managed by means of an Expert Hub, with currently two in operations (the Sentinel-3 Expert

Hub and the Sentinel-5P Expert Hub). The Expert Hubs are only ever available to a small number of users and so are not further described in this report.

Since mission commissioning the Sentinel-5P have been managed on a dedicated hub, allowing a to keep all the level-2 user level data available for immediate access. This configuration has been maintained for Y2021. The Sentinel-5P Hub provides access to all standard user-level data from Sentinel-5P published to date, and Near Real Time (NRT) user-level data from the previous month.

In response to a request from scientific users, the **GNSS RINEX Pre-Operations Hub** was opened on 13 February 2018 to provide the GNSS L1B data generated by the dual frequency GPS receivers on board the Copernicus Sentinel-1, -2 and -3 satellites. From the Hub, users can download all GNSS L1b RINEX user-level data relevant to the Copernicus Sentinel-1, -2 and -3 missions. This data has many scientific uses, including the study of orbit determination methods and the effect of non-conservative forces (for example, solar radiation, albedo, atmospheric drag, radiation pressure, ionosphere characterisation, gravity field monitoring and geodesy).

Another hub, called the **TMP Hub** (Temporary Hub) provides the last week of the published user-level data nominally available on Open Hub. This hub is not meant to be accessible by end users during nominal operations, but it is continuously updated with fresh user-level data in order to offer a recovery hub in case of major maintenance activities, providing continuity of the service, with all the end users of the various services being then redirected there.

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The **Copernicus Services Hub** (ServHub) guarantees free and full access to Copernicus Sentinel data for all Copernicus Services and EU institutions. Users are entitled to make up to 10 concurrent downloads. All user-level data from all missions in routine operations are published on the Hub.

The ServHub operates the same Rolling Policy for removing data from the online access as the Open Hub and ColHub: 6 months of user-level data is kept online (see Figure 3). Access to the nearline data is available for Sentinel-1, -2 and -3 data which has been removed through the Rolling Policy.

The DIAS partners have been provided with three dedicated access points on the Copernicus Sentinel Data Access System, to ensure a sufficient capacity to download the large volumes of user-level data which are required for their respective data offers. Those dedicated access points, known as the DIAS Hub, were linked to ServHub during Y2018 and opened to the DIAS partners on 9 March 2018.

In this Report, the downloads which are made by the DIAS operators from the Data Access System are separated out from the figures reported for the ServHub. Now that the DIAS are in routine operations, the DIAS operators download the entire data collection in real time, so their download figures are a repetition of the publication figures and, when included together in the ServHub statistics, mask the figures from the other activity on the ServHub due to their size. It is recalled that any statistics concerning the subsequent use of the data on the DIAS are outside the scope of this Report.

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The **Collaborative Hub** (ColHub) is open to all Copernicus Participating States, following signature of a CollGS agreement with ESA or an internal agreement with the European Commission. The ColHub is configured to support 10 concurrent downloads for each user.

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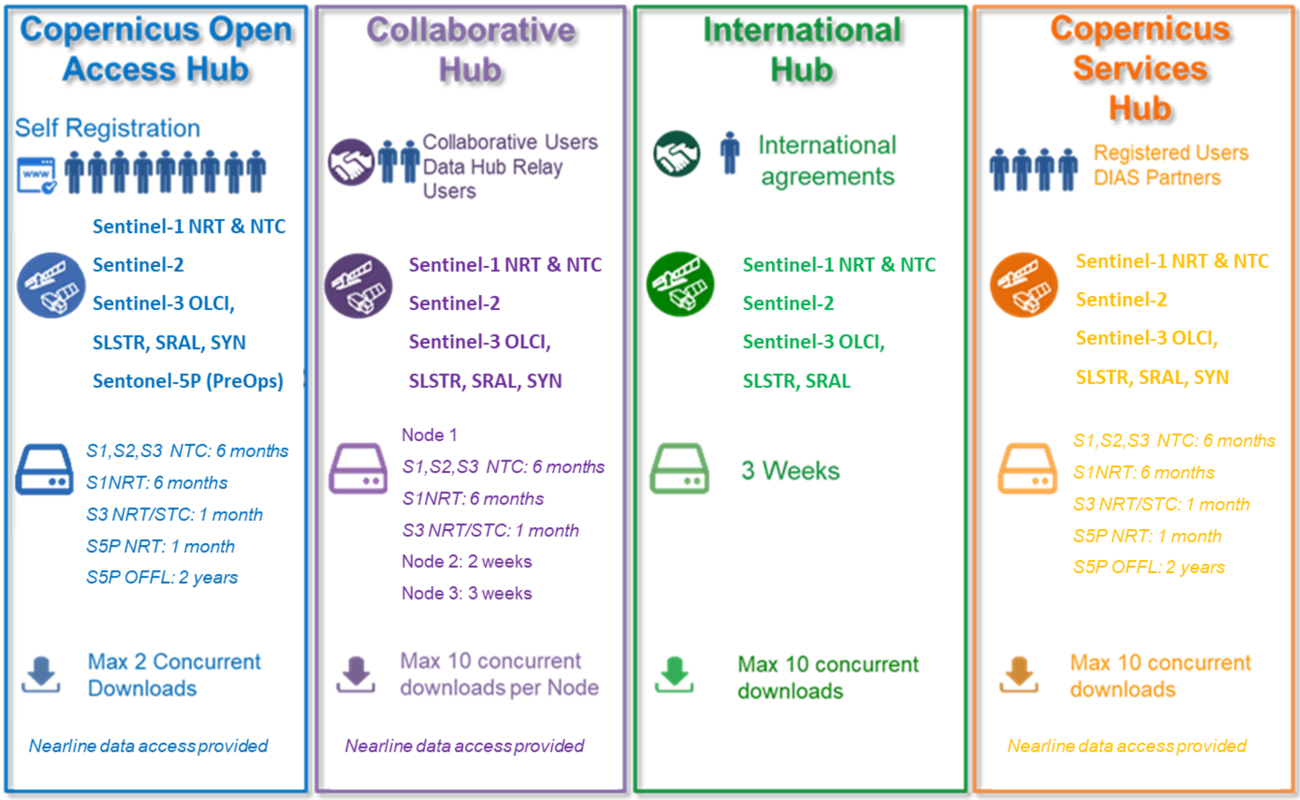

Figure 3: Copernicus Sentinel Data Access System hub characteristics at the end of Y2021

The CollGS partners download the Copernicus Sentinel user-level data as they are published on the hub, and then redistribute the data from their own storage and data access points. Accordingly, a Rolling Policy is applied to ColHub, removing user-level data which have been on the hub for longer than 6 months (this is for node 1 of 3 nodes: see Figure 3 for full details and other nodes). As for the Open Hub and ServHub, the ColHub now has the nearline access for historical Sentinel-1, -2 and -3 user-level data.

At the end of Y2021, there were 20 active CollGS agreements in place and 16 CollGSs in operation (see Chapter 4).

The dissemination capacity of the ColHub is enhanced by an interconnected data relay system which some of the CollGS partners run in addition to their standard data access point. Through this relay system, each CollGS partner is able to access data from a Data Hub Relay partner as well as directly from the ColHub, and this significantly increases the volumes of data which the CollGS partners are able to download at any given time.

By the end of Y2021, a set of 6 Data Hub Relays were deployed by the CollGS partners. These Data Hub Relays are connected to the CollGSs operated in Greece, Austria, Norway, UK (x2) and the Czech Republic.

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The **International Hub** (IntHub) is open to international partners, following signature of a cooperation agreement with the European Commission and a technical operating arrangement with ESA. The Hub is also configured to support 10 concurrent downloads. A rolling policy of 3 weeks is applied for all data and the IntHub does not currently have access to historical data.

At the end of Y2021, there were 10 technical agreements in place with international partners.

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Figure 3 summarises the overall Sentinel Data Access System front-end configuration at the end of Y2021. The Data Hubs described are operated under the responsibility of ESA and provide access to all Copernicus Sentinel user-level data apart from Sentinel-3 Level 1 and 2 marine data. These latter data are made available through the Copernicus Online Data Access (CODA) service which is operated by EUMETSAT and not covered by this report. Further information can be found at:

https://www.eumetsat.int/website/home/Data/DataDelivery/CopernicusOnlineDataAccess/index.html

1.1.1 Deployment Physical Architecture

During Y2021, a major evolution of the architecture of the overall Data Access System was implemented, as part of its transformation to a cloud-based infrastructure. This section provides a brief overview of the physical architecture of the Data Access System as it was at the end of the reporting period. Further detail about the transition to the cloud is provided in Section 1.2.2 below.

Figure 4 shows: on the left, the Sentinel ground segments and auxiliary centres which generate the data and provide them to the Data Access System; in the middle, the 'Back End' Data Access Centres through which the system is run; and, on the right, the 'Front End' Data Access Hubs through which the data is exposed to end users. The three Data Access Centres are each responsible for ingesting a defined sub-set of data from the Sentinel ground segments, archiving and cataloguing the data and publishing it to end users on the Data Access Hubs for which they are responsible. The Data Access Centres are composed of one Core Centre and two Complementary Centres. Core and Complementary Centres share the ingestion of the user-level data as depicted by the lines in Figure 5. During Y2021, the Core Centre was transferred to the OVH Cloud infrastructure, as reported in Section 1.2.2, so at the end of the reporting period the Core Centre and one of the two Complementary Centres are run on the OVH Cloud infrastructure and operated by Serco Italia SPA and Gael respectively. The other Complementary Centre is run on the GRNET infrastructure and operated by NOA.

The full set of hubs operated by the Data Access System is shown in the diagram, along with the Centre which operates them. The Open Hub and ServHub are operated from the Core Centre and the IntHub is operated from the Complementary Centre. However, the ColHub and the DIAS Hub are operated from three nodes each, in order to enhance access to data for their users. One node for each hub is operated by each Centre.

The Figure also highlights the data flows through the System. For example, in the case of Sentinel-1 all data are ingested by the Complementary Centre at GRNET, while only NRT data are sent to the OVH Complementary Centre. Only Sentinel-2 data are retrieved and synched from the Core Centre.

The dashed lines illustrate the asynchronous data retrieval flows which were in operation in Y2021 for recalling archived user-level data from Sentinels-1, -2 and –3. This revised configuration for the retrieval of archived data has been in place since 30 September 2020 for Sentinel-2, and 30 November 2020 for Sentinel-1 and Sentinel-3.

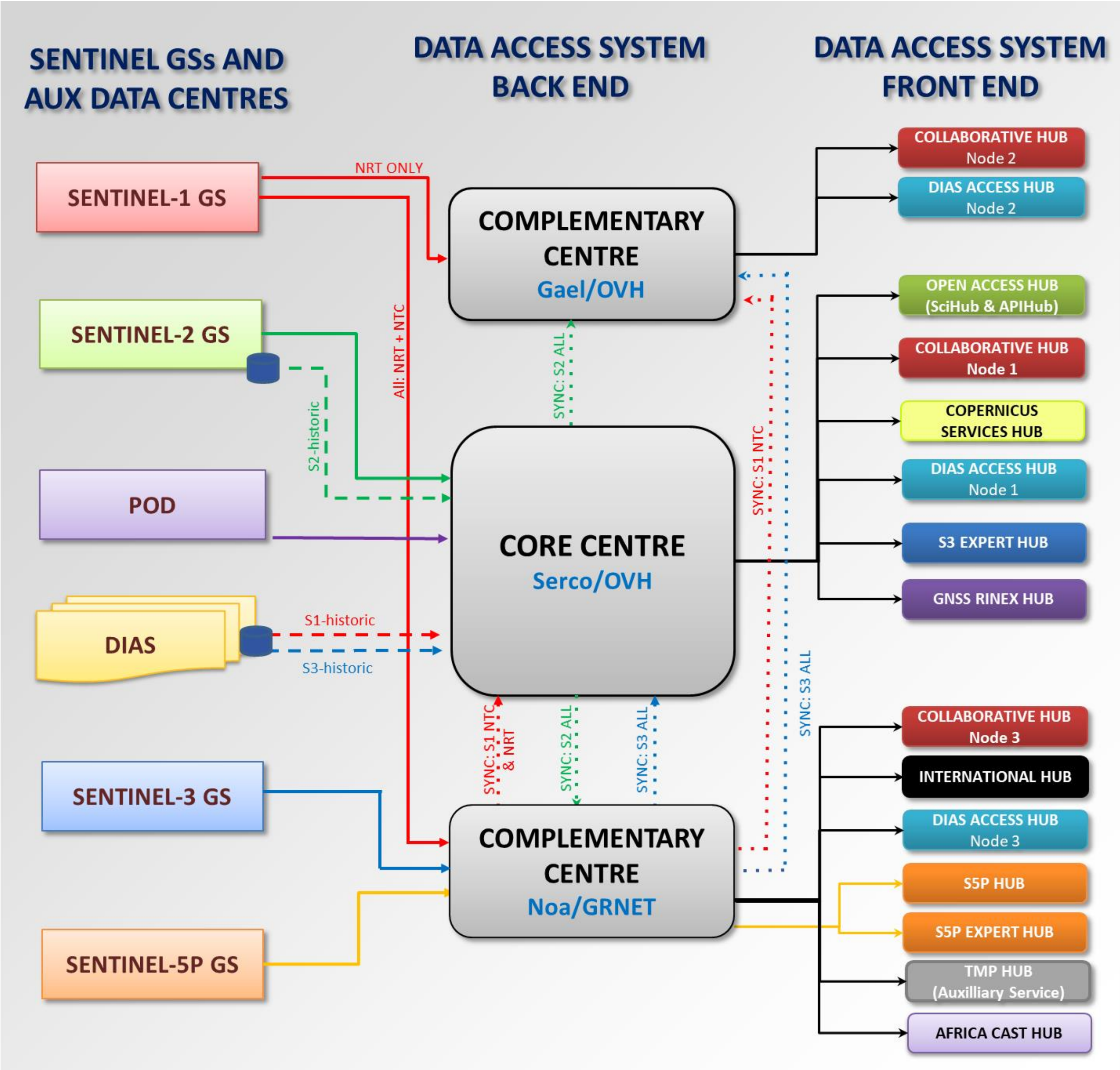


Figure 4: Data Access System Physical Architecture Overview

1.2 Main Evolutions of the Data Access System in Y2021

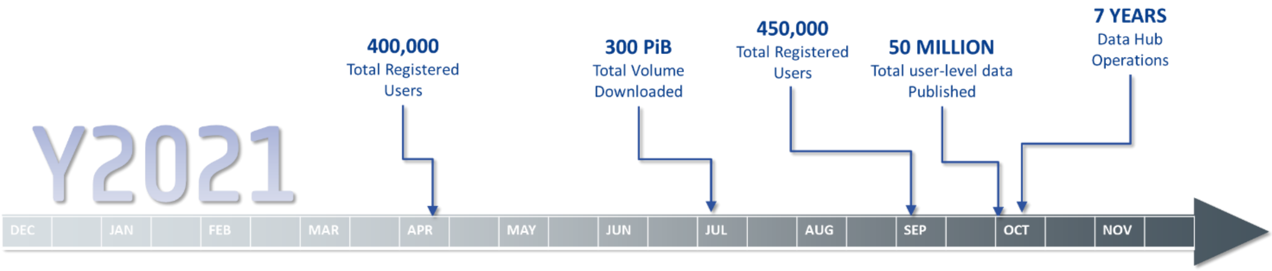


Figure 5: Timeline of the main Y2021 achievements related to data dissemination of the Data Access System

In Y2021 the major transformation of the Sentinel Data Access System was completed. This transformation took place as part of ESA's strategy to transfer the entire ground segment operations to a cloud environment, in anticipation of the enlargement of the Copernicus Sentinel missions and in response to the ever-increasing demand for Sentinel data. Deployment on public cloud infrastructures, together with a service-oriented approach will enable ESA to adapt the Copernicus Ground Segment to evolutions in the operational scenarios, in particular in terms of keeping the data offer appropriately scaled to user demand and the availability of resources.

1.2.1 Background to the ESA Ground Segment Transformation

One of the basic concepts being introduced within the transformation to the cloud-based architecture is that the data flow interfaces, for systematic data transfer between services, will be based on small data cache areas, referred to as data "interface delivery points". Each function or service which generates a systematic or routine data flow that will go on to be managed by one or more further service will make the output data available in an interface delivery point located on a cloud-based environment, which is logically considered part of, and under the responsibility of, the data source service.

Figure 6 below sets out the high-level design of the whole future Copernicus Sentinel ground segment (planned to be completed in 2022), based on this concept [taken from CSC Operations – ESA Framework – Ground Segment Architecture ESA-EOPG-EOPGC-TN-7].

The transformation will enable ESA to introduce new operations concepts in which the CSC data lifecycle will play a central role, with major implications for the user experience. A number of trade-offs will be regularly re-evaluated in light of evolving user demand, opportunities provided by the evolution of IT technology, and the potential for increased synergy with industrial offers.

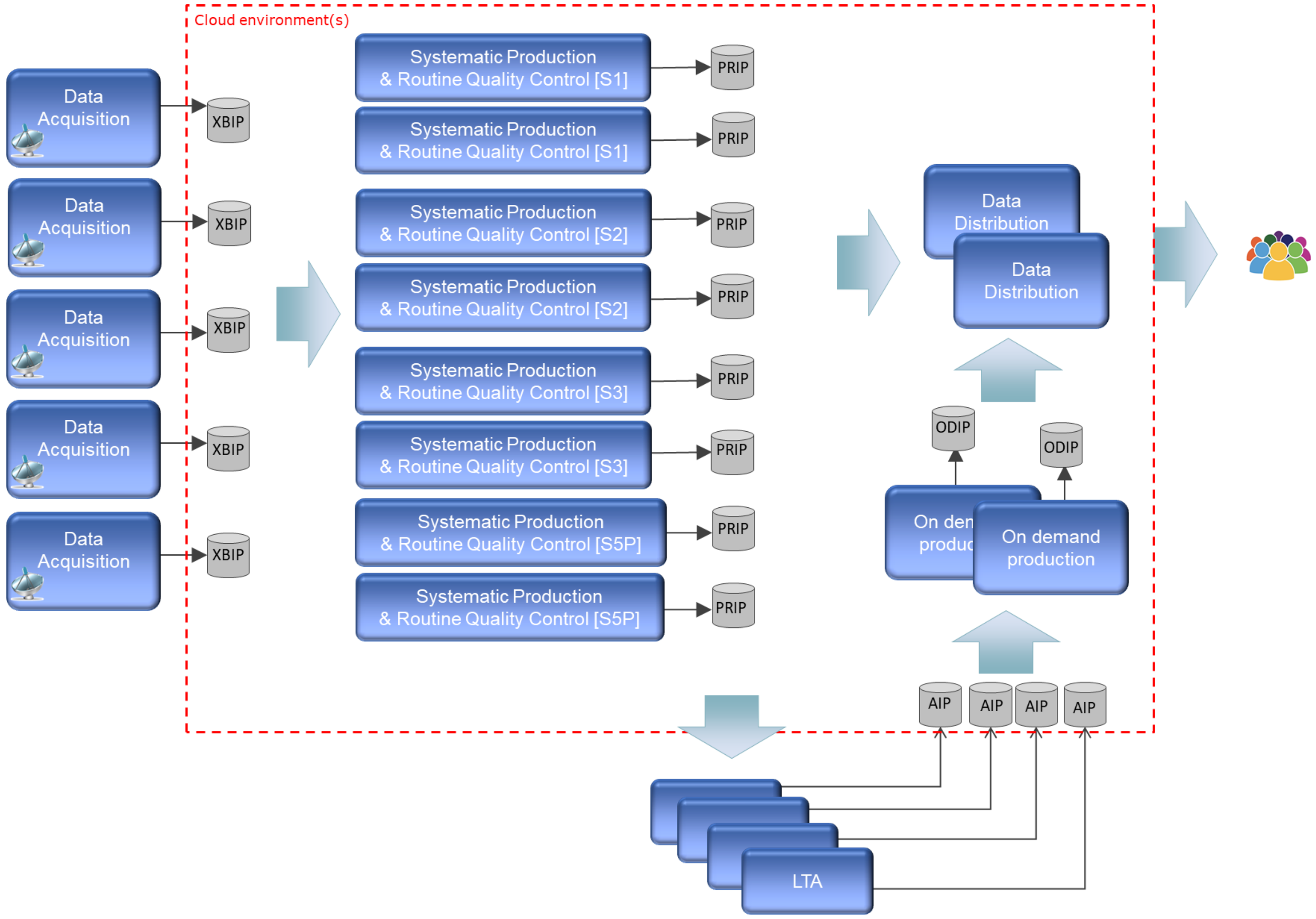


Figure 6: high level design of the future Copernicus Sentinel ground segment (planned for 2022)

The main elements in the data lifecycle, the baseline operations scenario and the key configuration options are:

- All data acquired by the Sentinels and received at the acquisition stations is converted into a raw data stream (in the form of CADU data) and systematically processed by the production services to a set of pre-defined data types, including engineering data required for e.g. calibration activities and user-level data to be made available to users.
- The lower level data (Level-0) is systematically archived for long term preservation.
- The user level data which is systematically generated is made available "immediately" (in line with the timeliness requirements for each user-level data) for on-line user data access. This data will remain available for immediate on-line download for a configurable time period (rolling period). The rolling period may be dynamically adjusted according to the observed user activity, to the geographical area, or to the type of data.
    - In some cases, the user-level data may be processed with more than one timeliness requirement, as improved auxiliary data (e.g. meteorology actuals vs. forecasts) are available. In such a case, the consolidated data generally will replace the previous versions, again according to a rolling policy.

- The consolidated version of the rolled-out data remains available for user discovery and download, ensuring access to all mission data. Different mechanisms are foreseen to ensure access to rolled-out data, and the operations configuration may be based on any combination of these mechanisms:
    - Rolled-out data may be made available from a storage point, with a different retrieval latency and same or different data access interfaces (typically as part of the LTA service operations or as part of the Data Access service operations);
    - Rolled-out data may be re-generated on-the-fly on user demand;

In addition, bulk reprocessing campaigns for a data period or a specific data type are envisaged, in order to ensure the availability of harmonised data series.

1.2.2 Specific Data Hub Evolution

In Y2021, the transition of Data Access System from the ESA-furnished network infrastructure at T-Systems to a public cloud environment, provided by OVH cloud hosting service, was completed.

The transition started in November 2020 and ended in April 2021, successfully achieving the objective to make the Data Access System completely independent from the previous infrastructure, whilst maintaining the interfaces operated by the Data Access System (APIs and GUI) without modification, and guaranteeing the same data offer currently available online. The Data Hub users were notified in advance about the transition schedule and there was no interruption of the service due to the transition activities.

The transition affected the Sentinel-1, -2 and -3 data flows, but for Sentinel-2 the transfer to the cloud in Y2021 only included the latest part of the data flow chain, and did not involve the data fetching flow from the new CSC data production interfaces, which will be completed in Q2 2022.

The main challenge of the Data Access transition was the parallel execution of application and data migration tasks while upgrading the current DHuS system solution to cope with the new CSC data production interfaces.

The figure below depicts the various phases of the transition and intermediate steps per mission.

In more details, in November 2020, with the provision of resources and datastores in the private cloud and deployment of the virtual machines in the cloud environment.

The transition was performed by a lift-and-shift process towards the new cloud environment.

The complete process involved a gradual transfer of 153 virtual machines which were running on the old T-Systems infrastructure to the OVH cloud infrastructure.

The data flows of various missions were gradually moved, in several steps, from the older infrastructure to the new infrastructure. In December 2020, the Sentinel-1 dataflow started to be activated and went through a pre-operational phase, before being declared ready for operations in February 2021. The transfer of the Sentinel-3 dataflow was carried out separately for each instrument, starting with SRAL, then OLCI, SLSTR, and finally SYNERGY.

By the end of February 2021, operational interfaces were ready and the transition of both the Sentinel-1 and Sentinel-3 dataflows was complete.

A significant delay in the transition was created by a fire incident which occurred on 10 March 2021 at OVH's premises in Strasbourg, the physical destination infrastructure where the virtualization of the services was already instantiated. Luckily from a user perspective, the full transition of the Data Access Points had not yet been completed, and the publication of Sentinel-2 and Sentinel-5P user level data was not affected.

It was possible to start publishing the fresh Sentinel-1 and Sentinel-3 data again within just two days of incident, thanks to a disaster recovery plan which was successfully put in place. The Complementary Centre hosted at GRNET (Greece) took charge of ingesting the Sentinel-1 and Sentinel-3 data and became the primary node for their data flow, from 12 March 2021. In fact, the performance demonstrated during this critical period was so successful that the revised Sentinel-1 and Sentinel-3 data flow configuration has been kept in place since that date.

From the user's point of view, the main detrimental impact of the fire was that users' requests of archived user level data were not satisfied for 5 days: the Cloud archive resided in OVH's data centre in Roubaix, which was not affected by the fire incident but the interface to it was not available. As a result of the flexibility of the cloud infrastructure, however, it was possible to reinforce the Roubaix data centre by increasing the computing resources and to build an intermediate node provided by ONDA-DIAS, and this bridging solution handled the requests for archived user-level data. By 14 March 2021, all the relevant activities to switch the fluxes and resume the full nominal operations had been finalised. This mitigation solution remained in place for a month.

The fire incident did not significantly impact the monitoring and alerting system, which was recovered by reactivating the system which had previously been deployed at T-Systems. However, the Sentinel Data Dashboard and the generation of the weekly reports were not available for 1 month.

By the end of April, also the configuration of Sentinel-2 data flow was ready for being moved to the new infrastructure, keeping the same interfaces for data fetching, and the transition to the cloud was completed and all the actions for recovering from the fire incident were concluded.

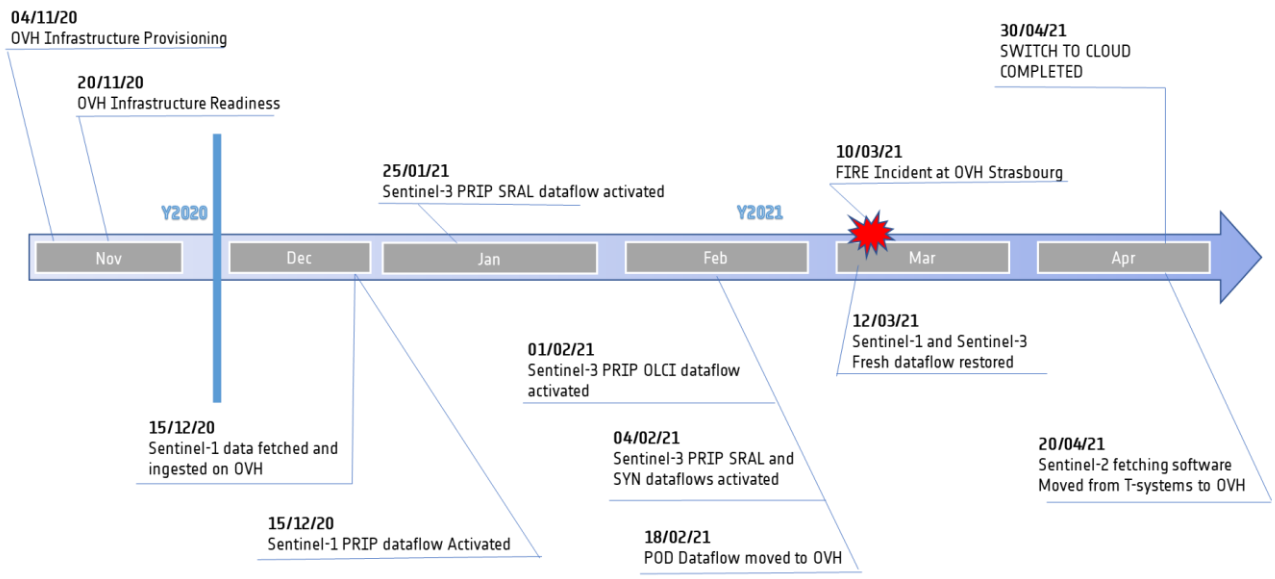


Figure 7: Timeline of the transition from T-System infrastriucture to the OVH cloud

1.3 Main Developments in the Data Offer in Y2021

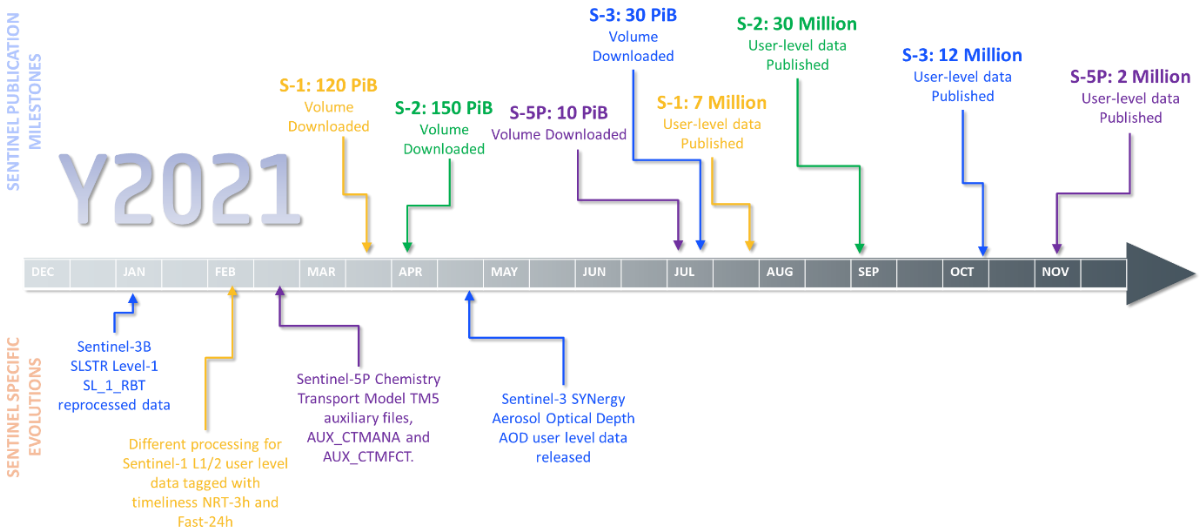


Figure 8: Timeline of the main Y2021 achievements related to Sentinel mission-specific user-level data publication and evolutions

The main mission developments that are relevant to the user-level data offer on ESA's Data Access system are outlined below.

Sentinel-1

Before 23 February 2021, a different processing was performed for Sentinel-1 L1/2 user level data tagged with timeliness NRT-3h and Fast-24h. Each NRT-3h user level data was processed independently from the whole data take, contrary to user level data tagged Fast-24h which were processed considering the complete data take (in particular, the calibration and noise information), ensuring the radiometric and geometric continuity between adjacent slices. This different processing flow resulted in a different radiometric quality between NRT-3h and Fast-24h. For this reason, NRT-3h user level data were processed subsequently in Fast24h and only the latter were made available to all users of the Open Hub.

In addition, NRT-3h user-level data were generated using the orbit information embedded in the satellite telemetry, while Fast-24h user level data were generated using Precise Orbit Determination (POD) information (POD-RESORB).

Since 23 February 2021, the same processing has been performed for Sentinel-1 Level 1 and 2 user-level data tagged NRT-3h and Fast-24h. The annotated timeliness depends on the geographical area covered by the user-level data and it is not any more an indication of a different data quality. Data is processed only once and is made available to all users of the Open Hub. Data tagged NRT-3h and Fast-24h is processed in the same way, by considering the complete data take (in particular the calibration and noise information) and ensuring the radiometric and geometric continuity between adjacent slices.

In addition, NRT-3h and Fast-24h user level data are processed using Precise Orbit Determination (POD) information, using typically POD-PREORB information for user level data tagged NRT-3h and POD-RESORB information for user level data tagged Fast-24h. POD-PREORB orbits have an accuracy typically below 10 cms RMS similar to POD-RESORB.

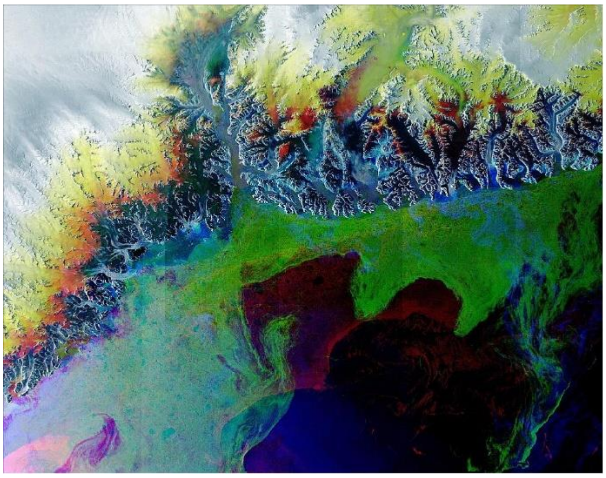


Figure 9: This Sentinel-1 radar image combines three separate acquisitions of the Kangerlussuaq Glacier, one of Greenland's largest tidewater outlet glaciers, during the summer of 2021 and shows visible changes on the ground and sea surface. The array of colours represents the seasonal retreat of ice during this time (image credit: contains modified Copernicus Sentinel data (2021), processed by ESA)

The number of Sentinel-1 user-level data published since the start of operations reached ~7,000,000, and the volume of downloads made since the start of operations reached ~120 PiB.

Sentinel-2

With over 30,000,000 user level data having been published in Y2021, and 155PiB of data downloaded since the start of operations, Sentinel-2 remained the mission with the highest volume of both published and downloaded user-level data of all the Sentinel missions in Y2021. No changes concerning its data offer during Y2021 were made.

Figure 10: This false-colour composite image , captured in August 2021, uses the near-infrared channel of Copernicus Sentinel-2 to highlight vegetation, which appears in red. Batura is bordered by several villages and pastures with herds of sheep, goats and cows where roses and juniper trees are quite common. In the upper-right of the image, pockets of cultivated vegetation alongside the Gilgit and Hunza rivers can be spotted. (contains modified Copernicus Sentinel data (2021), processed by ESA)

Sentinel-3

There were a few changes at the level of individual Sentinel-3 user-level data types during Y2021:

- Sentinel-3 SYNergy Aerosol Optical Depth AOD user level data released on April 2021 with user level data having sensing date from February 2020.
- Copernicus Sentinel-3B SLSTR Level-1 SL_1_RBT reprocessed data became available in January 2021

In Y2021, the number of Sentinel-3 user-level data which was published was about 12,000,000, while the volume of Sentinel-3 data downloaded since the start of operations was about 32 PiB.

Figure 11: This satellite image, captured on 12 January 2021 shows how much of the Spanish country faced hazardous conditions following the heaviest snowfall the country has had in five decades (contains modified Copernicus Sentinel data (2021), processed by ESA)

Sentinel-5P

New user level data types were introduced during this year: the Sentinel-5P Chemistry Transport Model TM5 auxiliary files, AUX_CTMANA and AUX_CTMFCT. The CTMANA and CTMFCT data files were available on expert hub since June 2018 and May 2019, respectively, but they started to be published on S5P dedicated hub from 26 February 2021.

The number of published Sentinel-5p user-level data considerably increased, passing from 1 million in Y2020 to 2 million in Y2021. Moreover, the volume of downloads reached 10PiB since the start of operations.

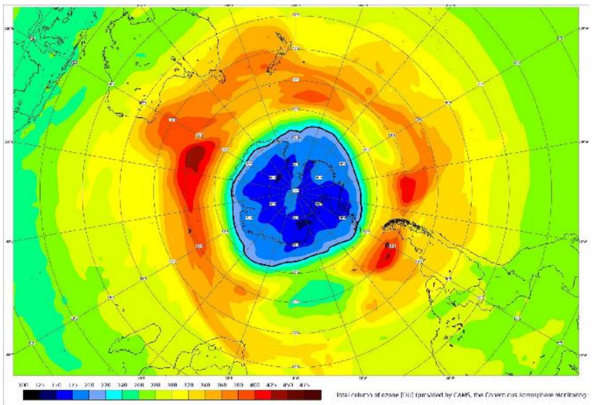


Figure *12: Map of the ozone hole over the South Pole on 16 September 2021. The 2021 ozone hole evolution appears to be similar to last year's size, currently around 23 million km2 – reaching an extent larger than Antarctica. According to CAMS, the 2021 ozone hole has considerably grown and now larger than 75% of ozone holes at that stage in the season since 1979. (contains modified Copernicus Sentinel data (2021), processed by ESA)*

Auxiliary Files

Accesses to the full set of Sentinel-1 orbit auxiliary files via the Open Hub node dedicated to Precise Orbit Determination (scihub.copernicus.eu/gnss) was put into place in March 2021, replacing previous ad-hoc access mechanisms.

2 Data Access Service Growth

During Y2021, the statistics which illustrate the level of public engagement with the Data Access System continued to increase dramatically. User registrations rose 29% to nearly 500,000 ; the number of Sentinel user-level data made available for download on the Open Hub rose 34% to 54 million user-level data; and the volume of Sentinel user-level data downloaded by users since the start of operations rose 33% to an enormous 320 PiB (not including the downloads made by the DIAS partners, which was a further 83.05 PiB). In this section, each of these increases is analysed in detail.

2.1 User take-up

By the end of Y2021, **496,382 users** were registered to access the four hub services offered by the Copernicus Sentinel Data Access System operated by ESA. Figure 13 breaks this overall figure down to show the number of users registered on each hub, and the percentage increase since the end of Y2020. These numbers represent the total number of user accounts opened on each hub since the start of their operations. It is highlighted that duplicated accounts are removed from this calculation, so the Figure provides the most accurate picture available of the number of registered users. As can be seen, in terms of percentage increase since Y2020, the greatest change took place on the Open Hub which gained 29% more registered users during the year, raising the total number of user accounts from 384,100 to 496,007. This increase of 111,907 registered users during the year is slightly higher than the number of new registrations in Y2020 (103,873) and so again this was the **highest yearly rise in user registrations yet seen since the start of operations**. It also gives some perspective to note that the number of new registrations in Y2021 is more than the total number of new users who registered on the Open Hub in the years between the opening of the Hub in October 2014 and the start of Y2018.

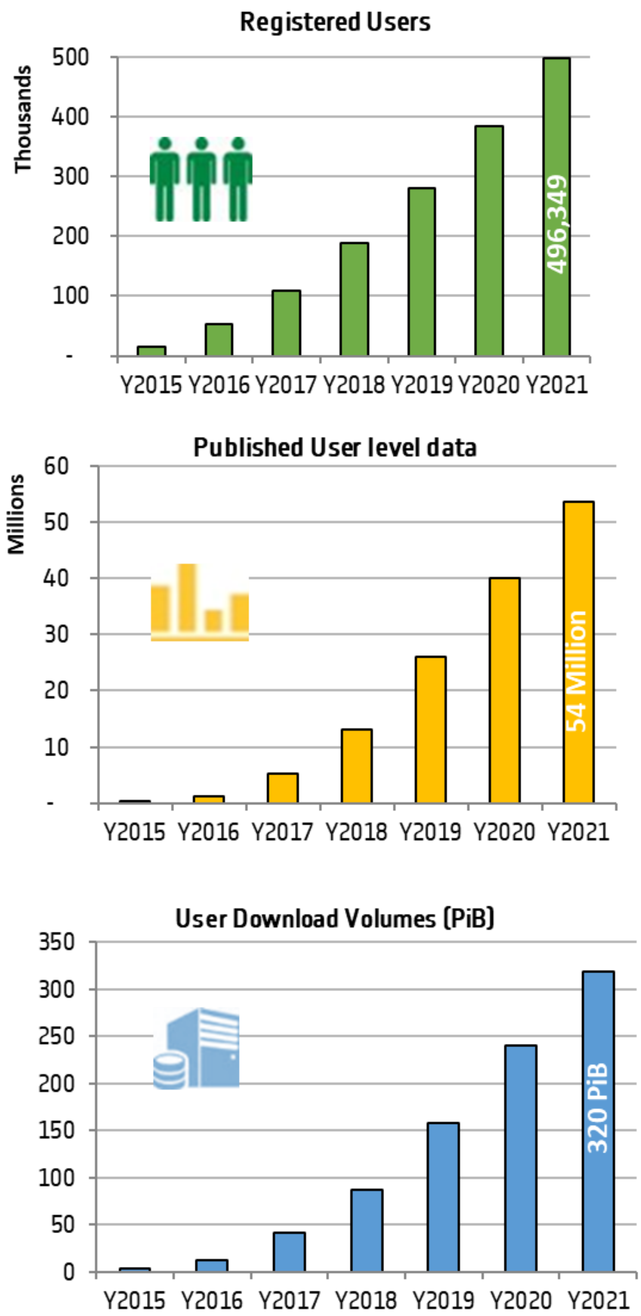


Figure 13: Overall rise in Data Hub Registered Users, Published User-level data and User Download Volumes, showing cumulative total for each year since the start of operations

It is interesting to break down this overall figure of user registrations on the Open Hub into greater detail, to examine the trends and range of users who are registering for access. This analysis only makes sense for the Open Hub because accounts on the other hubs are opened by ESA for qualifying users and not through a self-registration process.

Figure 14: Registered Users per Data Hub

2.1.1 User Registrations

The graph in Figure 15 above shows the number of users who registered each month for access to the Open Hub during Y2021, contrasted against the average number of user registrations made per month during Y2020. The cumulative number of registered users since the start of operations is also shown.

The graph shows that the number of new user registrations each month was mostly close to the monthly average for Y2020. Indeed, in Y2021 there was an average of 9,885 registrations per month, which is only 7% higher than the Y2020 average of 9,220, and 28% higher than the 7,721 Y2019 average. There were, however, five months in which the number of registrations significantly exceeded the Y2020 monthly average: in March, April, May, October and November.

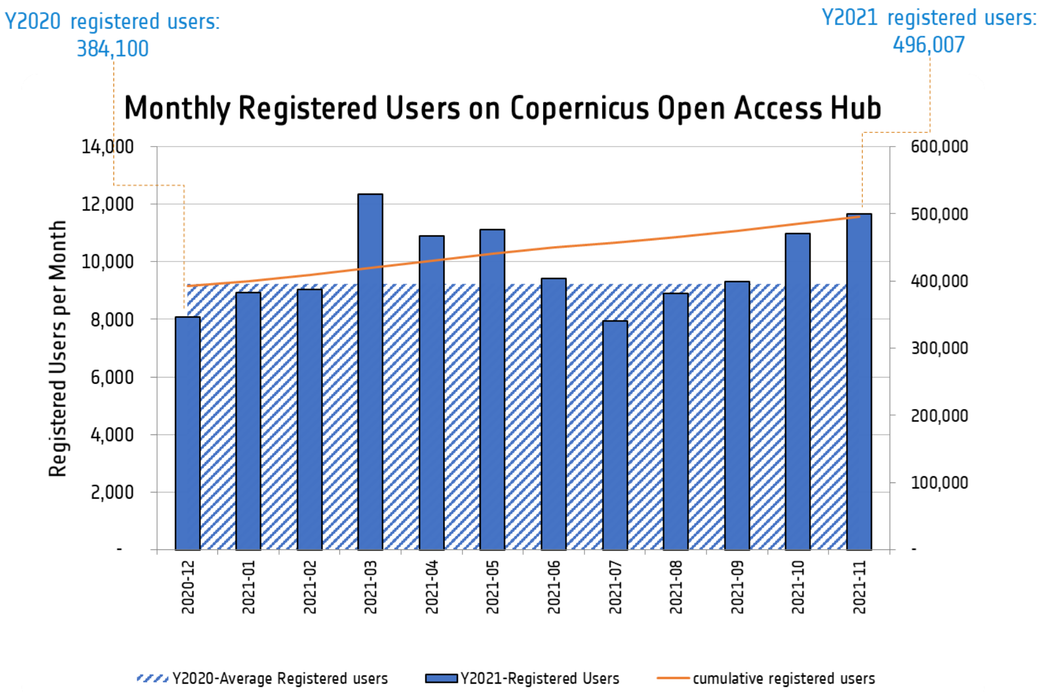


Figure 15: Trend of User Registrations on the Copernicus Open Hub

One potential trigger is international conferences at which there is a EO and Copernicus presence, such as the Sentinel-2 Validation Team Meeting (15-17 March 2021), the European Geosciences Union (EGU) General Assembly 2021 (19-30 April 2021) or the COP26 event in Glasgow (31 October – 12 November 2021). Moreover, the Earth Observation department at ESA hosts workshops and outreach events throughout the year at which Copernicus is presented, such as the EO Φ-WEEK (11-15 October 2021), which focuses on EO in the New Space economy and associated innovations, and these are also likely to generate interest in registering for access to Copernicus data. It is also worth noting that a dip in the number of registrations has been observed every year in the months typically associated with vacation periods in Europe.

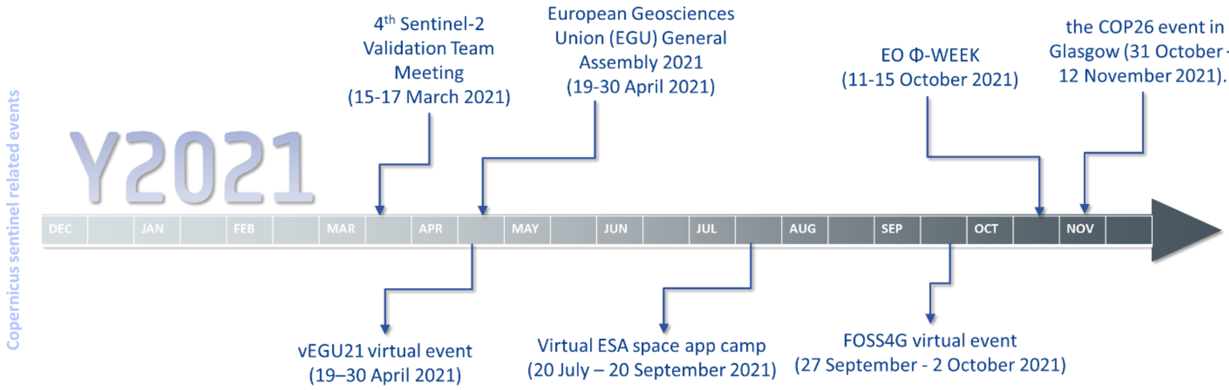


Figure 16: Highlighted Copernicus Sentinel-Related Events in Y2021

2.1.2 Open Hub Demography

In Figure 17 below, the increase in user registrations on the Open Hub during Y2020 is broken down by continent.

Europe remains the continent with by far the largest Open Hub user-community, with 177,883 registered users by the end of Y2021, up 27% from Y2020. However, the growing awareness of and interaction with the Open Hub has by no means been limited to Europe. Beyond Europe, the largest increase this year was in the new registrations made in Asia, where the total number of registrations rose by 36% to 131,538. A similar percentage increase took place in Africa, where there was 32% increase in the total number of registrations, with as many as 7,135 new users joining the Hub. In Oceania, there was a less dramatic increase in the total number of user registrations than was seen in Y2020 but it nonetheless rose by 28% in Y2021, reaching 13,300 users. In absolute terms, the highest number of new registrations in the year was again in Europe, and at 38,226 it was the highest number of new accounts opened in Europe for any year so far.

Another interesting view on the number of user registrations is the trend of countries worldwide reaching more than 500 user registrations. The graph in Figure 18 shows the monthly increase in the number of countries reaching this threshold. The number continues to grow: by the end of Y2021 there were 96 countries across the world with more than 500 registered users, a rise from the 83 at the end of Y2020.

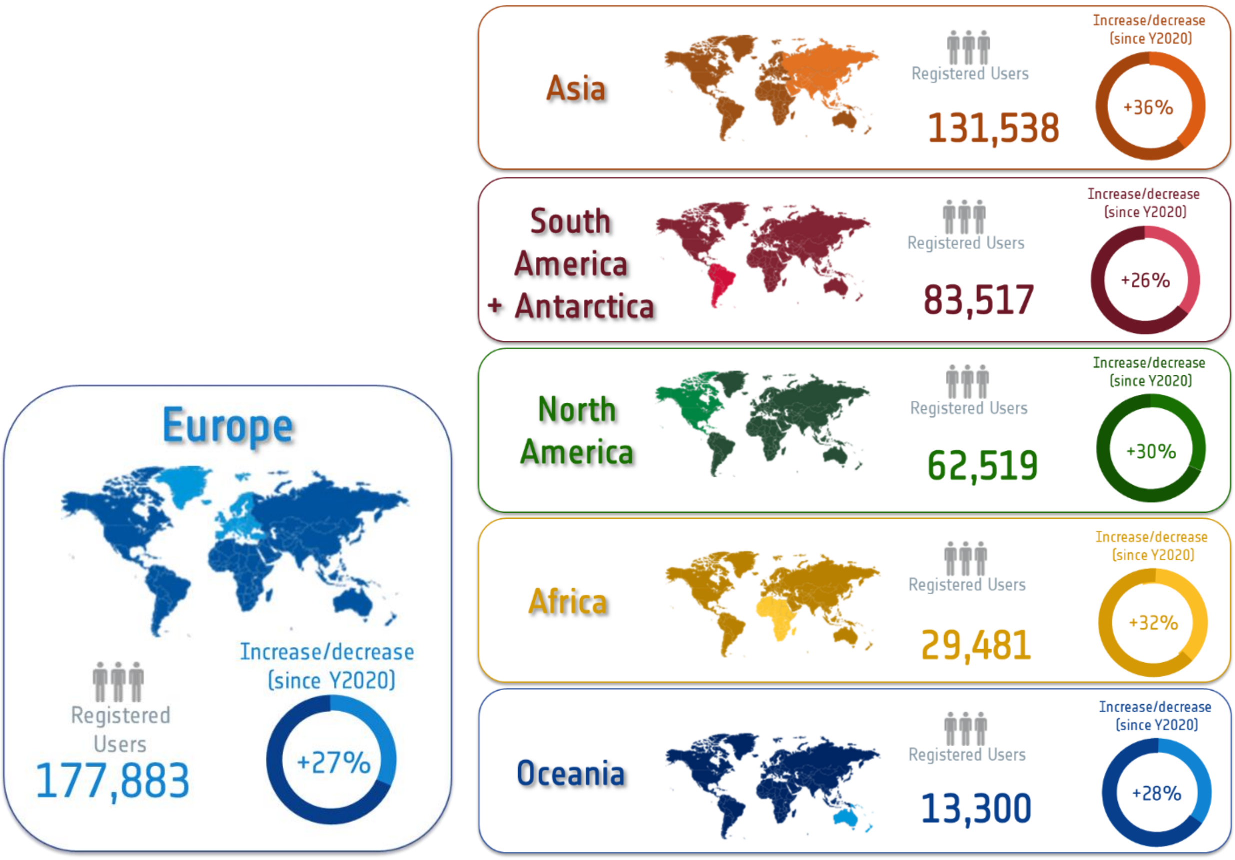


Figure 17: Open Hub registered users in Europe - on left -and number of registered users per continent since the beginning of operations and the percentage increase in the number of registrations per continent during Y2021 - on right

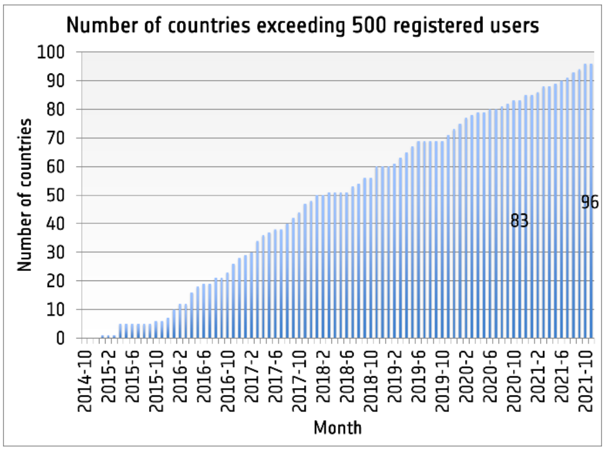


Figure 18: Growth in the number of countries exceeding 500 registered users on the Open Hub since the start of operations

Focusing specifically on Europe, there was a significant increase in registered user numbers in all of the ESA and European Union Member States. Figure 19 illustrates the figures for the 5 ESA and European Union Member States with the highest numbers of registered users, including the percentage change for each country since Y2020. The order of these countries is the same as it was in Y2020 but this year it was Spain which showed the highest percentage increase (33%) in the number of registered users, with Italy showing the second highest rise at 31%. In absolute terms, Germany remains the country with the largest number of registered users in Europe, and even there registrations increased by 23%, reaching a total of 26,302 registered users at the end of Y2021.

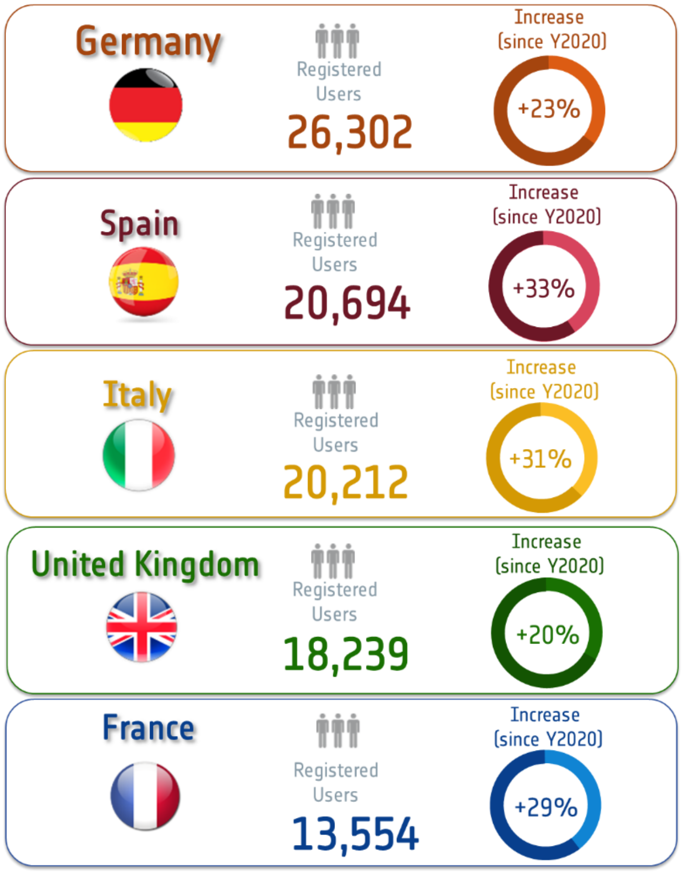


Figure 19: Distribution of Copernicus Open Hub registered user distribution in the 5 EU and ESA member states with the highest number of registered users

It is highlighted again that these statistics are generated on the basis of the nationality which users insert when they register for access to the hub, and no independent cross-checking based on the user's IP address is performed. It is also worth noting that the statistics here only account for the Open Hub and the true demography of users is likely also to be influenced by the availability of alternative national sources of Sentinel data, for example via the Collaborative GS or international mirror sites.

User activity on the Hubs is analysed in Section 3

2.2 Published Data

By the end of Y2021, almost all user-level data were being published routinely on each of the data hubs. The exceptions were the Sentinel-5P user-level data which were still being disseminated on the dedicated Sentinel-5P Hub, maximizing the retention period for the other Sentinel user-level data whilst providing an increased download capacity for the new Sentinel-5P atmospheric user-level data. The user-level data types available on each of the hubs during Y2021 were the following:

- After 23 January 2022, all ***Sentinel-1A/-1B*** user-level data were routinely published on all of the data access hubs. Before 23 January , the NRT user-level data were only available on the ColHub and ServHub, with only the NTC version on the Open Hub. After a change in the processing scenario on 23 January 2022, however, the same user-level datahave been made available on each hub. (See section 1.1.2 for more details)
- ***Sentinel-2A/-2B*** Level-1C and Level-2A user-level data were routinely published on all the data access hubs.
- ***Sentinel-3A/-3B*** OLCI, SLSTR, SRAL and SYNERGY user-level data were routinely disseminated on all hubs.
- ***Sentinel-5P*** user-level data were disseminated on the dedicated Sentinel-5P Hub.

This section presents the statistics for the publication of the user-level data on the Open Hub during Y2021. For the purpose of these publication statistics, the dedicated Sentinel-5P Hub is deemed to constitute part of the Open Hub.

2.2.1 Publication Growth

By the end of Y2021, **a total of 53,616,227 Copernicus Sentinel user-level data had been published on the Open Hub since the start of operations, with a total data volume of 32.21 PiB**. In Y2021 itself, a total of 13,514,222 user-level data were published, accounting for a total data volume of 7.34 PiB. To put this into context, by way of historical comparison the 7.34 PiB published during Y2021 alone is more even than ESA's entire collection of EO data from the pre-Copernicus era, which amounted to 5.6 PB by the end of 2013.

The chart in Figure 20 below compares the volume of user-level data published in Y2021 with the volumes published in the preceding years.

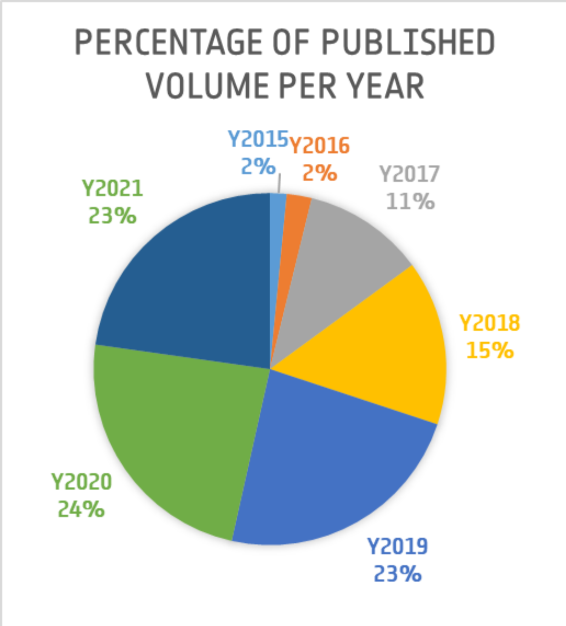


Figure 20: Percentage of the published volume of data per year since the start of operations (Y2015-Y2021)

The volume of Sentinel user-level data published on the Open Hub during Y2021 makes up 23% of all the user-level data published on the Open Hub since the start of operations, with a total volume roughly matching the level of user-level data published in Y2020 and Y2019 (this is slightly down compared with Y2020 but it is mostly due to less reprocessing made in Y2021).

Mission	No. of user-level data published in Y2021	No. of user-level data published since start of Ops	Y2021 No. as % of total published per mission since start of Ops	Volume of user-level data published in Y2021 (PiB)	Volume of user-level data published since start of Ops (PiB)	Y2021 volume as % of total published per mission since start of Ops
S1	1,439,646	7,451,432	19%	2.18	11.65	19%
S2	8,147,340	31,798,019	26%	4.18	16.20	26%
S3	3,302,695	12,350,106	27%	0.82	3.85	21%
S5P	624,541	2,016,670	31%	0.15	0.50	31%
ALL	**13,514,222**	**53,616,227**	**25%**	**7.34**	**32.21**	**23%**

Table 1: Overall number and volume of published user-level data on the Open Hub both in Y2021 and since the start of operations, per Sentinel mission

Table 1 above breaks these totals down by Sentinel, showing the number and volume of user-level data published in Y2021 as compared to the total since the start of operations in 2014. As reported in Table 1, in terms of the number of published user-level data, Sentinel-2 data continues to dominate: the mission accounts for 57% of the volume of user-level data published in Y2021 and 50% of all user-level data published since the start of operations. It should be noted that the relative differences between the number of user-level data and the volumes of user-level data published for each Sentinel depends on the definition of the user-level data types and their standard packaging. For example, the Sentinel-2 user-level data are packaged according to a standardised tiling scheme, with one user-level data per tile: so even though the number of Sentinel-2 user-level data published is over 6 times that of Sentinel-1, in terms of total volume of user-level data published in the year, the figure for Sentinel-2 (4.18 PiB) is only about 2 times that for Sentinel-1 (2.18 PiB). Moreover, the number of Sentinel-3 user-level data published in Y2021 is two times the number of Sentinel-1 data and, for the third consecutive year, the total number of Sentinel-3 user-level data published since the start of operations surpassed that of Sentinel-1. On the other hand, the volume of Sentinel-3 user-level data published in Y2021 was a third the volume of Sentinel-1 data published in Y2021, and the total published volume of Sentinel-3 user-level data since the start of operations amounted to a third of the total volume of Sentinel-1 data published since the start of operations.

As noted above, the overall publication flow was very similar to that of Y2020 and Y2019, although slightly less data were published, by number and volume (94% of Y2020 in both cases), during Y2021 than in Y2020. This slight dip in the totals happened because fewer Sentinel-3 reprocessing campaigns were carried out in Y2021 than were carried out in Y2020 (see Table 4 below). This point can be seen more clearly when looking at the average daily publication figures for November 2021, which are compared with the figures from November 2020 in Tables 2 and 3 below. Broken down like this, the average daily volume of data being published by the Data Access System in November 2021 was slightly higher than the average daily volume being published in November 2020 for Sentinel-1, 2 and 5P and it was only lower for Sentinel-3, again due to the Y2020 re-processing campaigns.

At the end of Y2021, the majority of NTC user-level data volume being published was still accounted for by Sentinel-1 and -2, and together they constituted the same proportion of the total average daily volume as they had in Y2019, with 86% of daily total, higher than the 78% seen in Y2020. Once more, this change appears largely accounted for by the fact that the Y2020 value for the Sentinel-3 user-level data were including the additional publication campaign of batch of re-processed SLSTR data from Sentinel-3B that was ongoing in November 2020. There was no change for Sentinel-5P user-level data, which still accounted for just 2% of the total average daily volume.

Mission	Daily Average Vol (TiB) published in November 2021	Nov 2021 Volume as % of overall daily average	Daily Average Vol (TiB) published in November 2020	Nov 2020 Volume as % of overall daily average
S1	6.51	35%	6.23	31%
S2	9.67	51%	9.56	47%
S3	2.19	12%	4.03	20%
S5P	0.42	2%	0.40	2%
All	18.79		20.22	

Table 2: Average volume of user-level data published per day in the last month of Y2021 and Y2020, with percentage splits per Sentinel mission

Mission	Daily Average Number of user-level data Published in November 2021	Y2021 no. as % of overall daily average	Daily Average Number of user-level data Published in November 2020	Y2020 no. as % of overall daily average
S1	4,280	13%	3,802	10%
S2	18,168	55%	17,869	48%
S3	8,787	27%	13,678	37%
S5P	1,763	5%	1,700	5%
All	32,998		37,049	

Table 3: Daily average number of user-level data published per mission during the last month of Y2021 and Y2020, with percentage splits per Sentinel mission

In terms of the average number of data being published per day, there was an overall decrease of -11% in daily published user level data but it can be seen that there was an increase in the average number of Sentinel-1 (+13%) and Sentinel-2 (+2%) user-level data published per day and the decrease is due to the -36% decrease in the number Sentinel-3 data published per day which is due to the bad choice of the month for the comparison; in fact, in November 2020, there was a reprocessing campaign held for SLSTR instrument (in case we take another month for comparing the daily publication flow – e.g. September 2020 with the 8,706 daily published user level data - such decay will not be visible).

2.2.2 Publication trends

The graphs below show, per Sentinel mission, both the number and volume of user-level data which were published per month on the Open Hub and the S5P Hub during the Y2021 reporting period. The values represent the sum total of all individual user-level data types published per mission, and for both –A and –B satellites where applicable. The values are also compared with the same months from Y2020, to highlight any changes which have occurred between the years.

Sentinel-1

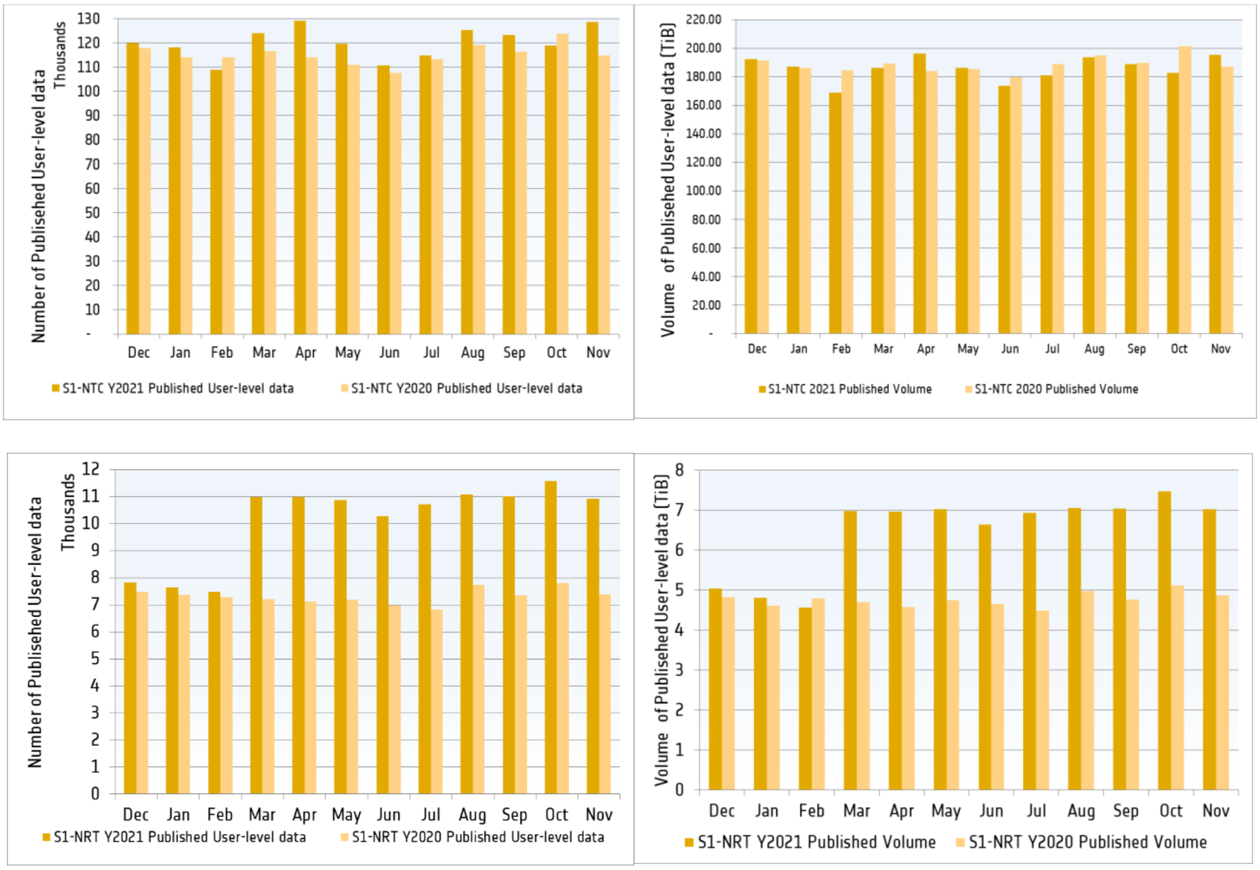


Figure 21: Y2021 and Y2020 monthly number and volume publication trend for Sentinel-1 Non time Critical (up) Near Real Time Production (down)

During Y2020, numbers and volumes of Sentinel-1 NTC published user-level data remained relatively stable, in line with a mission which remains at full operational capacity. The monthly average number of user-level data published in Y2021, 119,971, was only 4.3% up on the Y2020 value, while the monthly average volume of user-level data published in Y2021, 186 TiB, was only 1.3% lower than that of Y2020. Overall, however, the monthly averages are always higher in Y2021 than in Y2020, with the exception of some notable dips in publication in February and October 2021.

The Y2021 monthly averages for the Sentinel-1 NRT user-level data shows in Figure 21, however, clearly show the change in processing strategy carried out during the year for Sentinel-1 user-level data: as mentioned in Section 1.3 above, since 23 February 2021, the same processing has been performed for Sentinel-1 Level 1 and /2 user- level data tagged NRT-3h and Fast-24h. The annotated timeliness depends on the geographical area covered by the user- level data and it is not any more an indication of a different user level data quality. Data tagged NRT-3h and Fast-24h is now processed only once and is made available to all users of the Open Hub.This brings a 50% increase of the monthly average of NRT user level data publication, rising from an average of 7,308 in Y2020 to an average of 10,934 from March 2021 onwards.

Sentinel-2

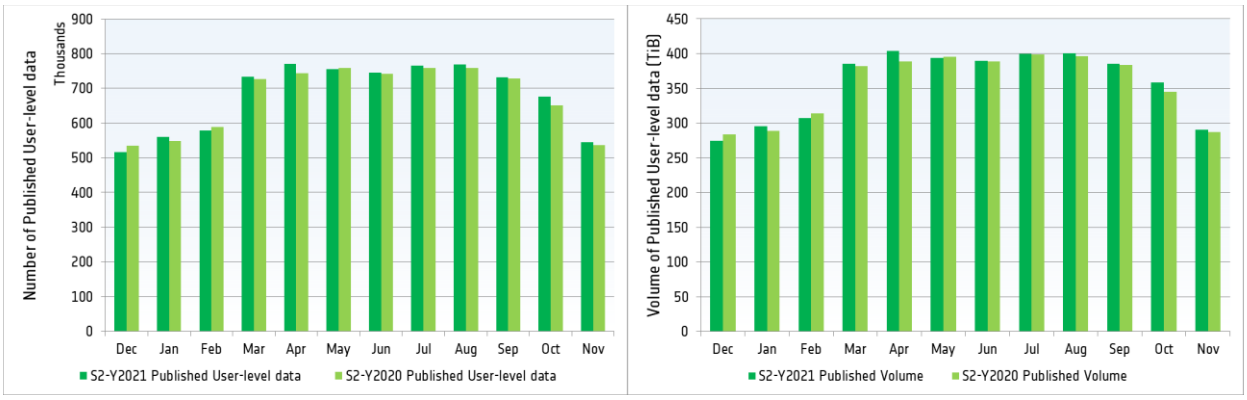


Figure 22: Y2021 and Y2020 number and volume publication trend for Sentinel-2

For Sentinel-2, the average number and volume of user-level data published per month during Y2021 were almost identical to the equivalent figures for Y2020: an average of 678,945 user-level data was published per month in Y2021 compared with an average of 672,670/month in Y2020; and an average volume of 356.98 TiB was published per month in Y2020 compared with an average of 354.25 TiB/month in Y2020.

As seen in Y2020, the Y2021 average monthly publication figures create a predictable seasonal curve. More Sentinel-2 user-level data are generated in the summer months, when there are more daylight hours in the Northern Hemisphere – which has the larger land mass and is therefore where the majority of Sentinel-2 imaging takes place - and fewer in the winter months.

The most notable deviations in the monthly averages occur in April and October, with respectively 16 TiB and 13 TiB more data published in these months in Y2021 than in the same months in Y2020. These minor fluctuations were due to the routine updating of Copernicus Sentinel-2 Level-1C and Level-2A Processing Baselines.

Sentinel-3

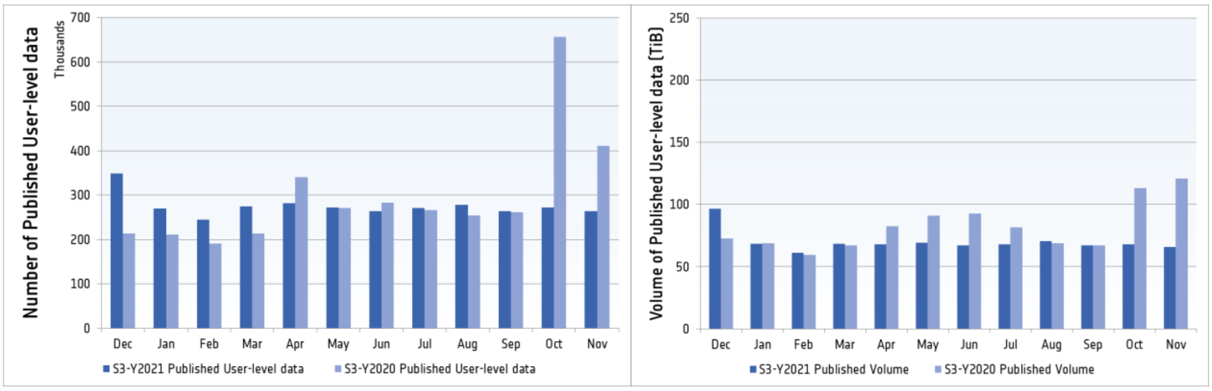


Figure 23: Y2021 and Y2020 monthly number and volume publication trend for Sentinel-3

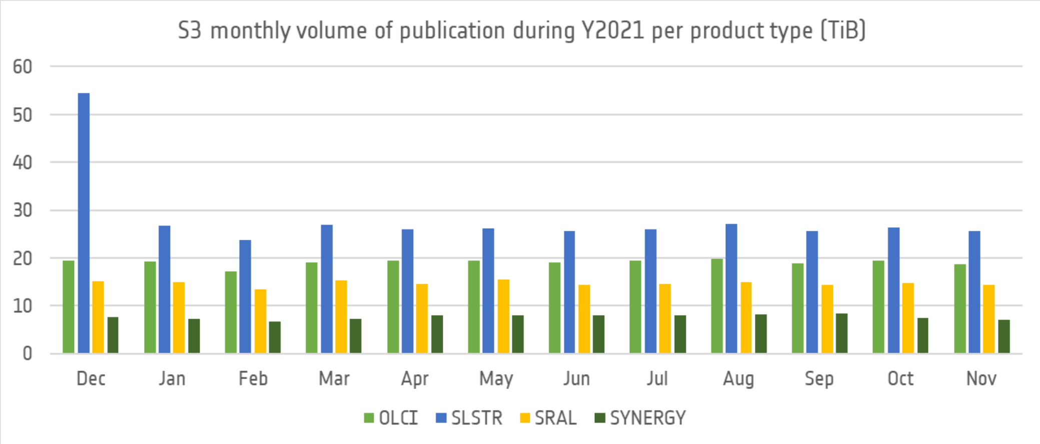


Figure 24: Y2020 monthly volume publication trend per Sentinel-3 user-level data group

The publication of Sentinel-3 user-level data was also relatively even during Y2021, although December 2020 is a notable exception and was the month with bar far the highest publication rate. A total of 349,074 user-level data were published in the month, which is a massive 27% higher than the 275,225 average number of user-level data which published per month in 2021.

The cause of the sharp increase in publication in December 2020 is illustrated in Figure 24, which shows the Sentinel-3 monthly publication volumes for each of the four user-level data groups (OLCI, SLSTR, SRAL and SYNERGY). It can be seen that in December 2020, there was a huge increase in the volume of SLSTR data published that month (+31 TiB), and this was the result of the continuing reprocessing campaign for the Sentinel-3B SLSTR user-level data, which was already noted in last year's Annual Report as affecting the publication figures for October and November 2020. . The reprocessed data published in Y2021 covered the Level-1 SLSTR user-level data for the reference period 9 May 2018 – 16 February 2020.

Table 4 presents the number of reprocessed data for SLSTR Level-1 in Y2021 and, supported by Figure 24, we see that the spike of publication of SLSTR in December 2020 is due to the 119,067 reprocessed user-level data that were published in addition to the nominal data flow and that constitute the 64% of all SLSTR Level 1 data published in Y2021. No reprocessed OLCI, SRAL or SYNERGY user-level data were published during the year.

Starting from April 2021, a new user-level data type has been released (SYNergy Aerosol Optical Depth AOD), and this led to an average increase of 9% on the monthly volume of SYNERGY user level data publication.

In summary, if all months in Y2020 are included in the calculation, the average publication rate for Sentinel-3 user-level data was 275,225 data/month and the average volume was 70 TiB/month. If the outlier month is excluded, the average publication rates become 268,511 data/month and 67 TiB/month, up 12% and down 9% respectively from the Y2020 averages.

Instrument	Product level	Y2021 Total No. of Published User-level data	Y2021 Total No. of Reprocessed Published User-level data	% Reprocessed User-level data
SLSTR	Level 1	119,067	76,207	64

Table 4: Y2021 total numbers of SLSTR reprocessed user-level data, and percentage of total number of Level-1 SLSTR data published during Y2021

Sentinel-5P

The dedicated Sentinel-5P Hub began routine operations on 11 July 2018, and was still being used to publish user-level data from the mission at the end of Y2021. During Y2021 an average of 52,045 data/month were published on the Sentinel-5P dedicated Hub, corresponding to an average volume of 13.2 TiB/month.

Figure 25 shows very consistent publication rates for each month except December 2020 and February 2021 in which the volumes of published user level data exceeded the average monthly publication rate measured excluding such peaks by 13% and 42% respectively. The larger peak seen in February 2021 was the result of the temporary publication of a set of Level-2 NRT data with improved algorithms in parallel with the nominal flow.

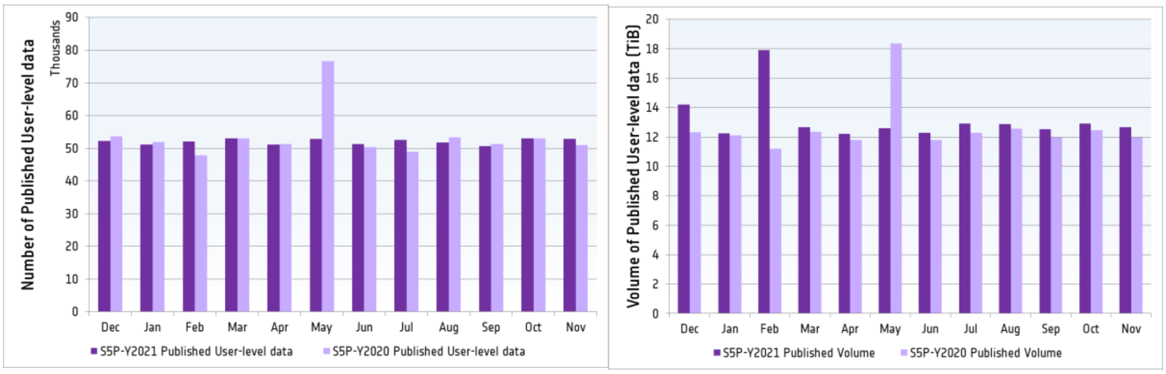


Figure 25: Y2021 monthly volume and number publication trend for Sentinel-5P

2.2.3 Publication Details

In this section, the overall publication figures are broken down by user-level data type and geographical coverage.

Publication per User-level data Type

Figures 26 and 27 show, for Sentinels 1, 2 and 3, the total percentage published for each user-level data type, both in terms of the number and volume of user-level data, during Y2021. For Sentinel-3, for the purposes of readability, the 17 individual user-level data types have again been collected into four user-level data groups: SRAL, SLSTR, OLCI and SYNERGY; similarly for Sentinel 5P, the 26 individual user-level data types have been grouped in either Level-1B or Level-2.

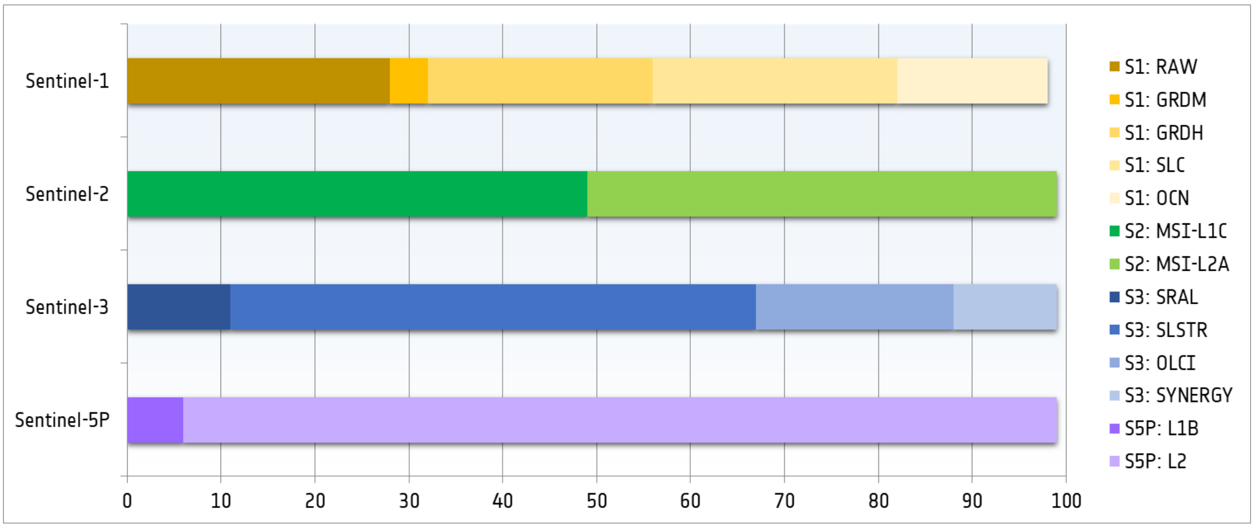


Figure 26: Percentage published number of user-level data per Sentinel mission and user-level data type during Y2021

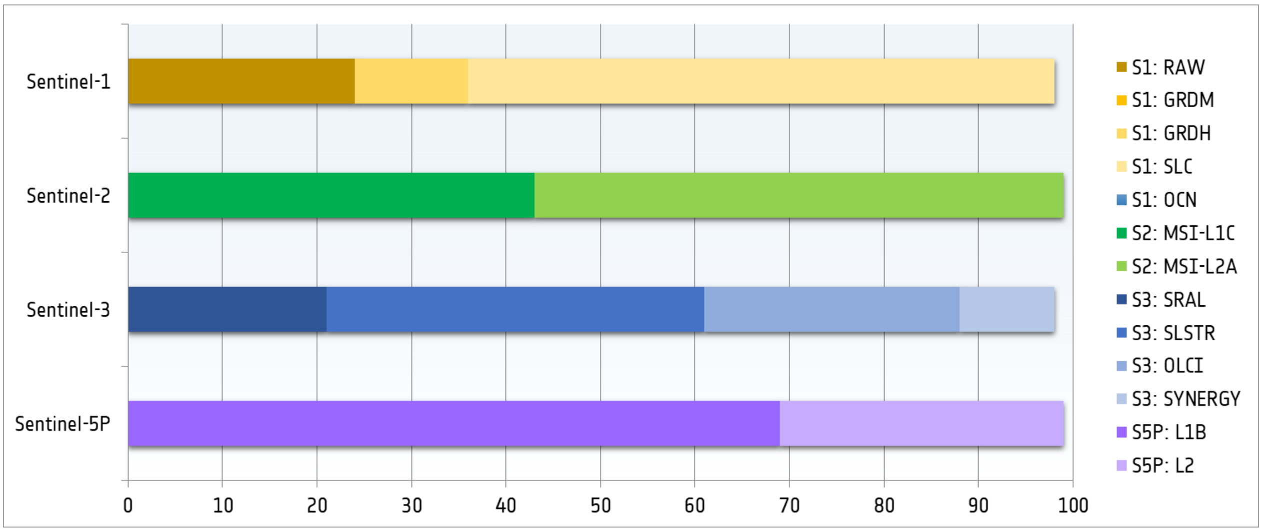


Figure 27: Percentage published volume of user-level data per Sentinel mission and user-level data type during Y2021

For **Sentinel-1** the following user-level data types were available during Y2019:

- Level 0 (L0-RAW)
- Level 1 Ground Range, Multi-Look, Detected: Medium Resolution (L1-GRDM)
- Level 1 Ground Range, Multi-Look, Detected: High Resolution (L1-GRDH)
- Level 1 Single-Look Complex (L1-SLC)
- Level 2 Ocean (L2-OCN)

Looking at the numbers published for each level individually, Level 0 accounts for 16% of user-level data, Level 1 for 54% and Level 2 for 16%. In terms of volumes, the totals are: 24% for Level 0, 74% for Level 1 and 0.1% for Level 2. These differences are accounted for by the relatively large size of Level 1 SLC user-level data and the relatively small size of Level 2 OCN user-level data. These percentages for number and volume are almost stable since Y2018.

For **Sentinel-2** the published user-level data types are:

- Level 1C (MSIL1C)
- Level 2A (MSIL2A)

Sentinel-2 published user-level data by number consisted of 50% Level-1C and 50% Level-2A. By volume, the split was: 43% Level-1C and 57% Level-2A. \ The split in the number of user-level data published is now absolutely equal, but the Level-2A user-level data now account for a higher percentage of the overall Sentinel-2 publication volume due to the larger size of individual user-level data.

For **Sentinel-3** the following user-level data types are published, divided per sub-mission and related instrument on board the satellite:

Synthetic Aperture Radar Altimeter (SRAL):

- Level 1 SR_1_SRA___ Echos parameters for LRM, PLRM and SAR mode (resolution 20Hz)
- Level 1 SR_1_SRA_A_ Echos parameters for PLRM and SAR mode (resolution 80Hz)
- Level 1 SR_1_SRA_BS Echos parameters for LRM, PLRM Level 1
- Level 2 SR_2_LAN___ 1-Hz and 20-Hz Ku and C bands parameters (LRM/SAR/PLRM), waveforms. Over Land Level 2

Ocean and Land Colour Instrument (OLCI):

- Level 1 OL_1_EFR___ Full Resolution top of atmosphere radiance
- Level 1 OL_1_ERR___ Reduced Resolution top of atmosphere radiance
- Level 2 OL_2_LFR___ Full Resolution Land & Atmosphere geophysical user-level data
- Level 2 OL_2_LRR___ Reduced Resolution Land & Atmosphere geophysical user-level data

Sea and Land Surface Temperature Radiometer (SLSTR):

- Level 1 SL_1_RBT___ Brightness temperatures and radiances
- Level 2 SL_2_LST___ Land Surface Temperature geophysical parameters Level 2
- Level-2 FRP with Fire Radiative Power (**new** since August 2020).

SYNERGY (synergy of OLCI OL_1_EFR and SLSTR SL_1_RBT user-level data):

- Level 1 SY_1_MISR__ Correspondence and collocation grids between OLCI/SLSTR acquisition and image grid and SYN Level 2 internal grid (i.e. OLCI instrument grid) – NOT available to users
- Level 2 SY_2_AOD___ Global Aerosol parameter over land and sea on super pixel resolution (4.5 km x 4.5 km)
- Level 2 SY_2_SYN___ Surface Reflectance and Aerosol parameters over Land
- Level 2 SY_2_VGP___ 1 km VEGETATION-Like user-level data (~VGT-P) - TOA Reflectance
- Level 2 SY_2_VG1___ 1 km VEGETATION-Like user-level data (~VGT-S1) 1 day synthesis surface reflectance and NDVI
- Level 2 SY_2_V10___ 1 km VEGETATION-Like user-level data (~VGT-S10) 10 day synthesis surface reflectance and NDVI

By number, SLSTR user-level data account for the majority of overall publication: 56%. Next are OLCI with 21%, SRAL and SYNERGY with 11%. The split by volume is quite similar.

For **Sentinel-5P** the published user-level data types are:

TROPOMI Level-1B radiance/irradiance user-level data:

- L1B_RA_BDx (x=1-8): Radiance user-level data bands 1-8 (UV (1,2), UVIS (3,4), NIR (5,6), SWIR (7,8))
- IR_UVN: Irradiance user-level data UVN module
- IR_SIR: Irradiance user-level data SWIR module

TROPOMI Level-2 geophysical user-level data:

- L2__O3___: Ozone total column
- L2__O3_TCL: Ozone tropospheric column
- L2__O3_PR: Ozone profile
- L2__O3_TPR: Ozone tropospheric profile
- L2__NO2__: Nitrogen dioxide, total and tropospheric columns
- L2__SO2__: Sulphur dioxide total column
- L2__CO___: Carbon monoxide total column
- L2__CH4___: Methane total column
- L2__HCHO__: Formaldehyde total column
- L2__CLOUD_: Cloud fraction, albedo, top pressure
- L2__AER_AI: UV aerosol index
- L2__AER_LH: Aerosol layer height (mid-level) pressure
- L2__NP_BDx (x=3,6,7): Suomi-NPP VIIRS clouds
- *AUX_CTMANA and AUX_CTMFCT: A-priori profile shapes for the NO2, HCHO and SO2 vertical column retrievals*

Split by data level and by number, Level-2 accounted for 93% while Level-1B accounted for 7%; by volume the split was 69% Level-1B and 31% Level-2. This is accounted for by the fact that Sentinel-5P Level-1B user-level data are much larger than Level-2 (see Annex 2).

More details on the user-level data types per mission and per instrument are available in Annex 2.

Publication per Geographical coverage

The geographical areas over which the Sentinels gather data are determined by the observation scenarios for each mission, which are available online via the following links:

For Sentinel-1:
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario

For Sentinel-2:
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/observation-scenario

For Sentinel-3:
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-3/observation-scenario

These scenarios are in turn governed by the overarching Sentinel High Level Operations Plan (HLOP), which is a document agreed between ESA and the European Commission and also available online from the Copernicus Sentinel Online Document Library at:

https://sentinels.copernicus.eu/documents/247904/685154/Sentinel_High_Level_Operations_Plan

For Sentinel-5P, there is no separate observation scenario as the operations do not in general vary from the baseline scenario set out in the HLOP.

Sentinel-1

Figure 28 displays a heatmap showing the geographical coverage of all Sentinel-1 user-level data published from the start of operations until the end of Y20120. The colour scale illustrates the differing numbers of user-level data published for each area around the globe; red zones are the areas over which the greatest numbers of Sentinel-1 user-level data have been published, as indicated by the key. All user-level data types except WV mode user-level data are included in the count; WV mode user-level data, which are available over oceans and coastal zones, are not included in the calculation due to the different footprint used in those user-level data.

The heatmap shows that Sentinel-1 user-level data cover all continents and major island groups, with the highest density of coverage over Europe, and far northern and southern sea ice regions.

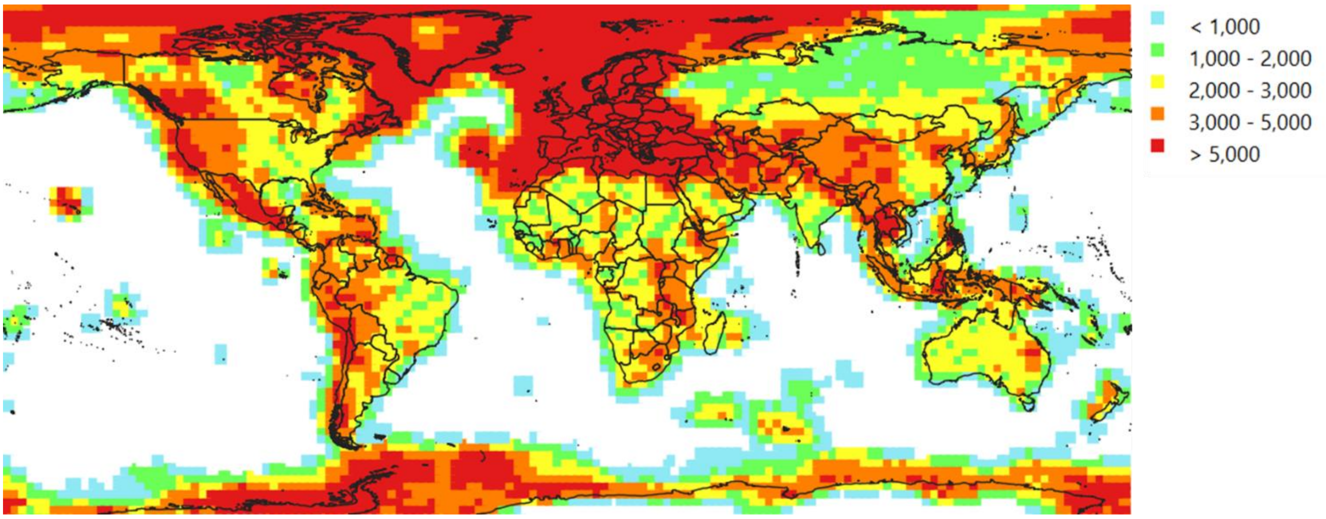


Figure 28: Heatmap of Sentinel-1 user-level data (excluding OCN) published from the start of operations to the end of Y2021

In line with the observation scenario, the greatest density of user-level data is seen over Europe, the arctic regions and, to a lesser extent, Antarctica. A full coverage of European land (EEA-39 countries) and surrounding seas (Exclusive Economic Zones - EEZ) is performed at each constellation repeat cycle (6 days) to support many Copernicus and national activities. A full coverage is ensured every constellation repeat cycle both in ascending and descending passes, thus providing a very good revisiting frequency. Sentinel-1 is also used to complement the observations over Europe and support in particular some activities of the Copernicus services outside Europe, some national services / use on national territories outside Europe (e.g. Canada or French and UK overseas territories / departments) and some national services / use outside national territories (e.g. Antarctica), as well as to support international cooperation. Moreover, additional observations are performed to support key activities which are only possible with SAR data (e.g. InSAR related applications for geo-hazard and tectonic areas monitoring).

The geographical coverage analysis can be extended by looking at the coverage of individual Level-1 user-level data types. The heatmaps for GRDM, GRDH and SLC user-level data are shown in Figures 29, 30 and 31 respectively. The Wave mode, continuously operated by default over open oceans, is not shown in a map. In all cases they take as input the locations of all user-level data published from the start of operations up to the end of Y2021. For ease of comparison, the keys and ranges are the same in each case. In general, the extent of data coverage may be summarized as follows:

- *GRDM* – mostly covering sea ice and marine areas, with a strong emphasis on the maritime regions of the far north. Other zones of high publication include the mid-Atlantic and the Indian Ocean around Madagascar. The GRDM user-level data are related to the EW mode (Extra Wide Swath).
- *GRDH & SLC* – mostly available over land masses. The GRDH and SLC user-level data are (mainly) related to the IW mode (Interferometric Wide Swath) and the SM mode (Stripmap). A marginal number of SLC user-level data are generated with the EW mode. The particular density of GRDH and SLC user-level data over Europe and Greenland areas reflects the evolution of the Sentinel-1 observation scenario, which initially focused on Europe, and generally the higher observation frequency over Europe.

Detailed information about the Sentinel-1 observation scenario is set out in the HLOP, and on the dedicated Sentinel-1 section of Sentinel Online, at https://sentinel.esa.int/web/sentinel/missions/sentinel-1/observation-scenario.

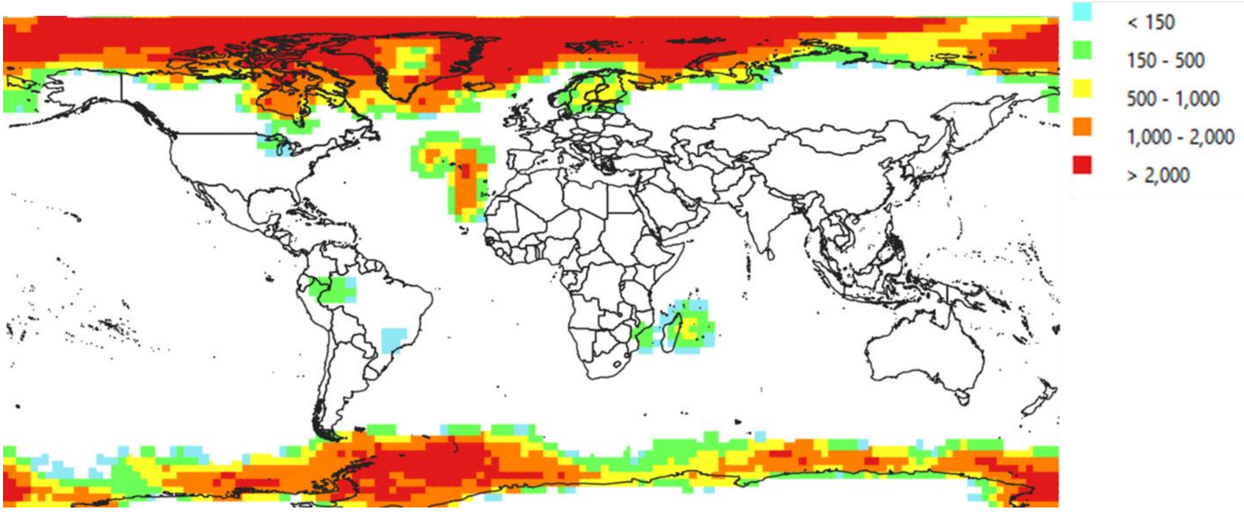


Figure 29: Heatmap of Sentinel-1 GRDM user-level data published from the start of operations to the end of Y2021

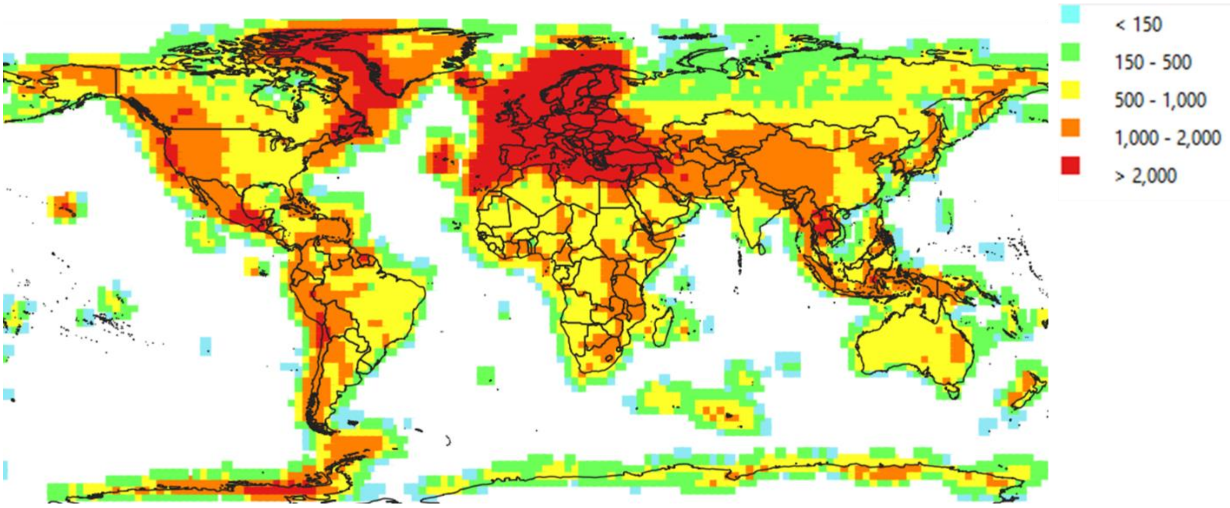


Figure 30: Heatmap of Sentinel-1 GRDH user-level data published from the start of operations to the end of Y2021

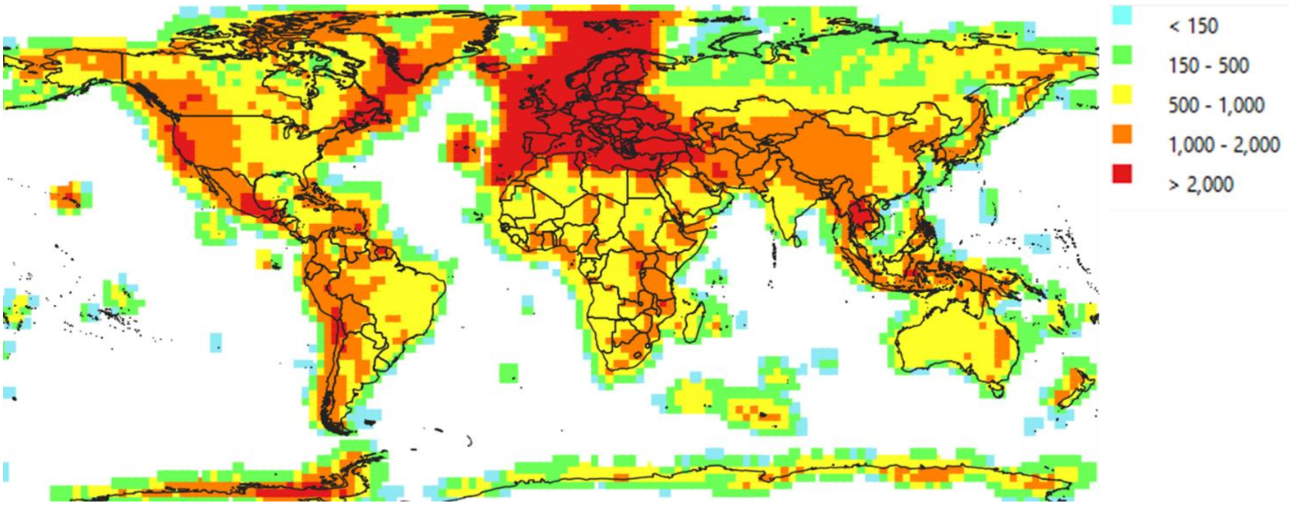


Figure 31: Heatmap of Sentinel-1 SLC user-level data published from the start of operations to the end of Y2021

Sentinel-2

Figures 32 and 33 below show heatmaps for Sentinel-2 published user-level data, respectively for Level-1C user-level data and Level-2A user-level data, and in both cases from the start of operations until the end of Y2021.

As in previous years, the L1C heatmap shows that the coverage is relatively evenly distributed over the globe's landmasses (excluding Antarctica). The particular density over the arctic regions is due to the polar orbits of the satellites, which mean the higher the latitude, the greater the revisit frequency. The same effect is not seen for Antarctica partly because only the coastline areas of Antarctica are included in the observation scenario, and partly because only one of the two Sentinel-2 satellites is used for observations over Antarctica.

Despite that Level-2A production has been available on a global-coverage basis since December 2018, few differences between L1C and L2A can be observed and this confirms the Level 2 production is in line with the Level 1 and the publication capacity has reached the same capacity of Level 1 (in terms of geographical coverage) – in fact, differences are mostly focused on the oceans, coastal areas and also near to the south pole, for which the Level 2 seems to have fewer number of published user-level data.

It should be noted that these heatmaps will always be an approximation and cannot represent a precise one-to-one mapping with the published user-level data due to the need to merge the Sentinel-2 data grid onto the heatmap global projection. Some small anomalies are visible; in particular, the red 'dots' across parts of Europe and Russia in both heatmaps are most likely an artefact caused by plotting the Sentinel-2 data grid onto the map projection. Similarly, the apparent lower publication levels in the heatmap over some small areas of southern Africa, Asia and South America are also likely to be the result of the map projection rather than truly reflecting lower publication levels over these areas.

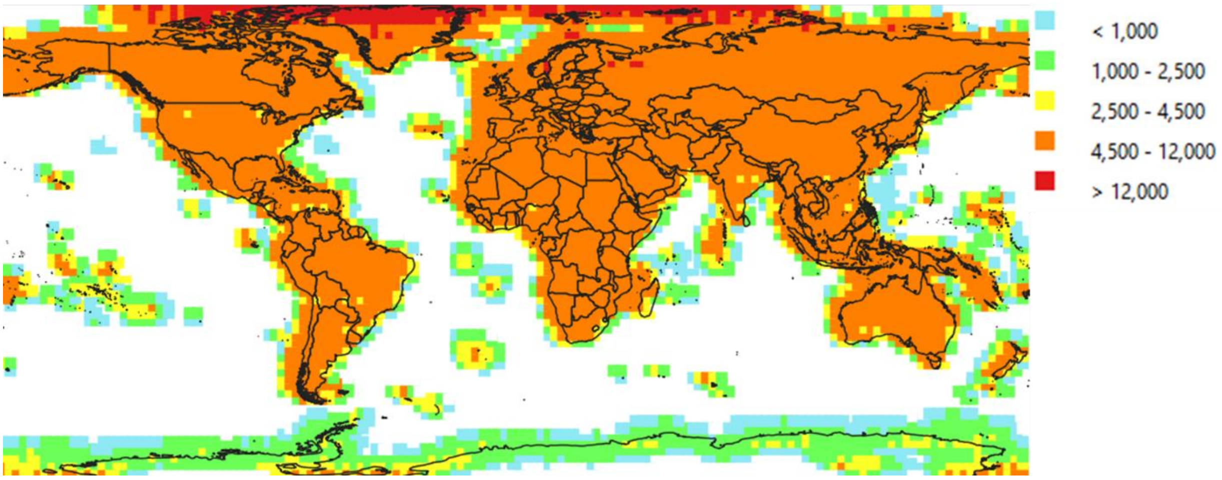


Figure 32: Heatmap of Sentinel-2 Level-1C user-level data published from the start of operations to the end of Y2021

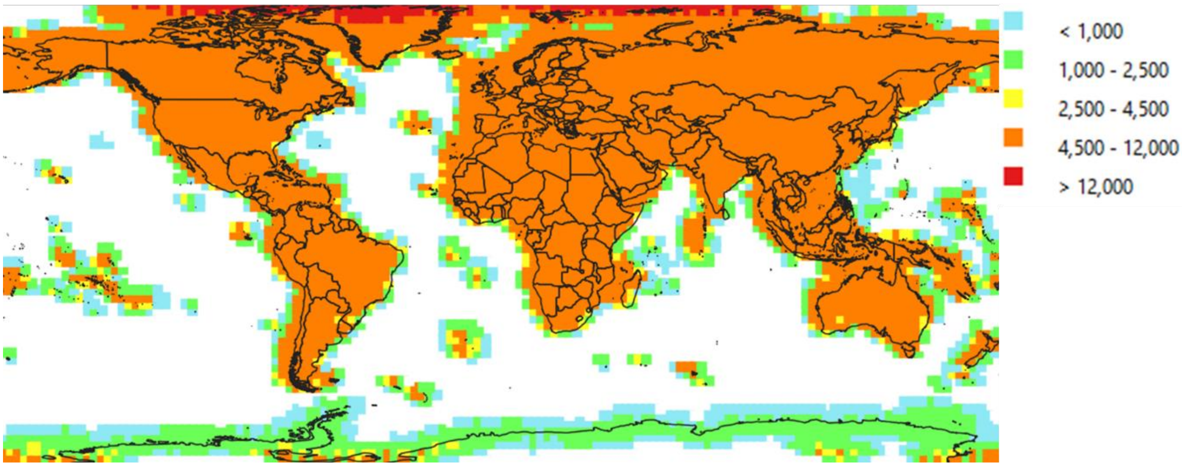


Figure 33: Heatmap of Sentinel-2 Level-2A user-level data published from the start of operations to the end of Y2021

Sentinel-3

The heatmaps below show the geographical coverage of Sentinel-3 Land user-level data, published and available on the Open Hub since the beginning of operations to the end of Y2021. They are separated out by user-level data group. For SRAL user-level data, a separate 'NRT Level-2' heatmap is also provided. SRAL, SRAL-NRT, OLCI, and SLSTR are shown in Figures 34, 35, 36, 37 and 38 respectively. Care should be taken when reading the keys, which are different for each plot depending on the number of user-level data published for each instrument.

Sentinel-3 user-level data are far more evenly distributed over the globe than for Sentinel-1 and -2. Only SRAL-NRT Level-2 user-level data are focused on land areas. The apparent emphasis on the poles for all user-level data types is a result of the higher revisit frequency over these regions.

No publication heatmap is provided for the SYNERGY data because the SYNERGY user-level data is composed of many user level data, including the VGT data which are provided in continental tiles, and this creates a heat map which gives little real idea of the publication density. The heat maps for OLCI and SLSTR are already provided and depict the actual "acquisition heat". For further details refer to Annex 2 and https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-synergy

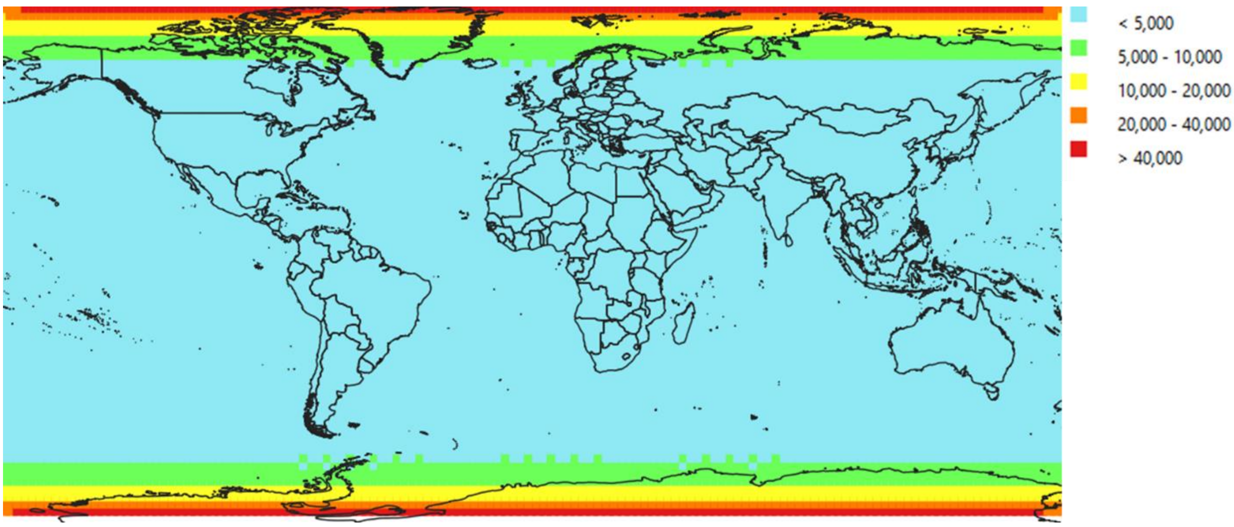


Figure 34: Heatmap of Sentinel-3 SRAL user-level data published since the start of operations to the end of Y2021 (excluding NRT and Level-2)

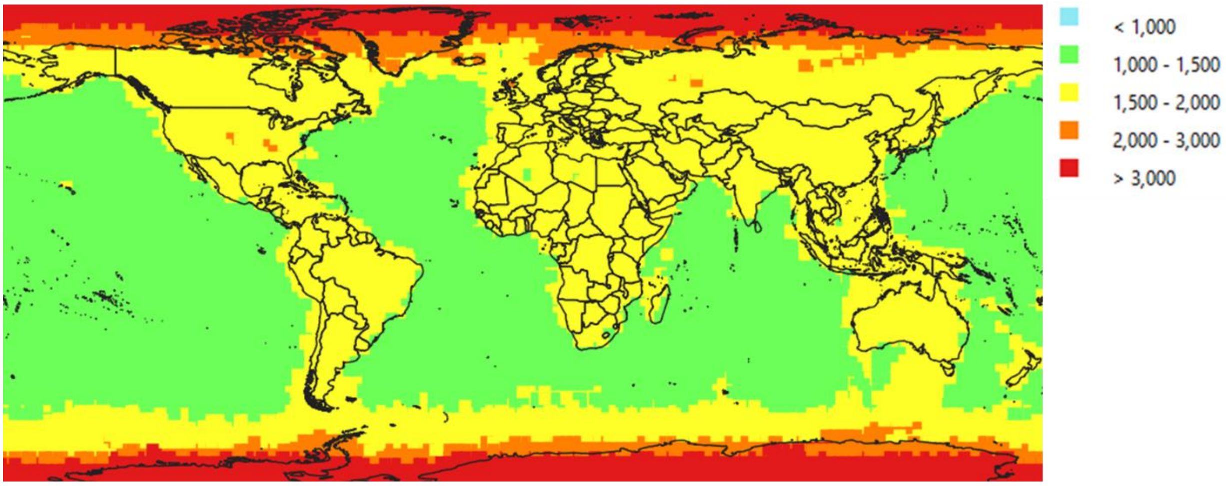


Figure 35: Heatmap of Sentinel-3 SRAL-NRT user-level data published from the start of operations to the end of Y2021

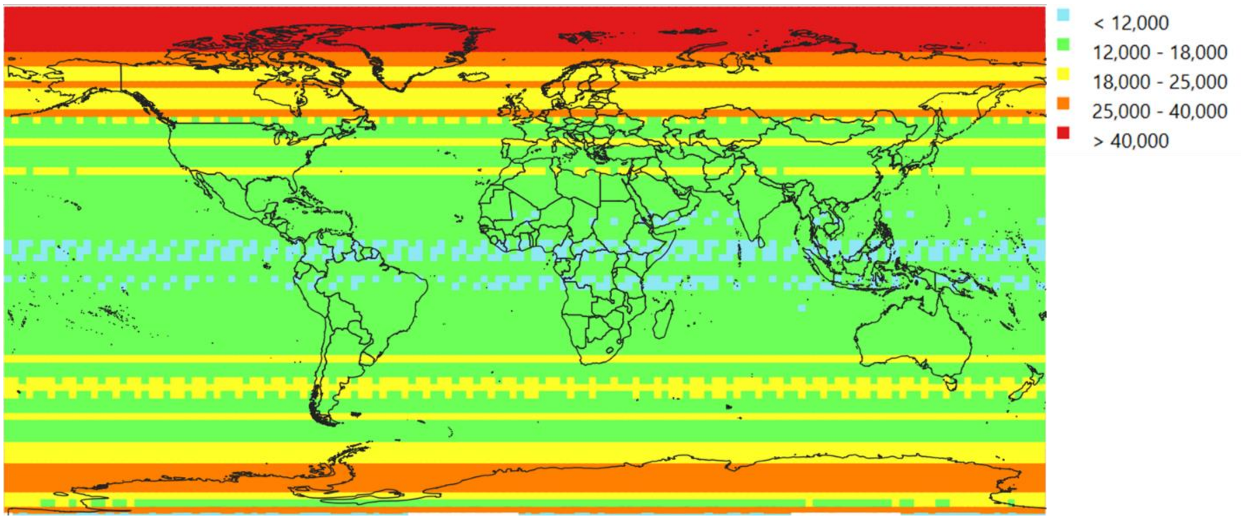


Figure 36: Heatmap of Sentinel-3 OLCI user-level data published from the start of operations to the end of Y2021

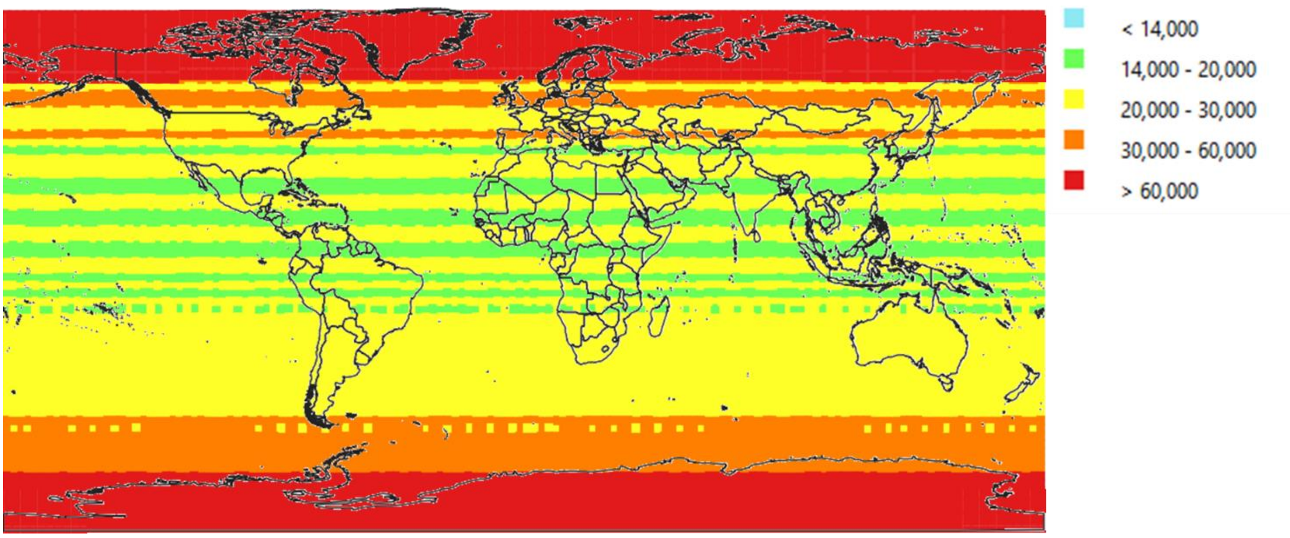


Figure 37: Heatmap of Sentinel-3 SLSTR user-level data published from the start of operations to the end of Y2021

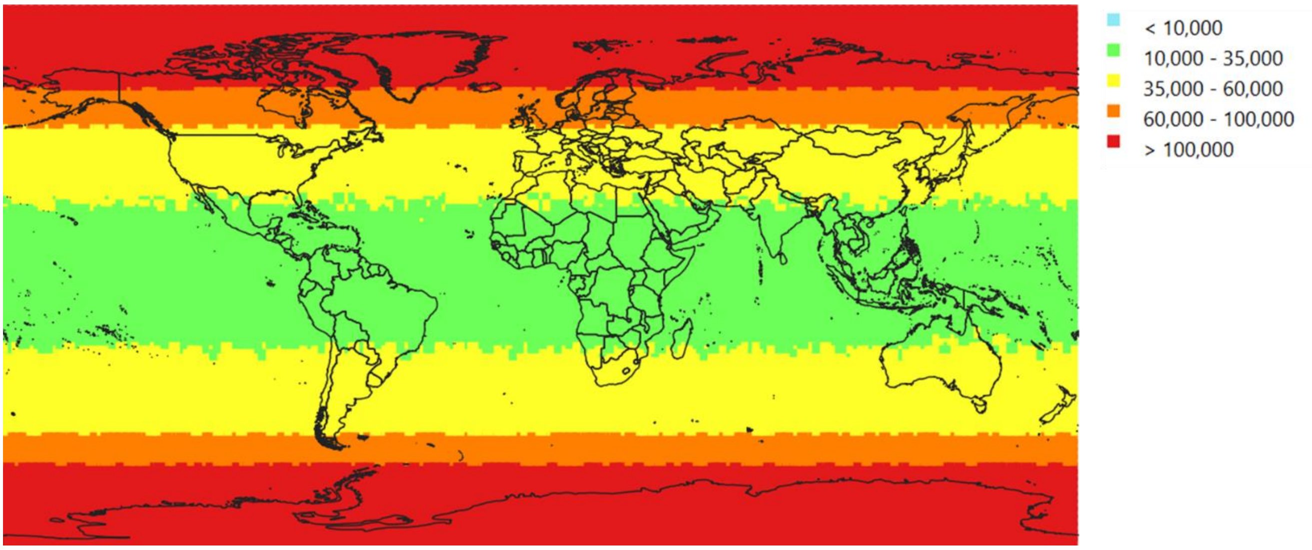


Figure 38: Heatmap of Sentinel-5P user-level data published from the start of operations to the end of Y2021

Sentinel-5P

Sentinel-5P systematically senses data on the daytime portion of all orbits, meaning the heatmap for publication is uniform (highlighting only the increased overlap of orbits towards the poles). It is shown below, made up from all Sentinel-5P user-level data published from the start of operations until the end of Y2021.

2.3 Data Downloads

This section looks at user activity in terms of the level of downloads which users made during Y2021 and the types of user-level data which they chose to download.

It is highlighted that 'one download' refers to an uninterrupted download of a complete user-level data. Partial downloads and data component downloads are not included in the overall statistics.

It should also be noted that in this section the statistics cover downloads from the following hubs: Open Hub, Collaborative Hub, International Hub and Copernicus Services Hub. Downloads from the DIAS Hub are presented separately, in Section 2.3.3.1, because the DIAS partners systematically download the full collection of user-level data, so the statistics are more predictable and risk masking the download patterns of the other ServHub users.

2.3.1 Download growth

By the end of Y2021, a huge 320 PiB of Sentinel data user-level data had been downloaded from the Data Access System since the start of. Figure 40 breaks this total down per mission, and compares the total volume of data downloaded by the end of Y2021 with the total volume which had been downloaded by the end of all previous periods, i.e. reporting years 2015-2020. As shown, 79.7 PiB of the total volume of downloads since the start of operations was downloaded during Y2021 alone. This represents about 25% of the total downloaded volume and, for the first time, it is actually 4% less than the volume downloaded during the previous year (Y2020). This suggests that the continual growth in the volume of data downloaded by users during the first 6 years of Sentinel operations is now stabilising .This should not be interpreted as indicating that the overall demand for the Sentinel data has now peaked, however: following the establishment of increasing numbers of platforms which provide computing resources with the data hosted locally, it could be expected that the overall need for users to download the data onto their individual computing resources would reduce.

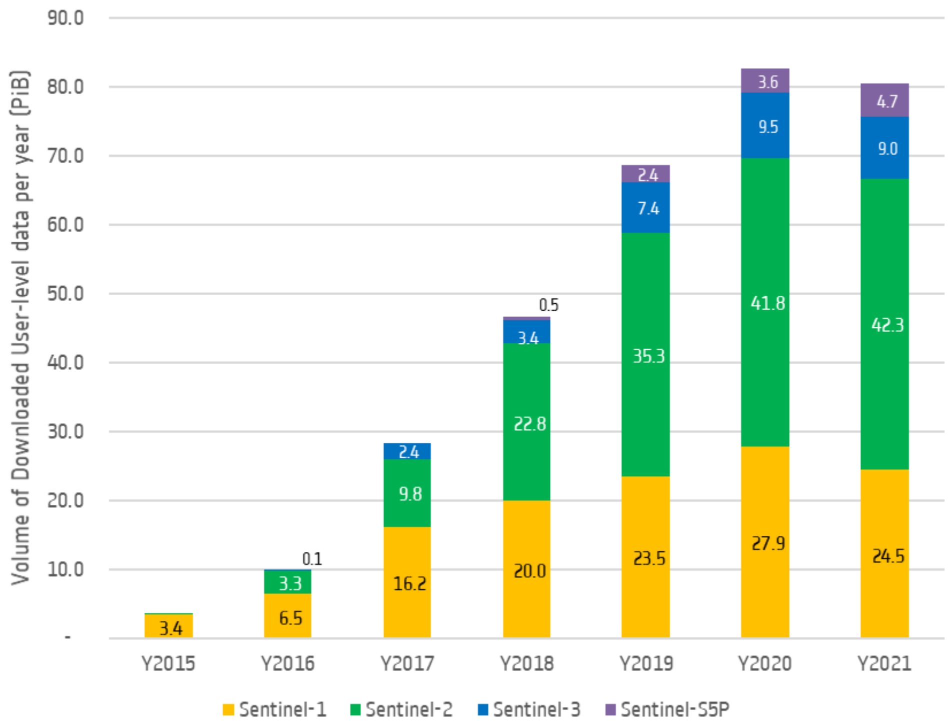


Figure 39: Total volume of user-level data downloaded per year since the start of operations from all of the four hubs, differentiated by mission

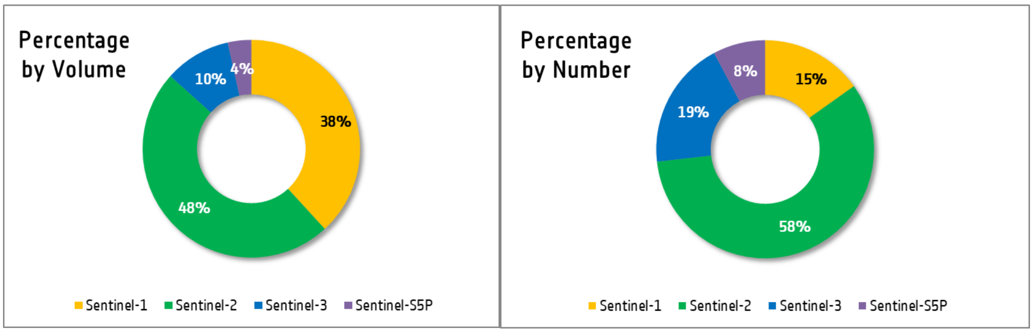


Figure 40: Percentage of total downloads per mission since the start of operations for all of the four hubs, on the left by volume and on the right by number

In terms of the *number* of user downloads, however, during Y2021 a total of 185.7 million user downloads were made, and this represents a 22% rise on the 151.5 million user-level data downloaded during Y2020. It is important to note, though, that the statistics for the number of downloads in this 2021 Report have been affected by an anomaly which resulted in the over-counting of number of downloads for Sentinel-1, 2, 3 in the first half of the year. The anomaly has meant that in certain circumstances partial downloads, which normally are removed from the statistics, were counted as full downloads. The statistics for the volume of downloads are only very marginally affected, however.

In Y2021, the most notable increase in download volumes was again observed for Sentinel-5P. Sentinel-5P downloads increased by 31%, rising from 3.6 PiB during Y2020 to 4.7 PiB during Y2021, and accounted for 6% of the total volume of user downloads for the year. There was a decrease in the volume of Sentinel-1 user-level data downloaded by users, with a total 12% lower than the volume downloaded in Y2020, though still accounting for 30% of the total user downloads made in Y2021.

Sentinel-2 registered an almost equal volume of user level data downloads as in Y2020, and, together with Sentinel-1 data, the total share of the volume downloaded during the year was 83% (in Y2020 it was 84%). As a proportion of the yearly volume of downloads, Sentinel-2 data continued to be the most downloaded for the year, and in Y2021 accounted for 53% of the volume of all user downloads during the year, slightly higher than the 50% from Y2020.

Figure 41 shows that when all downloads since the start of operations are taken into account, Sentinel-2 downloads constituted the majority of both the total *volume* (48%) and the *number* (51%) of user-level data downloaded. Sentinel-1 downloads accounted for a smaller proportion: 38% in terms of volume and only 15% in terms of number of downloads. Due to their smaller average user-level data size, both Sentinel-3 and Sentinel-5P have a greater impact in terms of number than in volume. While Sentinel-3 only made-up 10% of the total downloads since the start of operations by volume, it accounted for 19% by number; Sentinel-5P accounted for only 4% of volume but 8% by number.

2.3.2 Archive Exploitation Ratio (AER)

Interest in Sentinel user-level data can also be monitored by looking at the 'Archive Exploitation Ratio' (AER). The AERs which are shown in Figure 42 was calculated at the end of Y2021 and represents the total number of user downloads made from all the hubs since the start of operations, divided by the total number of user-level data which had been published on the hubs since the start of operations. An AER is expressed as a ratio of published user-level data vs downloaded user-level data: e.g., the ratio 1:X indicates that, for each of the user-level data published from a mission, there was an average number of X downloads.

The AERs reported in Figure 42 suggest that user interest in Sentinel-1 has slightly increased since Y2020: the AER has increased from 1:14 in Y2020 to 1:15 in Y2021. Engagement with Sentinel-3 user-level data increased even more significantly, rising from 1:9 in Y2020 to 1:11 in Y2021. The Sentinel-2 AER remains constant, again at 1:13, and the exploitation rate of Sentinel-5P user-level data remains the highest of all the missions, at a staggering 1:28, increased from 1:27 in Y2020.

In the following subsections, further details on the AERs are presented for each mission, grouped by instrument, user-level data level, resolution, and timeliness, for the period since the start of operations up to the end of Y2021. The timeliness values are NRT (Near Real Time), NTC (Non Time Critical) or STC (Short Time Critical). The heatmaps then break the exploitation ratio down according to geographical area, and this gives an approximate indication of the geographical zones over which users are particularly interested in downloading data.

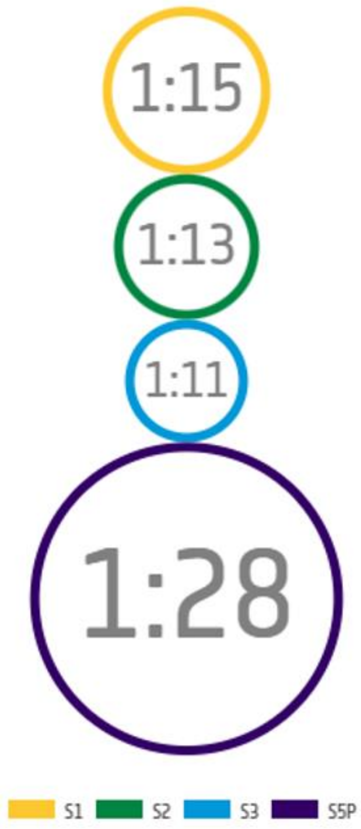


Figure 41: Archive Exploitation Ratio per mission at the end of Y2021

Sentinel-1

Level	Timeliness	Number of Published user-level data in Y2021	Number of Downloaded user-level data in Y2021	Archive Exploitation Ratio
Level 0	NTC	412,800	3,207,900	1 : 7.8
Level 1	NTC	691,051	13,946,187	1 : 20.2
	NRT	121,336	2,971,405	1 : 24.5
Level 2	NTC	231,111	4,474,123	1 : 19.4

*Table 5: Sentinel-1 User-level data Published, Downloaded and AER **for Y2021**, per user-level data level and timeliness*

Level	Timeliness	Number of Published user-level data since Start of Operations	Number of Downloaded user-level data since Start of Operations	Archive Exploitation Ratio
Level 0	NTC	2,270,865	15,896,631	1 : 7.0
Level 1	NTC	4,358,798	73,895,339	1 : 17.0
	NRT	438,070	5,864,319	1: 13.4
Level 2	NTC	868,386	15,502,530	1 : 17.9

*Table 6: Sentinel-1 User-level data Published, Downloaded and AER **since the start of operations**, per user-level data level and timeliness*

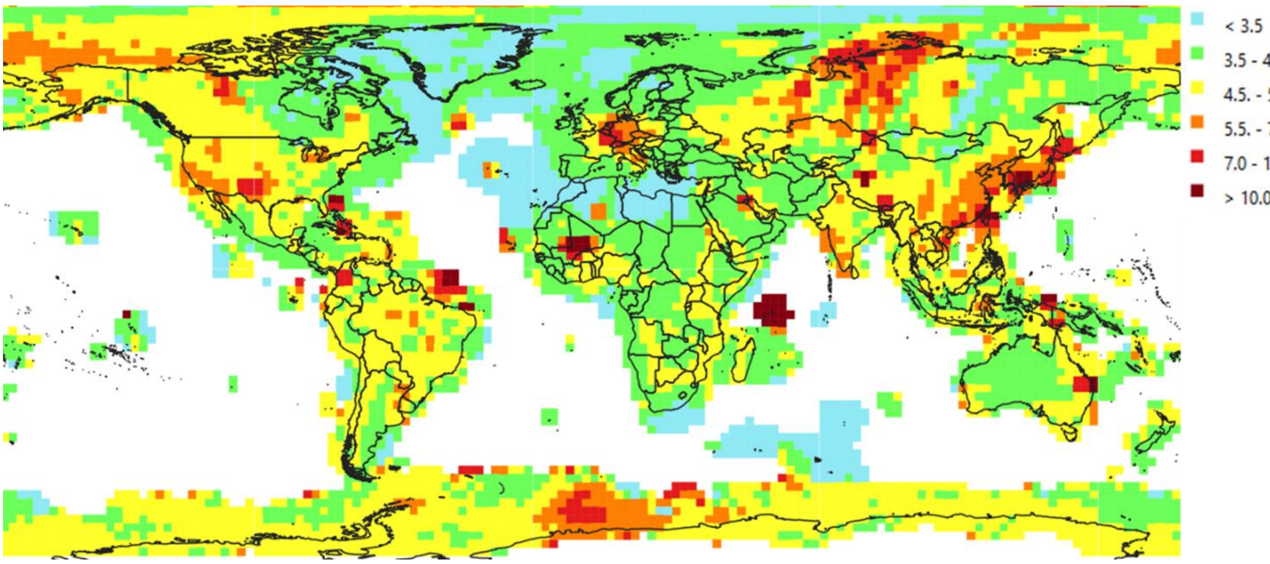


Figure 42: Heatmap showing the archive exploitation ratio for Sentinel-1 L0 and L1 NTC user-level data (excluding WV mode) during Y2021

Overall, the figures in Tables 5 and 6 suggest that user engagement with each of the Sentinel-1 user-level data types has increased since Y2020. This year the Sentinel-1 Level 1 NRT data registered a big jump from 1:12 in Y2020 to 1:24 becoming, for the first time, the most popular Sentinel-1 data levels/timeliness during the year. This is related to the change of observation scenario generating the NRT data and the introduction of publication of such data timeliness in all the hubs (until last year the NRT data were only published on ColHub).

The AER of the Level 1 and Level 2 NTC user-level data saw a decrease in terms of user interest, with 1: 20 and 1:19 respectively, slightly lower than to the ratios calculated for the Level 1 and Level 2 NTC in Y2020, respectively 1:21 and 1:20. The Level 0 NTC still have the lowest AER at 1:8, and this has also decreased since Y2020, down from 1:9 in Y2020.

Table 6 reports an overall upward trend observed for the AERs calculated from the start of operations. The AER for Level-0 NTC user-level data has risen the least, from 1:6.8 in Y2020 to 1:7 in Y2021 and the Sentinel-1 Level1 NTC user-level data show an increase, changing from 1:16.3 in Y2020 to 1:17 in Y2021. The same increase is registered for Level-1 NRT, showing a steep change in the AER from 1:9.1 in Y2020 to 1:13.4 in Y2021, in agreement with the growth of interest during the reporting year; for Level-2 NTC user-level data the rise was milder, from 1:17.3 to 1:17.9.

Looking at the figures underlying the AERs, the numbers of Level 0 NTC user-level data published during Y2021 was similar compared with that published in Y2020. User-level data types increased by a range of 1 - 68%, except for Level-1 NTC which dropped by 12%. In terms of number downloads, the Level 1 NRT shows an enormous increase of 240%, while Level 2 NTC user-level data shows an increase of 24%; Level 0 NTC and Level 1 NTC dropped by a range of 10 - 14%, respectively.

Figure 43 indicates the geographical areas of interest for users of Sentinel-1 L0 and L1 NTC user-level data, measured by AER. It shows how many downloads were made during Y2021 per available data over specific geographical points across the globe, taking into account all user-level data published since the start of operations. The Figure can be compared with the corresponding Sentinel-1 publication heatmap in Figure 28. Because of their particular footprint, which is constituted by more than one polygon, Wave mode user-level data (which include all Sentinel-1 Level-2 user-level data) are excluded from the map. It is also noted that all map cells which had fewer than 100 user-level data published within them since the start of operations are excluded from the AER heatmap as systematic downloads over them can give a misleading impression of which areas are most popular.

The heatmap shows that interest in Sentinel-1 user-level data is concentrated largely on the Earth's landmasses, almost all of which show an AER of greater than 1:3.5. Overall, the largest concentrations of interest appear over the Americas and some areas over Asia and the Southern ice-covered regions, for sea and land ice monitoring. In these areas the AER is generally above 1:4.5 and can go higher than 1:10. There are other AER hotspots across the globe including: Central Europe and the Australian coasts, and Central and Southeast Africa. Some of these are clearly linked to tectonic boundaries, for which interferometry based on radar data can be used to monitor activity levels and assist in disaster response operations. Some others may be linked to monitoring and forecasting the exceptional floods, or studies on climate change adaptation and disaster risk preparedness.

Sentinel-2

Level	Number of Published User-level data in Y2021	Number of Downloaded User-level data in Y2021	Archive Exploitation Ratio
Level 1C	4,072,524	87,144,018	1 : 21.4
Level 2A	4,074,814	35,370,481	1 : 8.7

Table 7: Sentinel-2 User-level data Published, Downloaded and AER for Y2021, per user-level data type

Level	Number of Published User-level data since the start of Operations	Number of Downloaded User-level data since the start of Operations	Archive Exploitation Ratio
Level 1C	18,880,911	320,007,941	1 : 16.9
Level 2A	12,411,937	102,045,067	1 : 8.2

Table 8: Sentinel-2 User-level data Published, Downloaded and AER since the start of operations, per user-level data type

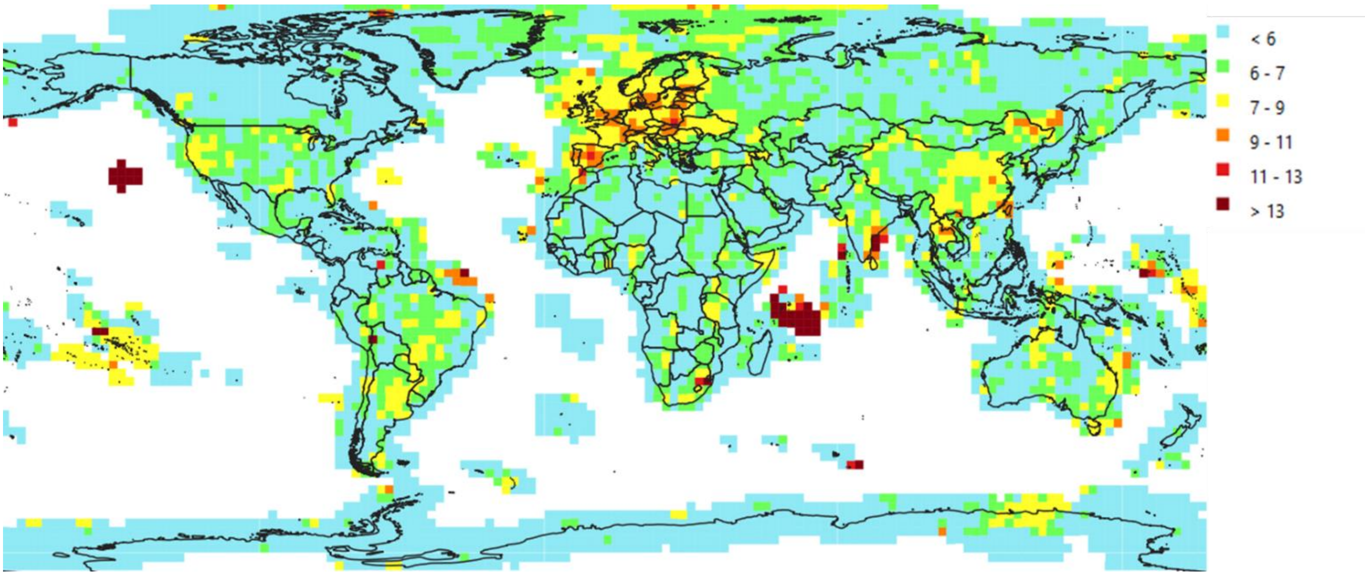


Figure 43: Heatmap showing the archive exploitation ratio for Sentinel-2 L1C user-level data during Y2021

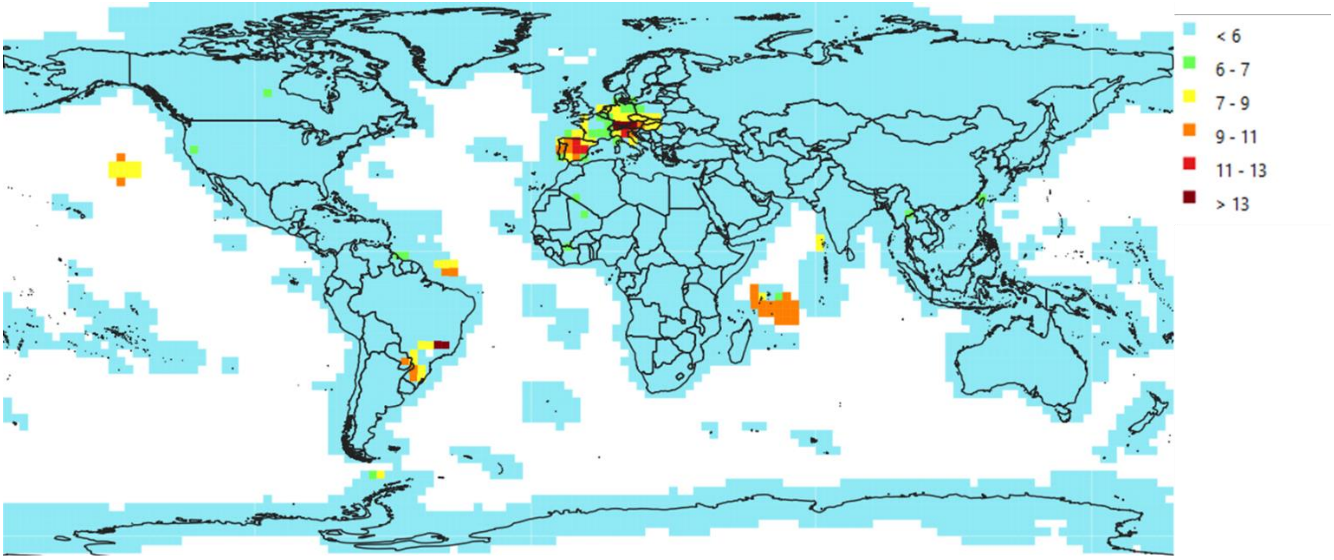


Figure 44: Heatmap showing the archive exploitation ratio for Sentinel-2 L2A user-level data during Y2021

Looking at the figures in Table 8, Sentinel-2 Level-1C user level data AER show an increase with respect to Y2020, changing from 1:19 in Y2020 to 1:21 in Y2021; Level-2A user-level data show a milder increase from 1:8.4 to 1:8.7. In terms of uptake of the two user-level data types since the start of operations, the increases were also visible with the Level-1C overall AER rising from 1:15.7 in Y2020 to 1:16.9 in Y2021; and the Level-2A overall AER rose from 1:8.0 to 1:8.2.

Figures 44 and 45 indicate the geographical areas of interest for users of Sentinel-2 Level-1C and Level-2A user-level data, respectively, measured by AER. They show how many downloads were made during Y2021 per available user-level data over specific geographical points across the globe, taking into account all user-level data published since the start of operations. It is noted that all map cells for Level-1C (Figure 44) which had fewer than 300 user-level data published within them since the start of operations are excluded from the AER heatmap, as systematic downloads over them can give a misleading impression of which areas are most popular.

For both user-level data types, the global spread is quite similar: the areas with the highest AERs are, as expected, European landmasses, where the AER is mainly greater than 1:7 for both Level-1C and Level-2A. High levels of interest are also shown over the landmasses of Americas, China, French Polynesia, Australia and some portion of Antarctica with AERs generally in the range of 1:6 – 1:9 for Level-1C but not noticeable for Level-2A. There are some other noticeable non-European 'hotspots' where user downloads have been concentrated, such as India, Southern and Eastern Africa (Seychelles islands) and some areas of the Pacific and Atlantic Oceans not specifically covered by land masses.

Sentinel-3

Instrument	Number of Published User-level data in Y2021	Number of Downloaded User-level data in Y2021	Archive Exploitation Ratio
OLCI	698,559	22,517,999	1 : 32.2
SLSTR	1,851,432	30,332,055	1 : 16.4
SRAL	369,523	3,928,035	1 : 10.6
SYNERGY	383,170	3,616,009	1 : 9.4

Table 9: Sentinel-3 User-level data Published, Downloaded and AER for Y2021, per user-level data group

Instrument	Number of Published User-level data since Start of Operations	Number of Downloaded User-level data since Start of Operations	Archive Exploitation Ratio
OLCI	3,176,259	47,335,659	1 : 14.9
SLSTR	6,517,326	66,702,070	1 : 10.2
SRAL	1,565,947	16,579,251	1 : 10.6
SYNERGY	1,090,559	8,308,738	1 : 7.6

Table 10: Sentinel-3 User-level data Published, Downloaded and AER since the start of operations, per user-level data group

Tables 9 and 10 show, for Y2021 and since the start of operations respectively, the AER for Sentinel-3 user-level data, split by user-level data group: SLSTR, SRAL, OLCI and SYNERGY. Of the user-level data groups, the most popular during Y2020, was OLCI with an AER of 1:32, followed by SLSTR with 1:16. OLCI in particular shows a steep increase in the AER with respect to Y2020 (1:32 vs 1:12 respectively), as the number of downloads is doubled (it was 11,361,931 in Y2020).

Both OLCI and SLSTR user-level data had higher exploitation rates in Y2021 with respect to SRAL and SYNERGY types, differently from Y2020 where OLCI and SRAL showed the highest ratios. SLSTR in particular showed the highest change, from 1:10 in Y2020 to 1:16 in Y2021, with the number of downloads reaching a 67% increase compared to the download number registered in Y2020.

For SYNERGY user-level data also show an increase in the number of user-level data which were downloaded in Y2021 as compared with Y2020, with the AER increased to 1:9.4 from 1:8.9 in Y2020. This reflects a change also in terms of publication number, which has changed by 7%. On the other hand, download numbers rose more steeply, changing by 13%, leading to the change in the AER. This rapid take-up rate suggests the SYNERGY user-level data have been adopted with enthusiasm by the Sentinel-3 user community.

When the AERs are calculated using the download and publication numbers from the start of operations, the AERs of each user-level data-type increased but patterns are different. OLCI shows the highest AER, registering a change from 1:10 to 1:15, followed by the SRAL data type, which remained stable at 1:11. SLSTR increased to 1:10 compared to 1:8 registered in Y2020 since the start of operations, while SYNERGY also has increased, from 1:7 to 1:8. The download number for OLCI, SLSTR and SYNERGY data types in fact have almost doubled compared to the figures recorded since the start of operations in Y2020. Changes registered for OLCI, SLSTR and SYNERGY data types since the start of operations are 91%, 83% and 77% respectively with respect to Y2020. The stability of SRAL AER does mask the increase in the number of SRAL user level data downloads since the start of operations, which changed by 31% compared to Y2020.

The remainder of this section examines in greater detail the AERs for each of the Sentinel-3 user-level data groups, as well as portraying geographical areas of interest for Sentinel-3 users in heatmaps.

SLSTR				
Level	Timeliness	Number of Published User-level data since Start of Operations	Number of Downloaded User-level data since Start of Operations	Archive Exploitation Ratio
Level 1	NTC	2,179,545	26,551,112	1 : 12.2
	NRT	1,313,279	14,709,266	1 : 11.2
Level 2	NTC	1,711,290	16,760,242	1 : 9.8
	NRT	1,313,212	8,681,450	1 : 6.6

Table 11: Sentinel-3 SLSTR User-level data Published, Downloaded and AER since the start of operations, per data level and timeliness

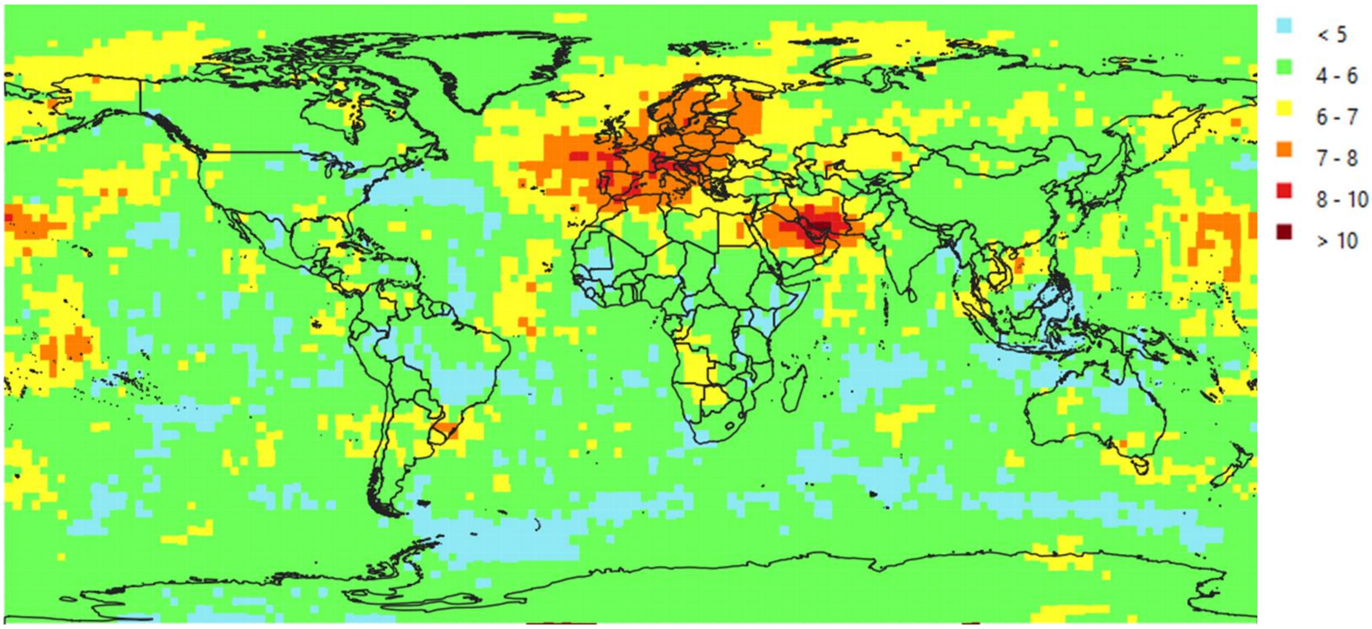


Figure 45: Heatmap showing the archive exploitation ratio for Sentinel-3 SLSTR Level-1 NTC user-level data during Y2021

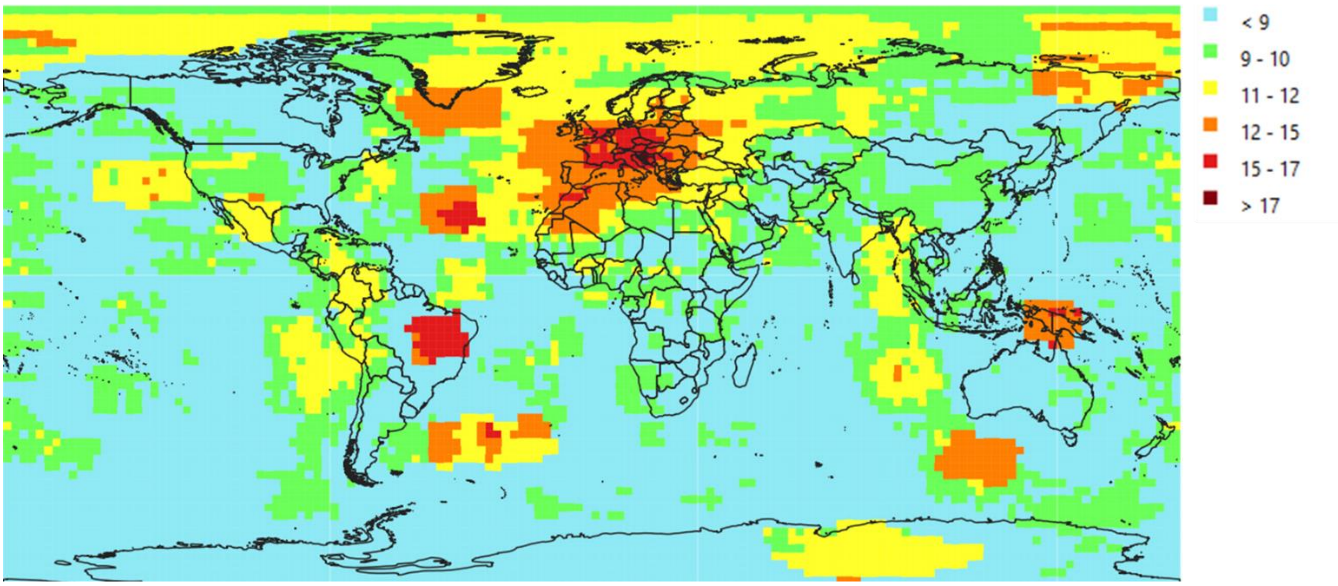


Figure 46: Heatmap showing the archive exploitation ratio for Sentinel-3 SLSTR Level-2 NTC user-level data during Y2021

Table 11 breaks down the AER for SLSTR user-level data by data level and timeliness (NTC or NRT). The AERs are calculated from the start of operations. From these figures, it seems likely that the overall increased AER of 1:10 for SLSTR user-level data was primarily the result of the increased AER for the SLSTR Level-1 NTC user-level data, which jumped from 1:9 to 1:12 in Y2021, and for the Level-2 NTC user-level data, which increased from 1:4 in Y2020 to 1:10 in Y2021. Also, the AERs for the SLSTR Level-1 NRT registered a growth from 1:10.6 in Y2020 to 1:11.2 in Y2021, while SLSTR Level-2 NRT changed from 1:6 in Y2020 to 1:7 in Y2021.

The heatmaps in Figures 46 and 47 show the geographical variation in AER for regions across the globe during Y2021 for SLSTR Level-1 and Level-2 NTC user-level data respectively. Figure 46, for SLSTR Level-1 NTC, shows that, this year, the greatest density of SLSTR Level-1 user-level data downloads were done over specific geographical points across the globe. Overall, the largest concentration of interest appears over Europe and the Middle East, where the AER is generally above 1:7. There are other AER hotspots across the globe including: Pacific and Atlantic Oceans, Quebec, Southern Africa and Southern America, where AER is higher than 1:6.

Figure 47 shows the equivalent heatmap for Level-2 NTC user-level data, the footprints of which cover the entire globe with each pass. All regions of the globe show an AER of at least 1:9. However, interest is concentrated in specific geographical areas centred on European regions, North African longitudes, some areas in the Atlantic Ocean, on Brazil and on the Papua and Papua New Guinea. In these regions the AER at some points rises above 1:15 (the red regions on the map). Other interesting hotspots are in Greenland, in the Indian Ocean right below the Australian continent and on the Siberian Sea reached an AER between 1:12 and 1:15.

SRAL				
Level	**Timeliness**	**Number of Published User-level data since Start of Operations**	**Number of Downloaded User-level data since Start of Operations**	**Archive Exploitation Ratio**
Level 1	NTC	315,625	2,711,791	1 : 8.6
	STC	252,105	1,701,475	1 : 6.7
	NRT	419,927	4,462,399	1 : 10.6
Level 2	NTC	133,797	3,219,131	1 : 24.1
	STC	106,720	978,697	1 : 9.2
	NRT	337,773	3,505,758	1 : 10.4

Table 12: Sentinel-3 SRAL User-level data Published, Downloaded and AER since the start of operations, per user-level data level and timeliness

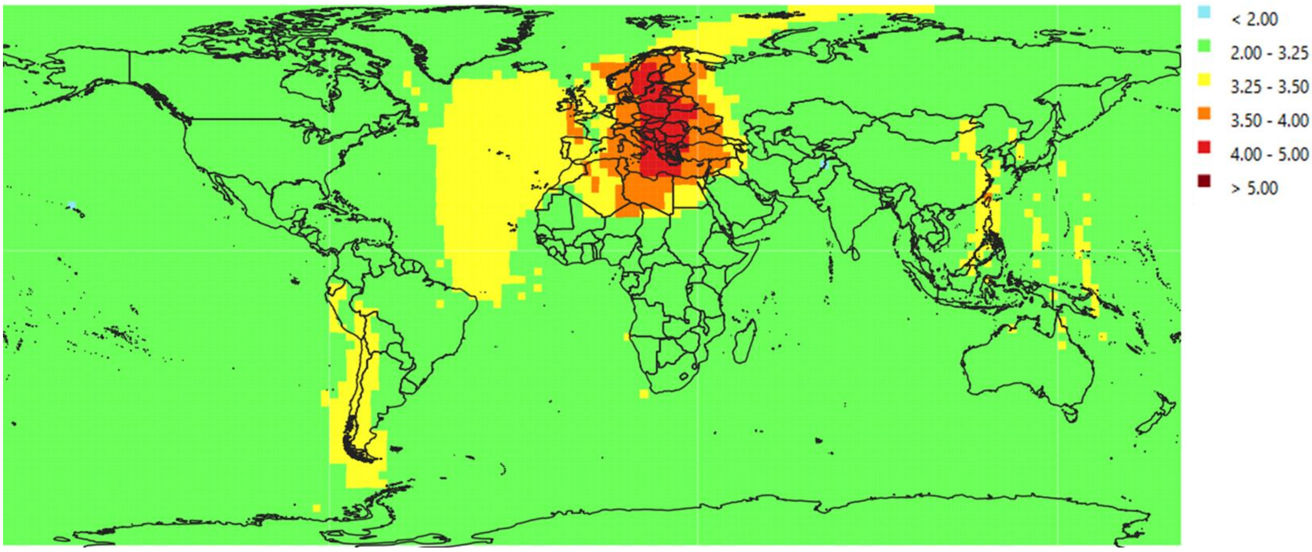


Figure 47: Heatmap showing the archive exploitation ratio for Sentinel-3 SRAL Level-1 NRT user-level data during Y2021

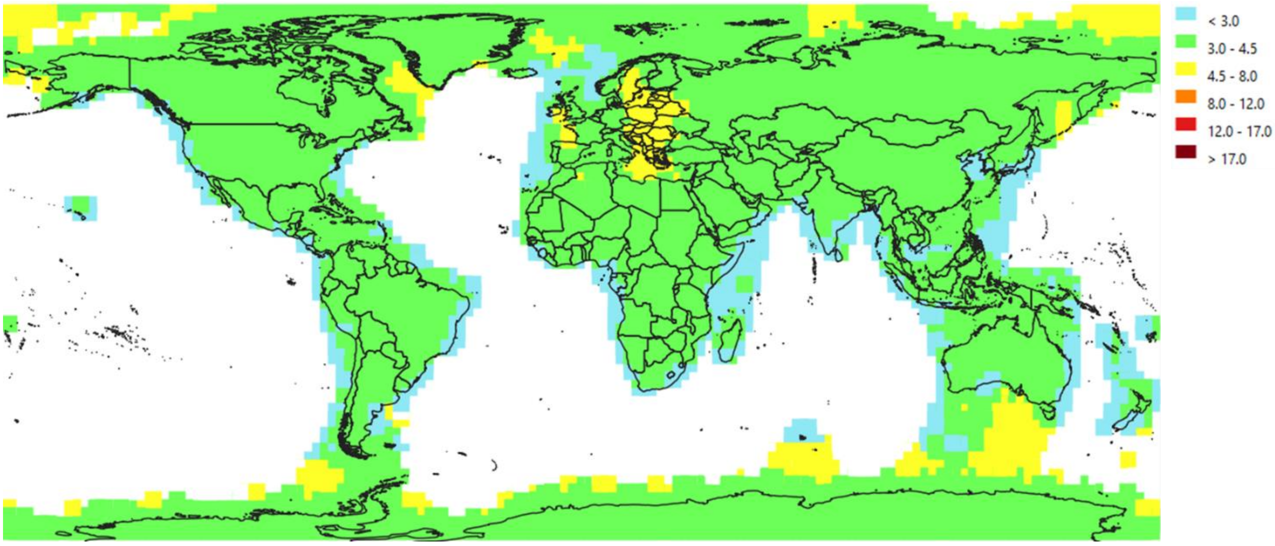


Figure 48: Heatmap showing the archive exploitation ratio for Sentinel-3 SRAL Level-2 NRT user-level data during Y2021

Table 12 shows a breakdown of AERs specifically for SRAL user-level data, by data level and timeliness (NTC, STC or NRT; for more information on timeliness refer to https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-altimetry/product-types/nrt-or-ntc). The AERs have been calculated from the start of operations.

The table shows that the most popular SRAL user-level data to date are the Level-2 NTC user-level data, which have an elevated AER of 1:24. This AER has also increased from 1:23 recorded in Y2020. In terms of the absolute number of downloads, it was still the Level-1 NRT user-level data which users had downloaded the most by the end of Y2021, although for these user-level data the AER has decreased from 1:12 in Y2020 to 1:11 in Y2021.

The heatmaps in Figures 48 and 49 show the geographical variation in AER for regions across the globe during Y2021 for SRAL Level-1 NRT and Level-2 NRT user-level data respectively. For Level-1 NRT, a high level of activity can be seen over Europe, over which AERs rise above 1:3.5 and, in some scattered regions, above 1:5. For the rest of the globe, there is interest in northern/central regions of the Atlantic, Chile and some regions in South-East Asia in which the AER is between 1:3.25 and 1:3.50 but across the rest of the globe, the AERs is <1:3.

The pattern of geographical interest for the Level-2 NRT user-level data is similar to that for the Level-1

NRT user-level data, although for the Level-2, data downloads are largely restricted to landmasses. As for the Level-1 user-level data, the AER is <1:3 (green areas on the map) for most of the Earth's land area. Again, however, there is a focussed area of high activity, covering less of the Atlantic and more the European, Mediterranean and North African regions in which the AER rises to up to 1:8. The regions in yellow at the borders of the land masses are, perhaps, the result of an artifact generated by the less user-level data published on those specific areas.

Table 13 shows a breakdown of the AER for OLCI user-level data, by data level, timeliness (NTC or NRT) and resolution (Reduced or Full). Again, the AERs have been calculated using publication and download figures from the start of operations. AERs range from 1:9 for Reduced Resolution Level-2 NRT to 1:38 for Reduced Resolution Level-1 NTC, showing that the Reduced Resolution user-level data have been more popular than Full Resolution, with overall AERs of 1:27 and 1:14 respectively.

OLCI					
Resolution	**Level**	**Timeliness**	**Number of Published User-level data since start of Operations**	**Number of Downloaded User-level data since start of Operations**	**Archive Exploitation Ratio**
Reduced	Level 1	NTC	47,603	1,794,392	1 : 37.7
		NRT	40,480	492,081	1 : 12.2
	Level 2	NTC	98,075	669,517	1 : 6.8
		NRT	39,869	341,693	1 : 8.6
	TOTAL		225,953	6,067,420	1 : 26.9
Full	Level 1	NTC	802,614	13,725,782	1 : 17.1
		NRT	681,808	8,098,978	1 : 11.9
	Level 2	NTC	793,309	14,213,747	1 : 17.9
		NRT	672,575	5,229,731	1 : 7.8
	TOTAL		2,950,306	41,268,239	1 : 14.0

Table 13: Sentinel-3 OLCI User-level data Published, Downloaded and AER since the start of operations, per user-level data level and timeliness

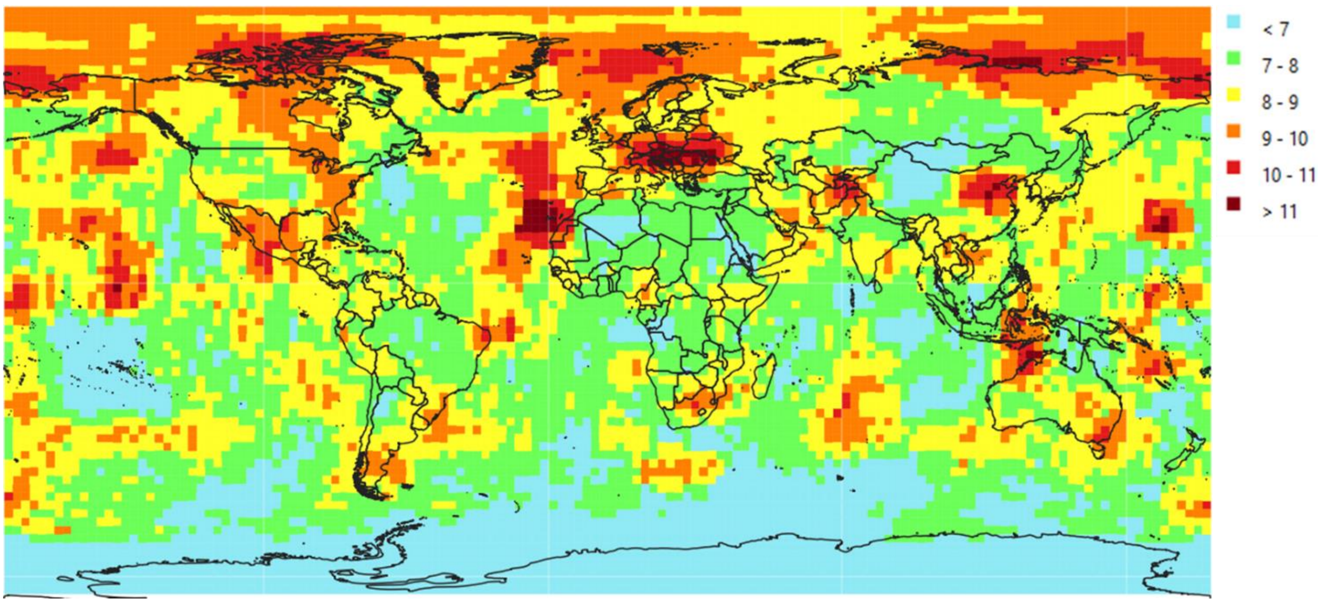


Figure 49: Heatmap showing the archive exploitation ratio for Sentinel-3 OLCI Full Resolution user-level data during Y2021

The Reduced Resolution ratio show a great increase since Y2020, by the end of which the figure was 1:9. The most exploited user-level data by the end of Y2021 were the Level 1 NTC user-level data, which had an overall AER of 1:38, much more than the ratio of 1:13 recorded for them at the end of Y2020. This huge variation is due to the number of downloads, that is up by 226% compared to Y2020, while publication has increased only by 28%.

The heatmap in Figure 50 shows the geographical variation in AER for regions across the globe during Y2021 for OLCI Full Resolution user-level data. There is interest in OLCI user-level data over the whole globe, with most regions exhibiting AERs of between 1:7 and 1:9. This year, the map shows many isolated hotspots where there is a concentration of interest with AER higher than 1:10 and they are located in the regions encompassing the Europe, the North Eastern Atlantic, North Pole including Siberia and Canada, North and Central America, Central Asia including China and Middle East, Indonesia, Southern Australia and some other sports on the Pacific Ocean; in those spots, the AERs rise above 1:10 and, over Europe and North Eastern Atlantic, it is higher than 1:11, the highest observed in any region for OLCI Full Resolution user-level data.

Table 14 shows a breakdown of the AER for SYNERGY user-level data, by data level (only Level 2 is applicable), and timeliness (NTC or STC). Again, the AERs have been calculated using publication and download figures from the start of operations.

As already noted, the overall AER for SYNERGY user-level data rose during Y2021. The AER of the Level 2 NTC user-level data has increased from 1:7.5 in Y2020 to 1:8.6 in Y2021, while Level 2 STC AER changed from 1:5.6 by the end of Y2020 to 1:6.5 by the end of Y2021. The relative number of user-level data which had been published by the end of Y2021 since the start of Operations increased by 57% for STC data and by 51% for NTC data with respect to the end of Y2020; in terms of download number STC user-level data increased by 82% while NTC increased by 74% compared to Y2020.

SYNERGY				
Level	**Timeliness**	**Number of Published User-level data since Start of Operations**	**Number of Downloaded User-level data since Start of Operations**	**Archive Exploitation Ratio**
Level 2	NTC	591,914	5,079,231	1 : 8.6
	STC	498,398	3,228,408	1 : 6.5

Table 14: Sentinel-3 SYNERGY User-level data Published, Downloaded and AER since the start of operations, per data level and timeliness

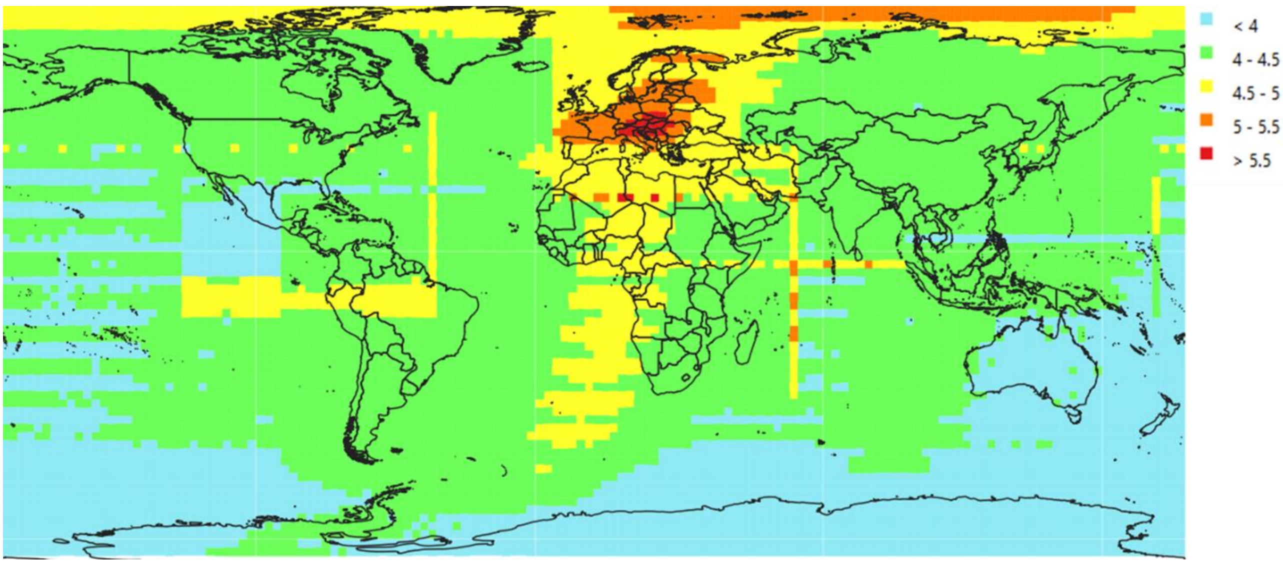


Figure 50: Heatmap showing the archive exploitation ratio for Sentinel-3 SYNERGY user-level data during Y2021

The heatmap in Figure 51 shows the geographical variation in AER for regions across the globe during Y2021 for SYNERGY user-level data. Interest over most of the globe seems to be around 1:4, though a concentration of interest over Europe and European longitudes is visible which echoes the SLSTR Level-2 NTC heatmap. Over central and western Europe, the AERs even rise to >1:5.5.

The overall shape of the features in the heatmap are the result of the large size and irregular shape of some SYNERGY user-level data. For more information, refer to Annex 2 and https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-synergy

Sentinel-5P

Level	Timeliness	Product Type	Number of Published User-level data since Start of Operations	Number of Downloaded User-level data since Start of Operations	Archive Exploitation Ratio
Level 1B	NTC	[ALL]	151,273	2,583,737	1 : 17.1
Level 2	NRT	L2__AER_AI	219,372	5,813,807	1 : 26.5
		L2__AER_LH	140,998	1,927,022	1 : 13.7
		L2__CLOUD_	219,245	2,797,326	1 : 12.8
		L2__CO____	194,455	7,482,104	1 : 38.5
		L2__HCHO__	204,118	4,095,886	1 : 20.1
		L2__NO2___	218,869	8,289,284	1 : 37.9
		L2__O3____	219,115	5,058,343	1 : 23.1
		L2__O3__PR	1,148	9,979	1 : 8.7
		L2__SO2___	204,115	5,030,755	1 : 24.6
		[ALL]	1,621,435	40,504,506	1 : 25.0
	NTC	L2__AER_AI	17,851	883,528	1 : 49.5
		L2__AER_LH	18,621	583,132	1 : 31.3
		L2__CH4___	18,523	2,307,388	1 : 124.6
		L2__CLOUD_	22,855	682,778	1 : 29.9
		L2__CO____	19,227	1,740,816	1 : 90.5
		L2__HCHO__	19,410	944,419	1 : 48.7
		L2__NO2___	20,012	2,644,129	1 : 132.1
		L2__NP_BD3	19,842	442,130	1 : 22.3
		L2__NP_BD6	19,146	376,799	1 : 19.7
		L2__NP_BD7	19,064	399,704	1 : 21.0
		L2__O3____	22,254	1,004,473	1 : 45.1
		L2__O3__PR	180	1,560	1 : 8.7
		L2__O3_TCL	1,331	96,581	1 : 72.6
		L2__SO2___	19,717	1,034,192	1 : 52.5
		[ALL]	238,033	13,141,629	1 : 55.2
	[ALL NRT + NTC]		1,859,468	53,646,135	1 : 28.9

Table 15: Sentinel-5P User-level data Published, Downloaded and AER since the start of operations, per data level, timeliness and (Level-2) user-level data type

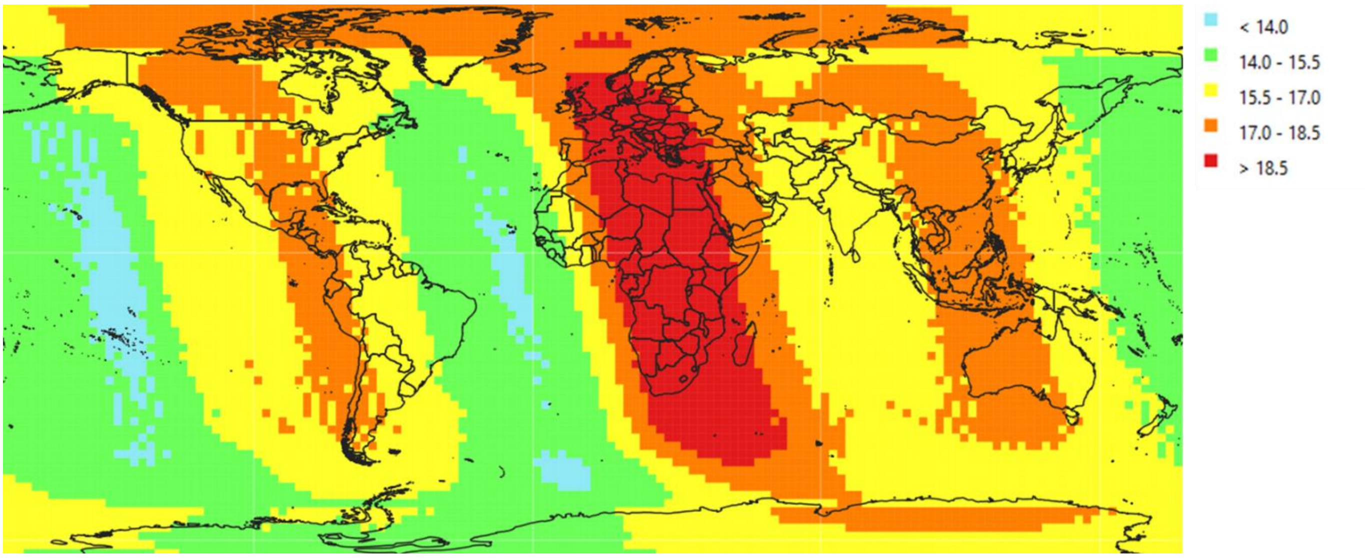


Figure 51: Heatmap showing the archive exploitation ratio for Sentinel-5P NTC (Level-1B & Level-2) user-level data during Y2021

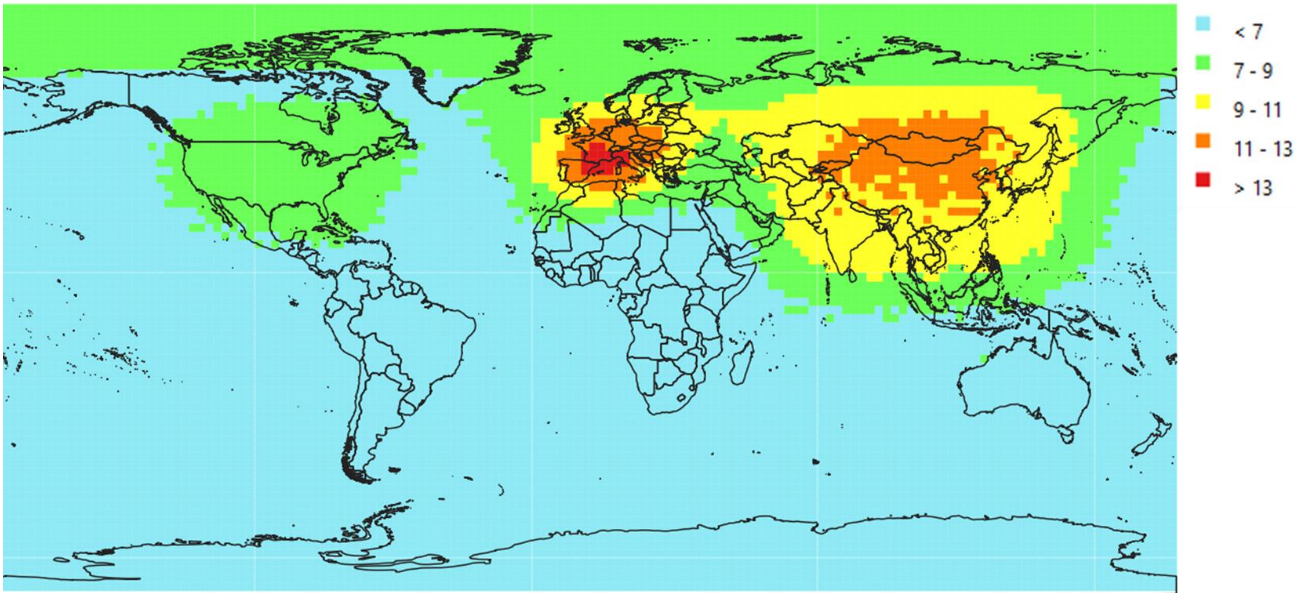


Figure 52: Heatmap showing the archive exploitation ratio for Sentinel-5P NRT (Level-2) user-level data during Y2021

Table 15 reports a detailed view of the take up of Sentinel-5P user-level data since the start of Sentinel-5P operations. AERs are presented for Level-1B and Level-2 user-level data, for both NTC and NRT and, for Level-2 user-level data, also per individual user-level data type.

There was a mild increase in the AER for Senitnel-5P user-level data overall, which rose to 1:29 from the 1:28 registered in Y2020. Within this rise, the Level 2 NRT AER actually decreased from 1:25.5 during Y2020 to 1:25.0; the AER for the Level-1B NTC increased from 1:15 in Y2020 to 1:17 in Y2021, but it still remains overall the least exploited Sentinel-5P user-level data; while for the Level-2 NTC there was a greater jump from 1:43 to 1:55 and Level-2 NTC remains the most actively downloaded user-level data for Sentinel-5P to date. The number of NRT published is ~7 times that of the NTC, the NRT statistic dominates in the overall statistic of the AER distribution for Sentinel-5P.

Within the highly exploited category of Level-2 NTC, by far the most popular user-level data were the Level-2 nitrogen dioxide (L2_NO2) and the methane (L2_CH4) user-level data, which had AERs as high as 1:132 and 1:124 respectively. The carbon monoxide user-level data (L2_CO) was almost as popular with another enormous AER of 1:91. Similarly, the uptake of the NTC Carbon Monoxide L2_CO___, which in

Y2020 had had AER of 1:75, also increased in Y2021 reaching 1:91.

As noted above, for the NRT user-level data there was a slight reduction in the overall AER in Y2021, down to 1:25.0 from 1:25.5 in Y2020. Within this group, it was the carbon monoxide and nitrogen dioxide user-level data which were most actively downloaded, with AERs of 1:39 and 1:38 respectively. It is interesting to note that only L2__CLOUD_ showed the highest change compared to Y2020, increasing from 1:12 to 1:13. The data type L2__O3__PR was introduced on November 2021 (16/11/2021 with OFFL timeliness and 24/11/2021 with NRTI timeliness) and showed an AER of 1:8. Thus overall, the growth of the AER of the Sentinel-5P NTC may justify the overall AER of Sentinel-5P increase from 1:27 in Y2020 to 1:29. Figures 52 and 53 show the heatmaps for Sentinel-5P NTC (Level-1B and Level-2) and NRT (Level-2A only) user-level data respectively. The footprint of NTC user level data encompass the entire orbit (portion daylight illuminated) and, surprisingly, the interest of Sentinel-5P NTC user-level data is the same as that seen in Y2020. It is suggested, therefore, that for the interest over Europe which then apparently extends through Africa and down into Antarctica, could be the result just of interest in user-level data covering Europe but which extend over a large latitudinal range (see Annex 2).

For NRT user level data, whose footprints are generally smaller, there is clearly an increased interest over the European continent, Central Asia and high northerly latitudes. There is also a (lesser) increase in interest over North America, with AER within the range 1:7 and 1:9.

2.3.3 Download trends

Hub	Number of User-level data Downloaded since Start of Operations	%	Volume of User-level data Downloaded since Start of Operations (PiB)	%
Open Access Hub	295,403,017	50	133.86	42
Collaborative Hub	184,967,804	31	122.92	38
Copernicus Services Hub	70,437,415	12	37.93	12
International Hub	40,336,789	7	25.60	8
All hubs	**591,145,025**		**320.31**	

Table 16: Number and Volume of user-level data downloaded since the start of operations, per hub

The hub experiencing the greatest load of download requests since the beginning of operations remains the Open Hub, despite the large year on year increases in the volume of data being downloaded from ColHub. At the end of Y2021, 50% of the total number of downloads since the start of operations had been made on the Open Hub, similar to the 47% at the end of Y2020, while ColHub shows 31% (33% during Y2020). ServHub shows a mild decrease to 12% with respect to the 13% of Y2020, while IntHub shows the same proportion compared to Y2020, remaining stable at 7% of the total.

Looking at the proportions by volume a similar split between the missions is seen. However, in this view, ColHub (38%) is now much closer to the Open Hub (42%), and this is likely to be accounted for by a larger number of high-volume Sentinel-1 user-level data being downloaded from the ColHub.

Table 17 below shows the average daily volume of downloads handled by each hub during November 2021, as well as the corresponding value for November 2020, and the percentage change between the two years. The average total daily volume of data downloaded by users across all hubs was down to 203.05 TiB in November 2021, having been 217.81 TiB in November Y2020, constituting a 7% decrease.

Three of the hubs experienced a decrease in the average daily volume of user downloads in the compared months, which potentially reflects the decrease of 21% of Sentinel-3 data being published in November 2021, as noted in Section 2.2.2. An exception was ColHub, on which the average daily download volume in November 2021 was very similar to that recorded for November 2020, with a mild increase of 4%. For ColHub, there was an average of 85.46 TiB downloaded per day which is actually higher than the average daily volume downloaded from the Open Hub in November 2021 and close to half the total daily average volume of user-level data disseminated from all of the hubs. ServHub shows the highest decrease in download volume, down to 22%, followed by IntHub with 16%.

Hub	Daily average volume (TiB) downloaded in November 2021	Daily average volume (TiB) downloaded in November 2020	% increase
Open Access Hub	83.12	92.53	-10%
Collaborative Hub	85.46	82.44	4%
Copernicus Services Hub	20.31	25.96	-22%
International Hub	14.16	16.87	-16%
All hubs	**203.05**	**217.81**	**-7%**

Table 17: Average volume of data disseminated per day during the last month of Y2021 and Y2020

The overall download volume was 3% lower in Y2021 (with 80.45PiB instead of 82.77PiB), and surprisingly given the average daily download volumes noted above, the hub with the highest percentage decrease in user-level data downloads was actually the ColHub, from which the total volume of data downloaded was 7% less than it had been in Y2020 (30.71PiB compared to 33.3PiB). In comparison to Y2020, 17% less Sentinel-1 data and <2% less Sentinel-3 data was downloaded from ColHub in Y2021, though <1% *more* Sentinel-2 and, as reported above, the Data Hub Relay contribution should also be taken into account.

A total of 33.5 PiB was downloaded from the Open Hub in Y2021, just marginally less than the 33.77 PiB downloaded from it in Y2020, and the Open Hub kept its place as the hub which disseminated the greatest volume of data during the year.

By contrast, the volume of user-level data downloaded from the IntHub actually increased in Y2021, rising by 12% from 5.64PiB in Y2020 to 6.35PiB in Y2021, perhaps due to the increased activity of the newest international account opened , which is discussed in more detail in Chapter 4.

Focusing on total downloads per mission during Y2021, Figure 54 shows the volume of user-level data which users downloaded from each hub and per mission during the year.

There was a 5.5% drop in the overall volume of Sentinel-2 data downloaded from all of the hubs, from 17.73 PiB in Y2020 to 16.69 PiB in Y2021, but it should be highlighted that the volume of Sentinel-2 data downloaded from IntHub actually increased significantly in Y2021: 3.32 PiB were downloaded, which represents an increase of 63% with respect to the 2.04PiB of Sentinel-2 data downloaded in Y2020. Overall, Sentinel-2 continues to constitute by far the most downloaded mission from the Open Hub, and this year was also the most downloaded mission from ColHub.

Sentinel-1 downloads decreased by 12% with respect to Y2020. For Sentinel-3, the decrease was slightly lower (less than 6%) and appears to have been driven mostly by a 22% decrease in Sentinel-3 downloads from ServHub, which fell to 0.75 PiB in Y2021 from 0.96PiB in Y2020.

a

Despite the overall downward download trends, the volume of Sentinel-5P data continued to rise, up from 3.58 PiB in Y2020 to 4.69 PiB in Y2021, which constitutes a 24% increase. This uptake was of course limited to the Open Hub, because throughout Y2020 it was still only possible to download Sentinel-5P data from the dedicated S5p Hub, and the figures for the dedicated S5P Hub are only included in the Open Hub download statistics.

Figures 55, 56, 57 and 58 separate out by Sentinel the total number of user-level data downloaded from each hub, to show the percentage share of the downloads per user-level data type.

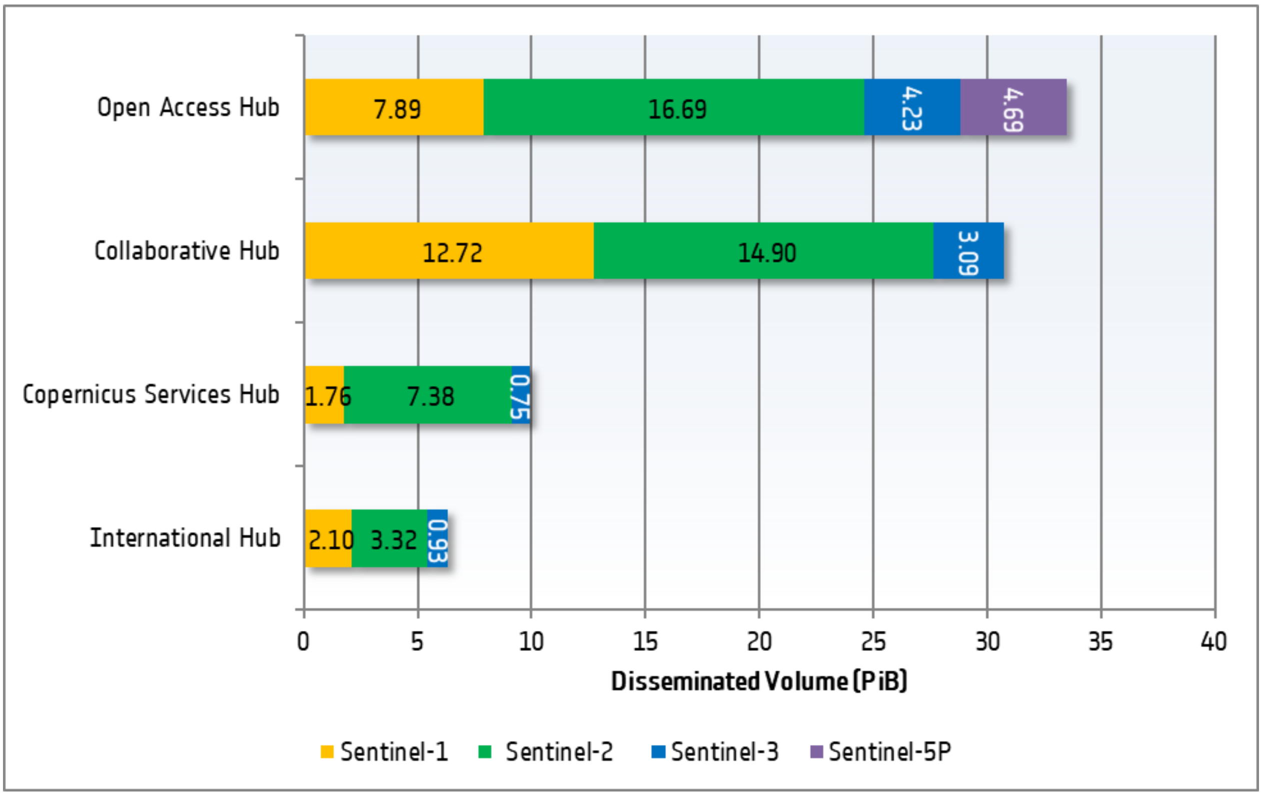


Figure 53: Downloaded volumes (PiB) during Y2021 per Hub and per Mission

Sentinel-1

The most frequently downloaded Sentinel-1 user-level data from all hubs during Y2021 were the Level 1-GRDH user-level data, like in the previous years. At the level of each individual hub, Level 1-GRDH user-level data were also the most frequently downloaded user-level data, making up between 28% (IntHub) and 59% (ServHub) of the number of user-level data downloaded from each hub. The exception was on ColHub, from which the most downloaded data type for Sentinel-1 was Level-1 SLC (32%), though by a small margin and the overall proportion of Level 1-SLC user-level data downloaded from all of the hubs in Y2021 did not change compared with the proportion in Y2020, at 23% of the total number of Sentinel-1 downloads. This year the Level 1-GRDM user-level data did not exceed 12% of the Sentinel-1 downloads from any of the hubs.

For Lo-RAW user-level data, interest on the Open Hub and ServHub, at 3% and 8% of the total respectively, was much lower than seen on IntHub and ColHub (24% and 16% respectively), suggesting that users of the latter two hubs are more likely to prefer to perform their own processing on raw data than users of the other hubs.

For the Level 2-OCN user-level data, there was negligible change with respect to Y2020. The number of downloads followed the same pattern as seen in Y2020, with the Level 2-OCN user-level data constituting 17-25% of the Sentinel-1 downloads from each hub except ServHub, on which they constituted only 6%.

Sentinel-2

Y2021 was the third consecutive year of Sentinel-2 Level-2A systematic publication. Interest in the Level-2A user-level data continued on each hub apart from on IntHub, where the decrease in the number of Level-2A user-level data downloaded from the Hub continued so that Level-2A user-level data constituted only 9% of the Sentinel-2 user-level data downloaded from IntHub in Y2021. On the Open Hub, Level-2A user-level data were a large proportion of the Sentinel-2 user-level data downloaded in Y2021, although overall Level-2A constituted a smaller proportion of the overall number of downloads of Sentinel-2 data from the Open Hub compared with Y2020, decreasing from 31% in Y2020 to 24% in

Y2021. There was also a decrease on ServHub: Level-2A user-level data constituted 35% of the total number of Sentinel-2 downloads in Y2021, whereas in Y2020 they had constituted 39%. The split in downloads from ColHub between Level-1C and Level-2A was equivalent to that in Y2020 (65% and 35% respectively).

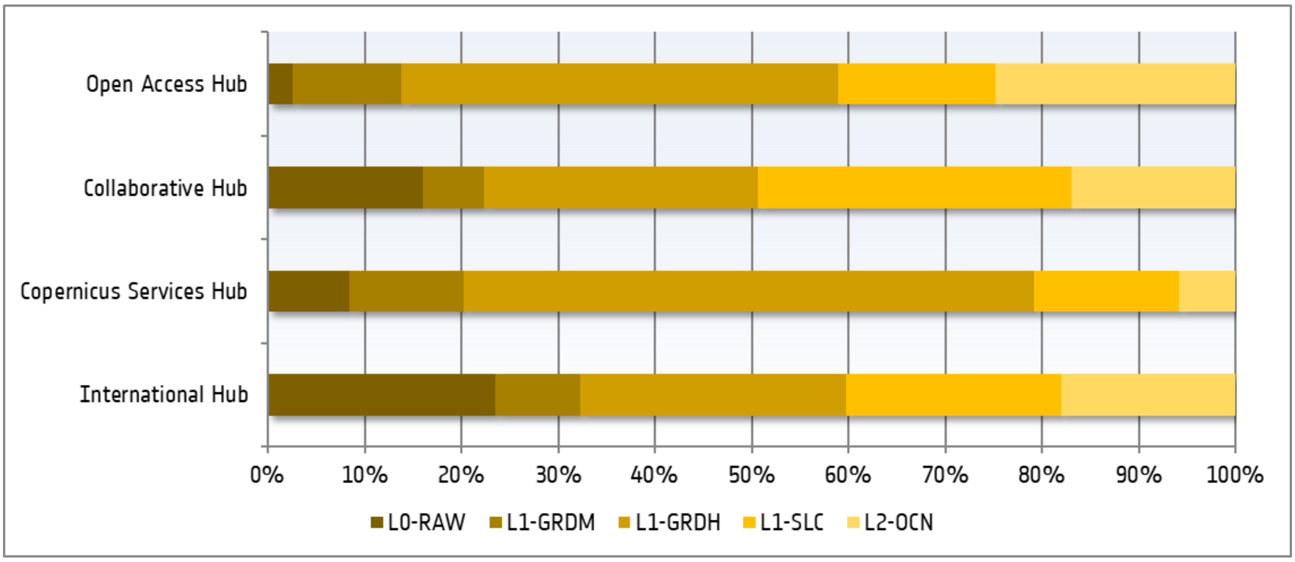


Figure 54: Percentage of total number of Sentinel-1 user-level data downloaded from each hub during Y2021 per user-level data type

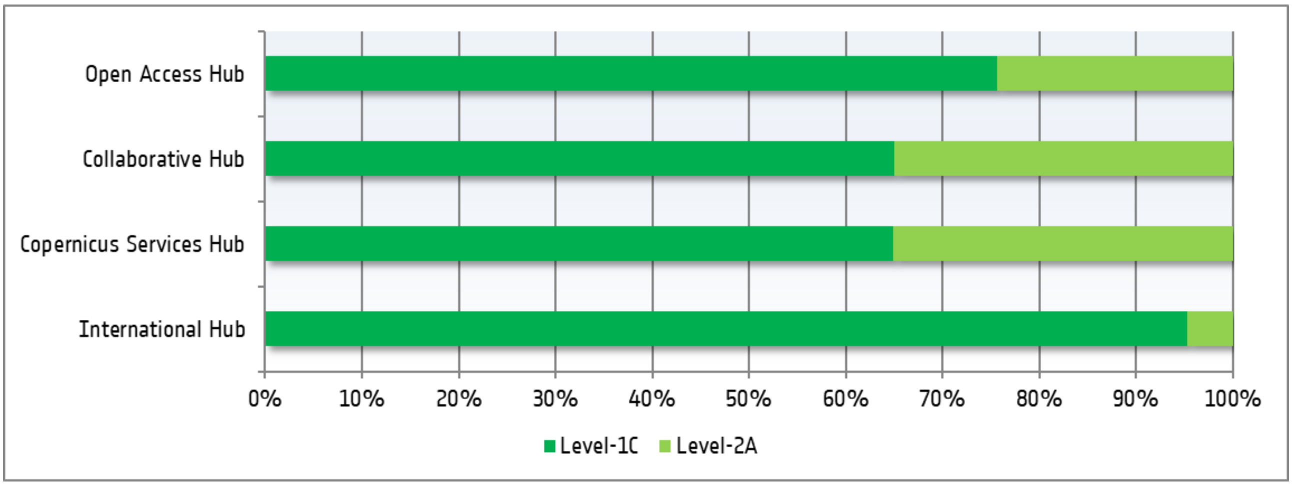
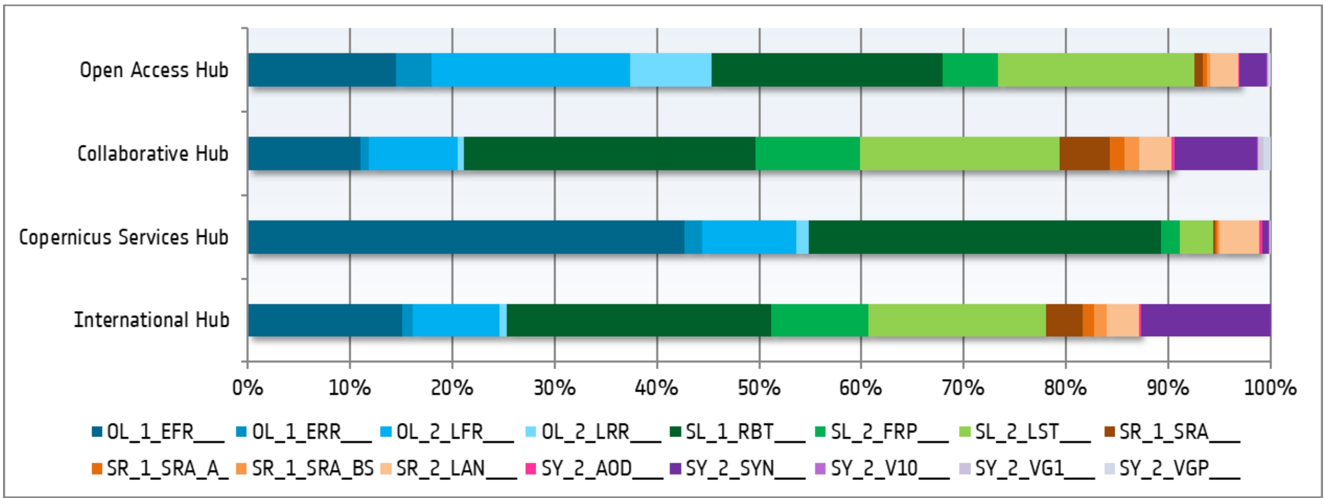


Figure 55: Percentage of total number of Sentinel-2 user-level data downloaded from each hub during Y2021 per user-level data type

Sentinel-3

With the new user-level data type SY_2_AOD___, there were 16 distinct user-level data types in Y2021 for Sentinel-3 (split between SRAL (4x), OLCI (4x), SLSTR (3x) and Synergy (5x)). The first graph in Figure 57 shows the percentage split of the overall number of Sentinel-3 user-level data downloaded from each of the four hubs per user-level data type. Given that individual user-level data types can be hard to distinguish on this scale, the second graph in Figure 57 shows the same proportions but with the user-level data combined into user-level data groups (each instrument plus SYNERGY user-level data). It is recalled that since Y2020 only one SYNERGY user-level data type (SY_2_SYN___) has been available on IntHub.

It is confirmed that the majority of downloads is accounted for by SLSTR and OLCI user-level data, which together ranged from 94% to 78% of Sentinel-3 downloads from each hub, as for the previous years. SLSTR constituted 57% of Sentinel-3 user-level data downloaded from ColHub, and 53% and 47% of Sentinel-3 user-level data downloaded from the IntHub and Open Hub respectively. From ServHub, however, it was OLCI user-level data which were the most frequently downloaded, at 55% of the total. SRAL user-level data constituted only a small proportion of the Sentinel-3 downloads from each hub, between 4-11%, and SYNERGY user-level data accounted for 13% or less.



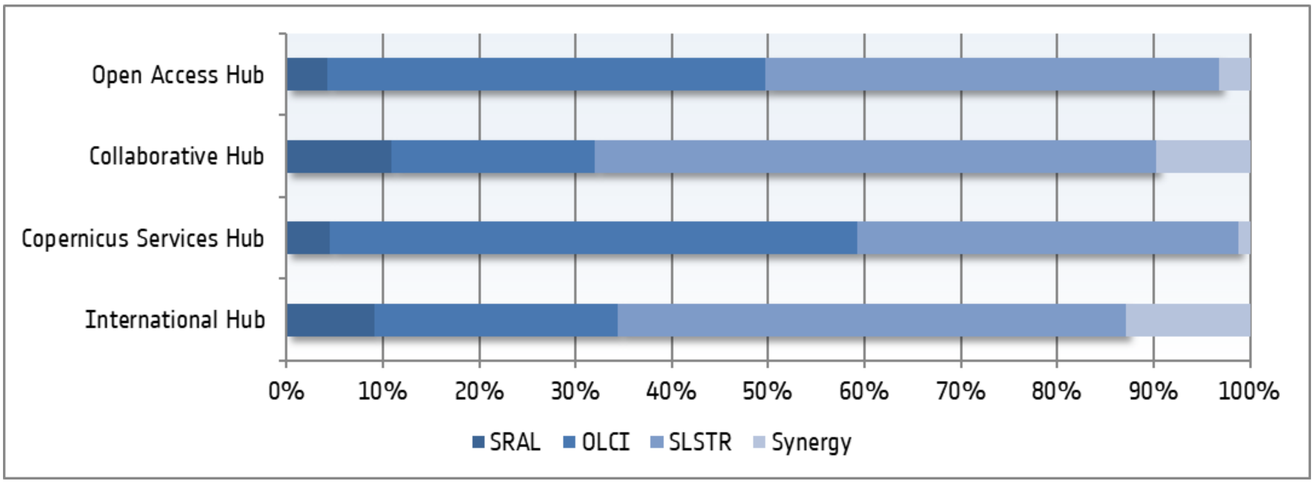


Figure 56: Percentage of total number of Sentinel-3 user-level data downloaded from each hub during Y2021 per user-level data type (graph 1) and user-level data group (graph 2)

Sentinel-5p

Due to the number of different Sentinel-5P user-level data which are published, the per user-level data download percentage is not shown. However, Figure 58 does show the download split on the Sentinel-5P Hub for the two data levels: Level-1B and Level-2. The download split per level was 5% Level-1B (998,177 user-level data) and a massive 95% Level-2 (17,832,213 user-level data)

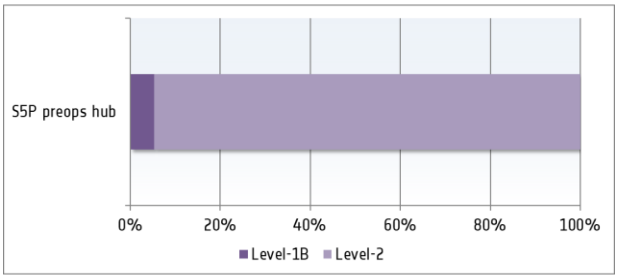


Figure 57: Percentage of total number of Sentinel-5P user-level data downloaded from S5p Hub during Y2021 per data level

Overall Monthly downloads

The graph in Figure 59 below shows the monthly volume of user-level data downloads made from each hub during Y2021, with the average monthly volume and number of downloads made on each hub during Y2020 included for comparison.

The average monthly volume of downloads was slightly lower than for the previous year from three of the hubs. The most significant variation is given by ColHub, from which the monthly average volume downloaded was 10% lower in Y2021 than it was in Y2020, with a monthly average of 2,562TiB/pcm of user-level data downloads in Y2021 compared to 2,842TiB/pcm in Y2020. The variation in the monthly averages compared to last year was between 1-2% for the Open Hub and ServHub. The exception was IntHub, on which the average monthly volume of user-level data downloads increased by 12% this year, rising from 481.24 TiB/pcm in Y2020 to 541.33 TiB/pcm in Y2021.

Looking more closely, however, in the period in which the transition to the cloud started (Dec 2020 – Feb 2021) the downloads from the Open Hub were higher than the average downloads registered in Y2020 and, in February, the downloads were 13% more than average of downloads during the previous year, while, on the contrary, the Collaborative Hub registered a decrease in downloads and, in February, the downloads from Collaborative Hub were 14% less than the Y2020 average. No deviation from the nominal download behaviour was observed in the other hubs during the first quarter of the reporting year.

It is worth highlighting that the fire incident which took place in March 2021 did not impact the download volumes; in fact, the Open Hub and ServHub registered respectively up to a 21% and 35% increase of downloads in the period March-April 2021 comperad to the Y2020 monthly averages.

Interestingly, this year there was not the usual dip in download activity in July and August (corresponding to the northern hemisphere holiday period) which has been observed in other years, and this year the notable dip occurred during the last quarter (September-November), especially for the Open Hub on which there was a 23% lower volume of downloads less than in the previous quarter (June-August).

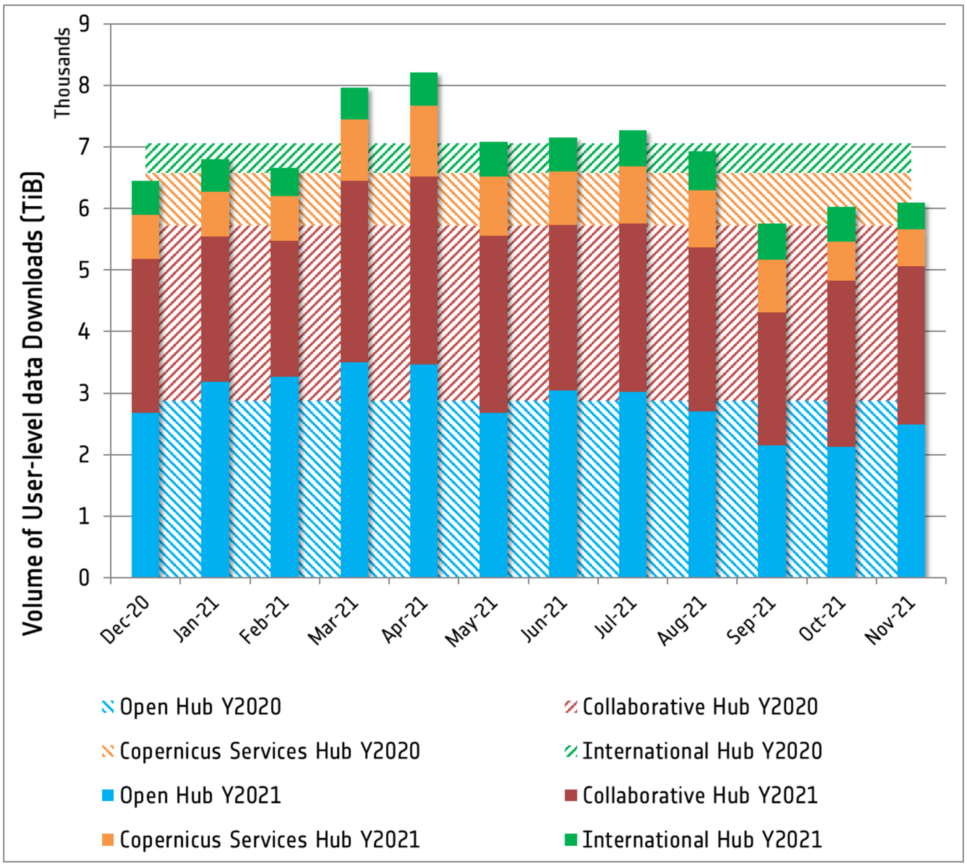


Figure 58: Dissemination volume trend per hub during Y2021, with Y2020 averages for comparison

DIAS Hub Downloads

Downloads by the DIAS service providers from the dedicated DIAS Hub have not been included in any of the download figures presented in the sections above. The DIAS service providers are necessarily systematic downloaders, who retrieve all or most of the published user-level data, meaning they are not likely to display any particular trends and are thus considered separately in this section.

Since the start of DIAS Hub operations in Y2018, a total of almost **134 million** user-level data have been downloaded by the DIAS service providers, comprising a total volume of **83.05 PiB**. In terms of the proportion of all downloads on all hubs since the start of operations, DIAS downloads now account for 19% by number and 21% by volume. During Y2021 alone, nearly 39 million user-level data were downloaded, making up a yearly volume of 22.90 PiB.

In terms of average daily download volume, 61.2 TiB were downloaded per day during November 2021. This was more than the average daily volume downloaded from either ServHub or IntHub, but less than the average daily volume downloaded from Open Hub and from ColHub.

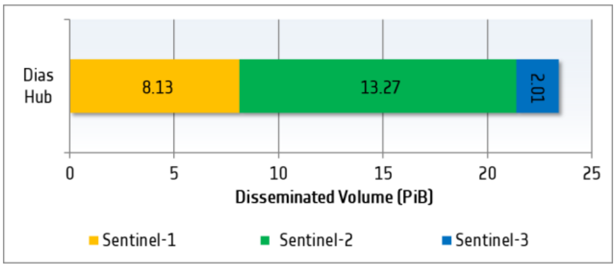


Figure 59: Disseminated volumes (PiB) during Y2021 per Mission on the DIAS Hub

Figure 60 shows the total volume of user-level data downloaded in Y2021 from the DIAS Hub, split by mission. The percentage split between Sentinel-1/Sentinel-2/Sentinel-3 is 35%/57%/9% (similar to the values registered last year).

2.3.4 Offline Data Retrievals

In Y2021, offline data retrievals have been based on an interface which retrieves the data from a DIAS infrastructure and unseals it in less than 60 minutes after the user's request, very much faster than the older solution based on the Long Term Archives (LTAs). This interface allows older user-level data to be removed from the online data store (i.e. moved nearline). Users can request access to these offline user-level data and all data remains available to all users. However, with the offline retrieval there is some amount of unavoidable time delay following the request, while the user-level data are retrieved from the archive. The threshold for this time delay is 24 hours, although in practice it is usually much less. Once retrieved and restored on the hub, user-level data are then available online to all users for download for a limited amount of time (at least 3 days), following which the user-level data are put offline again. A user quota on the maximum number of user-level data retrieval requests per hour is applied.

This retrieval scenario was transferred to operations for Sentinel-2 in September 2020, and then for Sentinel-1 and Sentinel-3 in November 2020. In this reporting period, responding to the user feedback pointing to limitations in the capacity for retrieval of historic data (quota exhaustion), the interface connecting to the DIAS infrastructure for the retrieval of historic data continued to be operational for all the period, except for four days following the fire incident in OVH in March 2021.

Nearline data are available for all data hubs except the IntHub.

Offline User-level data per mission

During Y2021, the rolling policy governing the period in which each of the published user-level data remain online has been tuned to satisfy the user request and optimize the functionality enabling the data retrieval from offline data storages. As shown in Figure 61, by the end of Y2021, a total of 41.86PiB of user-level data are available offline for retrieval, consisting of 16.01 PiB from Sentinel-1, 23.34 PiB from Sentinel-2 and 2.50 PiB from Sentinel-3.

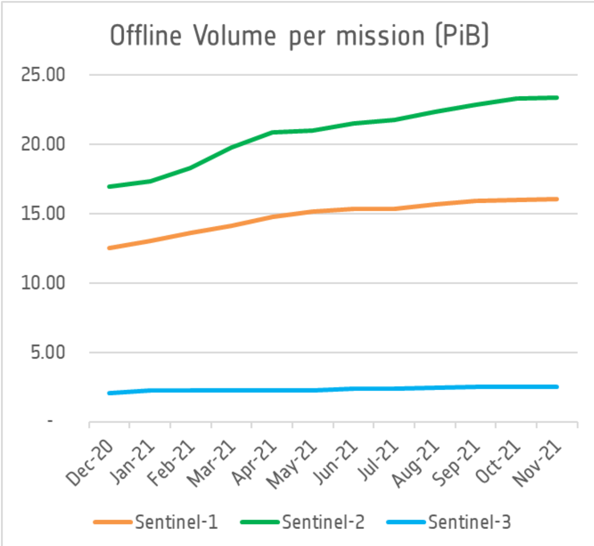


Figure 60: Cumulative growth of Offline user-level data volume (PiB) per mission during Y2021

Active Users of the Offline Data Retrieval

An active user of the offline data retrieval is defined as a user who submitted at least one request for the retrieval of an offline user-level data. It is worth highlighting, that the figures do not distinguish between requests which resulted in a successful data download and those which did not.

During Y2021, there were a total of 48,300 active users of the offline data retrieval, composed of 48,208 from the Open Hub and 92 from the other hubs. The table below shows the total number of active users of the offline data retrieval per mission and per hub. Note that the total of these is greater than the total given above, because a single user can request user-level data from more than one Sentinel.

Hub	Sentinel-1	Sentinel-2	Sentinel-3
Open Access Hub	15,119	38,108	3,434
Collaborative Hub	17	12	14
Copernicus Services Hub	36	48	14
DiasHub	6	6	5

Table 18: Total Active Users of Offline Retrieval during Y2021, per mission and per hub

It is interesting to note that of the 83,872 active users of the Open Hub in Y2021 (meaning a user who successfully downloaded at least one user-level data during the year either from the online or offline service), 57% of these submitted a request for an offline user-level data (in Y2020 there were just 37%). This calculation does not distinguish between those active users who made only a successful request for offline data and those who made a request for both online and offline data, but it does mean that only 43% of the Open Hub active users did not make a request for offline user-level data. Figure 62 shows the total number of active users of offline data retrieval per month during Y2021 (from December 2021), for each Sentinel. For Sentinel-1, there was an average of 2,210 active users per month for offline data, registering a 26% increase since last year. This number was almost constant during the reporting year, with a small increase in the May-July 2021 period.

Sentinel-2 continued to have always more than 4,000 active users per month and registered a sharp rise in active users of offline data retrieval in May 2021, when the number of active users went up from 4,000 to 9,000. This trend was already observed during last year in the same period but this time, it was not caused by the introduction of offline user-level data for Level 2A as appeared to be the case last year. It may, therefore, be due to some case-studies on vegetation growth that need to access the previous year's data for comparison with the current up-to-date data.

The active users of Sentinel-3 offline data retrieval increased gradually over the year, starting from 232 active users in December 2020 and rising to 572 active users in November 2021, more than doubling the active users at the end of Y2021.

User-Level Data Retrieval Requests

During Y2021, the number of requests for offline data retrievals was greater than 115 million.

Table 19 shows the number of requests per hub during the year. The total number of requests reported in Table 19 is twice the total number of retrieval requests made in Y2021.

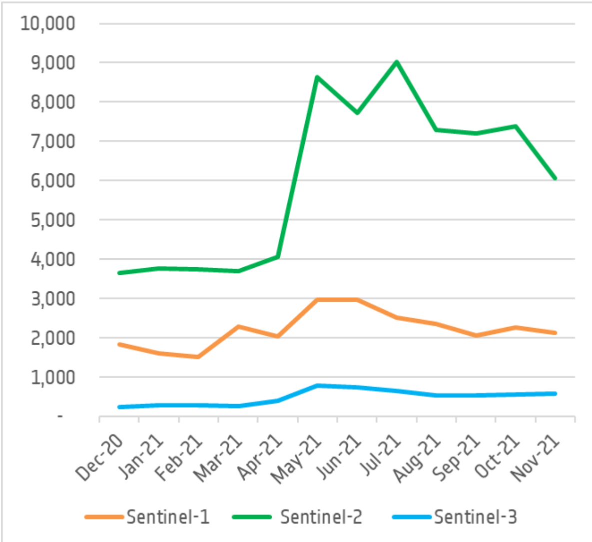


Figure 61: Total Active Users of Offline Retrieval per mission on the Open Hub per month during Y2021

Open Hub registered a 346% increase of user retrieval requests in Y2021 and this year made 97% of the requests, while users of the other hubs account for the remaining 3%. It is interesting to recall that this year the ServHub active users for Sentinel-2 and Sentinel-3 increased by 50% and 27% respectively but they made few offline retrieval requests.

In Figure 63, the totals are broken down to show the total number of requests per month and per hub (note that, in order to appreciate also the differences between hubs, the OpenHub user activity is represented separately).

It is worth mentioning that, following the transfer to the cloud, it was initially decided to keep the user-level data online for just one month and this policy was maintained until July 2021. This may explain the significant peak in user requests which started in April 2021, with an enormous increase in offline retrieval user requests, and in July 2021 the numbers reached more than 17 times the number registered in March 2021 (before the change in the online policy). From August onwards, the rolling policy of online user-level data was progressively changed and, from a user perspective, the user-level data were kept online up to 6 months. From the first of the graphs in Figure 63, it can be seen that the significant offline retrieval activity by the Open Hub users took place primarily in the period in which the rolling policy was changed to one month and when fine-tuning of the rolling policy took place: the increase of requests started from 5 million in April to 30 million in July, with the trend line following more closely the volume of user-level data being moved offline and the amount of user requests gradually decreased to 5-10 million from September.

The activity of the ServHub users of the offline retrieval services was more evenly spread throughout the year, starting from 5,000 requests in December 2020 to 120,000 in October 2021. A peak in retrieval requests was registered in March, with approximately 600,000 requests. It is suggested that this might have been due to users having difficulty retrieving data in the 5 days following the fire incident in OVH in which the offline retrieval service was temporary disabled, and so submitting multiple requests for the same data.

Hub	Numbers of retrieval requests in Y2021	%
Open Access Hub	112,364,572	97
Collaborative Hub	801,756	0.7
Copernicus Services Hub	1,540,776	1.3
DiasHub	998,727	0.9
TOTAL	**115,705,831**	

Table 19: Total offline user-level data retrieval requests during Y2021 per hub

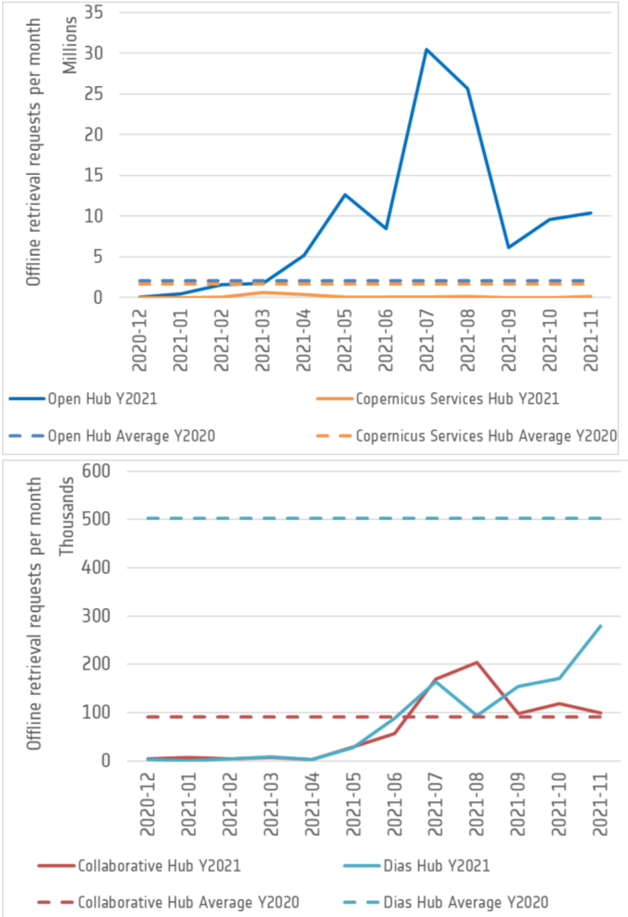


Figure 62: Total offline retrieval requests during Y2021, per month and per hub

As might be expected, and as was already observed last year, only a small interest in offline user-level data retrieval is visible from ColHub and DIASHub users. It is assumed that these users will have been downloading all of the user-level data they need at the moment they appear online on ColHub, and storing them on their own national data access sites, with no need to access the archived user-level data. In the second graph in Figure 63, it seems that there was moderate interest from ColHub users in offline user-level data in the months between May and September 2021, but it is recalled that the rolling policy of online data was 1 month so any requests of offline user level data may be led back to some delay in fresh user-level data retrieval from the ColHub users. It is interesting to note that after the online rolling policy was changed back to 6 months, the DIASHub user requests followed the opposite trend with respect to the ColHub users, and the number of retrieval requests started increasing month-by-month, reaching almost 300,000 requests in November 2021, although this was still lower than the average number of DIASHub retrieval requests registered in Y2020.

Restored User-Level Data and Retrieval Performance

Table 20 below shows the number of restored user-level data during Y2021 per mission and per hub. Note that, for reasons resulting from the infrastructure architecture, the ColHub, ServHub and DIASHub publish the same restored user-level data, so they are reported together in the table.

This year, the number of restored user-level data from the Open Hub was almost 7 times the number of restored user-level data from the three other hubs combined, and the number of the overall restored user level data from all the hubs was 2.4 times the Y2020 number (4,009,557 compared with 1,703,919). Most of the restored user-level data were Sentinel-2 user-level data (49%), followed by Sentinel-3 (32%) and Sentinel-1 (19%). Offline retrieval of Sentinel-2 user-level data was particularly high from the Open Hub, whereas for the other hubs, the majority of restored user-level data were Sentinel-3 user-level data.

Overall, it is noted that the total number of requests reported in Table 19 is 29 times the total number of user-level data which were restored in Y2021. This number becomes 32 times for the Open Hub and it is reduced to 6 times for the other hubs. The difference gives an indication of the number of retrievals which were either not successful or which were requests for user-level data which had already been requested by another user.

Hub	Sentinel-1	Sentinel-2	Sentinel-3	total per hub
Open Access Hub	612,026	1,815,678	1,072,575	**3,500,279**
ColHub/ServHub/DiasHub	167,236	132,869	209,173	**509,278**
Total	779,262	1,948,547	1,281,748	**4,009,557**

Table 20: Total offline user-level data restored during Y2021 per hub and per mission

Retrieval Timeliness

During Y2021, the overall average time it took between a retrieval request being made and the user-level data being restored to the hub, across all hubs, was **20 hours**. This was 1 hour and 32 minutes more than the average time it took during Y2020 but nonetheless remained under the 24 hour threshold communicated to users. However, there were considerable variations behind this figure. Figure 64 shows the average monthly retrieval timeliness across all hubs during Y2021. As can be seen from the graph, in May, September and October the average time for the retrieval of offline user-level data overpassed the 24 hours goal and, comparing this graph with the one in Figure 63, this behaviour cannot be associated to any specific increase in the user requests in the same period. It has instead been noted that in a specific week between the end of September and the beginning of October, 5.6% of the overall restored user-level data took more than 1 week to be restored, while 81.8% of data were nominally restored within 1 hour. The 5.6% appear to have been user retrieval requests which were just kept pending and not executed for days. This issue was solved by including an additional check on the retrieval requests submitted by users and their effective execution. In fact, the monthly average for restoring user level data in the following month (November 2021) returned to be well within the optimal delivery range (Figure 65 shows the detailed weekly average time to restore in the last 8 weeks of the Y2021).

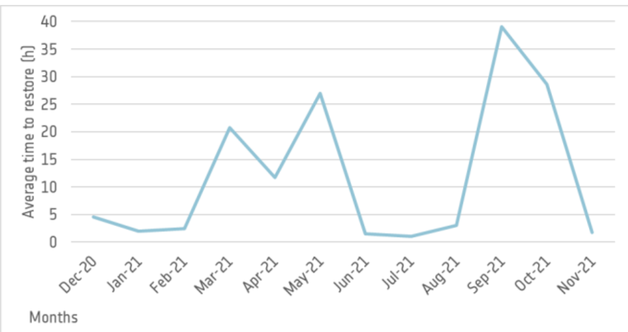


Figure 63: Monthly average time to restore of offline user-level data Y2021

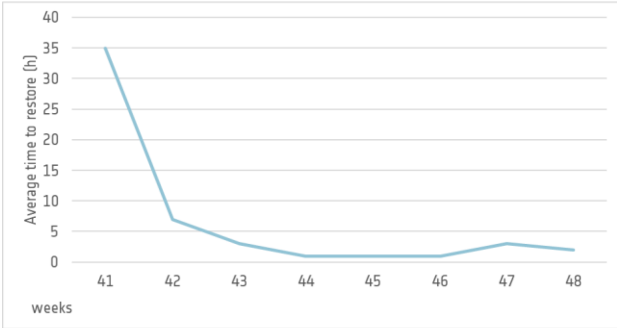


Figure 64: Weekly average time to restore of offline user-level data in the last 8 weeks of the Y2021

2.3.5 Downloads per Continent and Country

Another way of examining user-level data dissemination during Y2021 is by looking at the continents and individual nations which have performed the most downloads from the Data Access System. Tables 21 and 22 present views of the percentage of downloads (by number and by volume respectively) which were completed in each continent from each of the four main hubs during Y2021. The overall percentage split is also shown. For the case of Sentinel-5P, all downloads are made on the Sentinel-5P dedicated node of OpenHub, where the identity and locations of end users are not known. The assumption has therefore been made to take the total of Sentinel-5P downloads and split them per continent in the same proportion as the total [Sentinel-1+Sentinel-2+Sentinel-3] downloads split.

As in previous years, Europe continued in Y2021 to be the continent which made the most active use of Copernicus Sentinel data, making 67% of the total volume of user downloads from all of the hubs. For the sake of completeness, it is noted that if the downloads made by the DIAS service providers were taken into account in this breakdown by continent, the overall proportion of volume of downloads which were made by European users in Y2021 would rise 73.9%.

On the Open Hub, however, for which all continents have registered users, North American users accounted for 44.3% of the user-level downloads this year, having made almost 14.83 PiB of user level downloads, increasing by 15% the volume of downloads they made during the Y2020 (12.88 PiB), and becoming for the first time the continent with the most active user group on the Open Hub. The volume of downloads which European users made actually decreased by 12% with respect to the previous year, down to 12.84 PiB from 14.63 PiB in Y2020, and the European downloads accounted for 38.4% of the total volume of downloads. Also, the volume of downloads made by Asian users decreased to 4.21PiB (counting 12.6% of the overall downloads, lower than the13.6% registered in Y2020). In contrast, the proportions for Oceania (0.93PiB, up to 2.8% from 2.4%) and South America (0.43PiB, (up to 1.3 from 1%) have all increased slightly.

However, the same discrepancies which were observed in the previous year between the number of active users in a continent and the proportion of the downloads they make are still in evidence. While users from Asia made up 33.6% of the total number of active users on the Hub by the end of Y2021, they only accounted for 12.6% of the total number of downloads. Similarly, users from South America made up 12.3% of active users but only 1.3% of downloads. By contrast, users from North America constituted only 17.3% of active users but accounted for 44.3% of downloads. These figures seem to indicate that many North American users download data in large quantities, while the Asian and South American users choose to download a more specific selection of data.

It is also interesting to note the differing intensity of activity on IntHub between the continents. It is particularly striking that such a high proportion (12.2%) of the user-level data downloaded from IntHub were downloaded in Oceania because there is only one partner connected to IntHub from Oceania, Geoscience Australia (see Section 4.2). It is also exciting to see that the activity from the more recent international partners is growing Asia (India) and South America (Chile, Brazil and Colombia). It is not yet possible to characterise the use being made by the partners in each continent according to their differing volumes of downloads, though, because it is still such early days for the new sites, and the statistics are not comparable across sites. For instance, although there are now three international accounts in both North America and South America, the data access sites in North America were already operational even before the start of Copernicus, whereas the three South American sites are being specifically built, following the signature of the Copernicus cooperation arrangement with the EU, to house and distribute the Copernicus Sentinel data.

ColHub and ServHub are almost entirely dedicated to Europe, in line with the programmatic role of the hubs, with the continent accounting for 99.8% and 100% of total number of downloads respectively. The small amount of non-European (North American) downloads on the ColHub (0.2%) are accounted for by the Canadian Collaborative Ground Segment.

The remainder of this section focuses on download statistics from the Open Hub alone

Continent	Open Access Hub	Collaborative Hub	Copernicus Services Hub	International Hub	Overall
Europe	38.4	99.9	100	2.3	66.6
North America	44.3	0.1	N/A	81.0	18.6
Asia	12.6	N/A	N/A	1.6	11.6
Oceania	2.8	N/A	N/A	12.2	2.1
South America	1.3	N/A	N/A	2.9	0.8
Africa	0.5	N/A	N/A	0	0.2

Table 21: Percentage of Y2021 downloads (by volume) per Continent and per Hub and overall

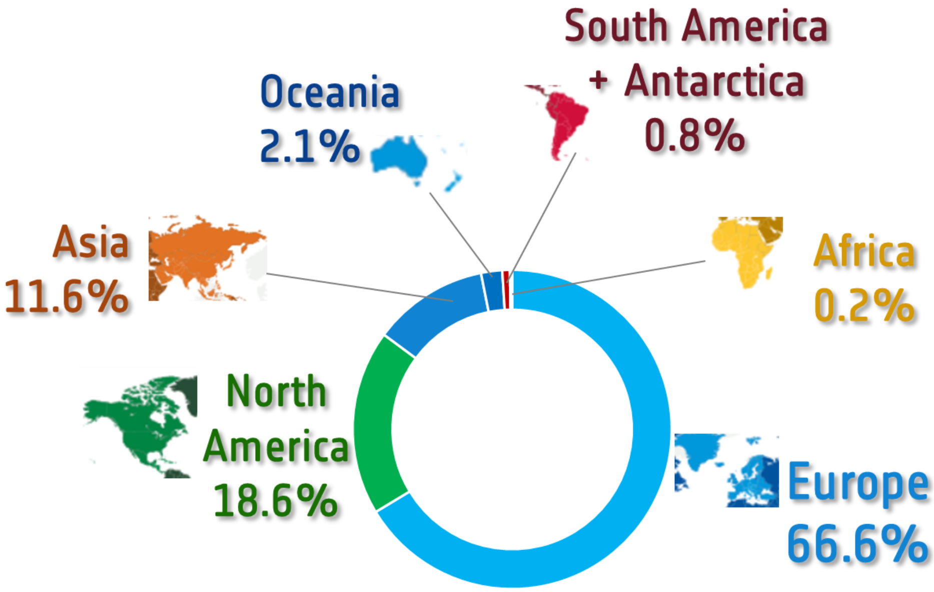


Figure 65: Overall percentage split of Data Access System downloads (all Hubs) by number, per Continent, during Y2021

Continent	% of Sentinel-1 Downloads during Y2021	% of Sentinel-2 Downloads during Y2021	% of Sentinel-3 Downloads during Y2021	% of Y2021 Downloads
Europe	44.3	31.9	44.6	38.4
North America	38.5	47.2	49.8	44.3
Asia	12.6	15.1	4.6	12.6
Oceania	3.6	3.0	0.8	2.8
South America	0.5	2.0	0.1	1.3
Africa	0.5	0.7	0.1	0.5

Table 22: Continental percentage split of Y2021 downloads (by volume) on the Open Hub, for each Sentinel mission and overall

Open Hub Focus

Table 22 breaks down the overall per continent figures for the Open Hub in Y2020, showing the percentage split between the continents of downloads from each Sentinel mission during the year. It is again recalled that the nationality of users on the Open Hub is based only on the information they themselves provided during registration; no further verification is performed (e.g. via IP check). It is also recalled that statistics for Sentinel-5P are not included as all downloads are still on the dedicated node of the OpenHub, as mentioned above, and it is not possible to categorise the users of the dedicated node.

Table 22 shows that this year the sequence of continents is no longer the same for all Sentinels, and there is evidently a growing popularity of Sentinel data around the globe. While European users still downloaded the highest volume of Sentinel-1 user-level data in Y2021 by a long margin (44.3% of total Sentinel-1 downloads), it was the North American users which downloaded the highest number of both Sentinel-2 and Sentinel-3 user-level data, as it was for the past year. The sharp increase in interest from North American users was particularly striking for Sentinel-3 user-level data. Overall, Sentinel-3 downloads by European and North American users together made up a huge 94.4% of the total number of Sentinel-3 downloads.

It is recalled that, even if there was a 6% decrease in the overall volume of Sentinel-3 data downloaded during Y2021, Europe actually downloaded 9% more

Sentinel-3 data than in Y2020: more than 1.88PiB of Sentinel-3 user-level data were downloaded in Europe during Y2021, whereas in Y2020 the downloads were 1.72PiB.

It is also highlighted that the North American proportion includes the mass downloads of Sentinel user-level data which are made by the US corporate cloud service providers, which source their Copernicus Sentinel data directly from the Open Hub.

In Asia, interest remains clearly tipped towards Sentinel-1 and Sentinel-2 data, with Asian users having made respectively 12.6% and 15.1% of the total number of downloads, and their proportion of Sentinel-3 downloads having decreased further, from 8.7% in Y2020 to 4.6% in Y2021. A similar preference is shown by Oceanian users, which this year showed similar levels of interest in Sentinel-1 and Sentinel-2 but made only 0.8% of Sentinel-3 downloads.

A notable increase in the interest in Sentinel-2 user-level data in South America and Africa is indicated, with the proportion of downloads made by the continents rising from 1.4% to 2.0% and from 0.4% to 0.7% respectively in Y2021.

	Sentinel-1		Sentinel-2		Sentinel-3	
	Country	Y2021 Number of user-level data downloads	Country	Y2021 Number of user-level data downloads	Country	Y2021 Number of user-level data downloads
1	France	1,644,034	France	3,499,449	Germany	2,134,768
2	Germany	601,044	Germany	2,214,644	Italy	1,933,028
3	United Kingdom	419,642	Slovenia	870,850	Czech Republic	582,173
4	Italy	168,382	Spain	662,888	United Kingdom	483,888
5	Norway	151,149	United Kingdom	392,229	Spain	405,538
6	Spain	136,384	Poland	367,718	Norway	333,226
7	Denmark	107,470	Italy	301,731	Belgium	262,259
8	Finland	90,195	Latvia	150,270	France	173,616
9	Slovenia	80,727	Austria	138,691	Denmark	151,747
10	Switzerland	58,616	Switzerland	134,129	Poland	94,349

Table 23: Top 10 ESA/EU states by number of downloads in Y2021 on the Open Hub, for each Sentinel mission

Focussing specifically on user activity in Europe, Table 23 above presents a breakdown of the ten ESA/EU member states with the highest number of downloads for each of the three Sentinels during Y2021. It is exciting to see that this year there are four new countries in the lists, Finland, Latvia, Austria and Czech Republic, and for all but Czech Republic, this is the first time they have appeared among the top Sentinel downloaders. The Czech Republic was the third most active downloader of Sentinel-3 data in Y2021. The usual five nations which regularly appear as top 10 downloaders for all the missions (France, Germany, Italy, Norway and the United Kingdom) mostly appear as usual in the top 10s for each of the Sentinel missions, but surprisingly this year Norway was not one of the top 10 downloaders of Sentinel-2 data. By contrast, Spain entered the top 10 for Sentinel-1 downloaders and so became the other state to feature in each of the top 10s. Another change compared with Y2020 is that the top downloaders overall this year were the French users, who downloaded 7,278,251 user-level data (30% more than the 5,598,630 they downloaded last year), and overtook the German users who this year downloaded 4,950,456 user-level data. The French users downloaded the highest number of both Sentinel-1 and Sentinel-2 user-level data but, it was the German users who gain downloaded the highest number of Sentinel-3 user-level data. Slovenia jumped from tenth place to third place in the list of top Sentinel-2 downloaders, and Switzerland joined the Sentinel-2 list. Poland, Sweden and Portugal dropped out of the top 10 for Sentinel-1 downloads; Belgium dropped out of the Sentinel-2 list, along with Norway; and Portugal also dropped out of the Sentinel-3 list.There was a particularly notable increase in Sentinel-3 activity by the Italian users this year: they were the second highest downloaders for Sentinel-3, up from 4th place, and this year they made almost 4 times as many Sentinel-3 downloads as they had in Y2020 (last year they made ~ 500,000Sentinel-3 downloads and this year they almost reached 2 million).

It is recalled that the distribution of user downloads from the Open Hub is not necessarily a good indication of national interest in data from the Copernicus Sentinels, since the data may now also be accessed through many national mirrors and via the DIAS initiatives as well.

2.3.6 Fresh vs Old User-level data

Download statistics can be further examined by looking at the age of the user-level data which are downloaded on each hub. This provides an understanding of the extent to which users are interested in historical data in addition to new publications. Even though a rolling policy is now applied to each of the hubs, determining when a user-level data is removed from online access, that data can still be retrieved from all hubs except the IntHub. However, a time lag can be expected as the user-level data is retrieved from an external source.

The graphs in Figure 67 below show, for each Sentinel mission and per Hub, the percentage of downloads during Y2021 for user-level data within six age ranges (measured from the date of publication). These are:

- 0 – 2 days
- 2 days – 1 week
- 1 week – 1 month
- 1 month – 3 months
- 3 months – 1 year
- > 1 year

The first observation to be made is that – as in previous years – there is a clear preference for newer user-level data over old. This is to be expected for several reasons: many user applications are likely to have a preference for the most recent data; most large-scale downloaders are already likely to have the older data they are interested in, with downloads focusing on the latest available data; and, as the operations mature, not only is the infrastructure supporting the downloads increasingly fine-tuned but users are also getting more experienced at optimising the download processes on their side.

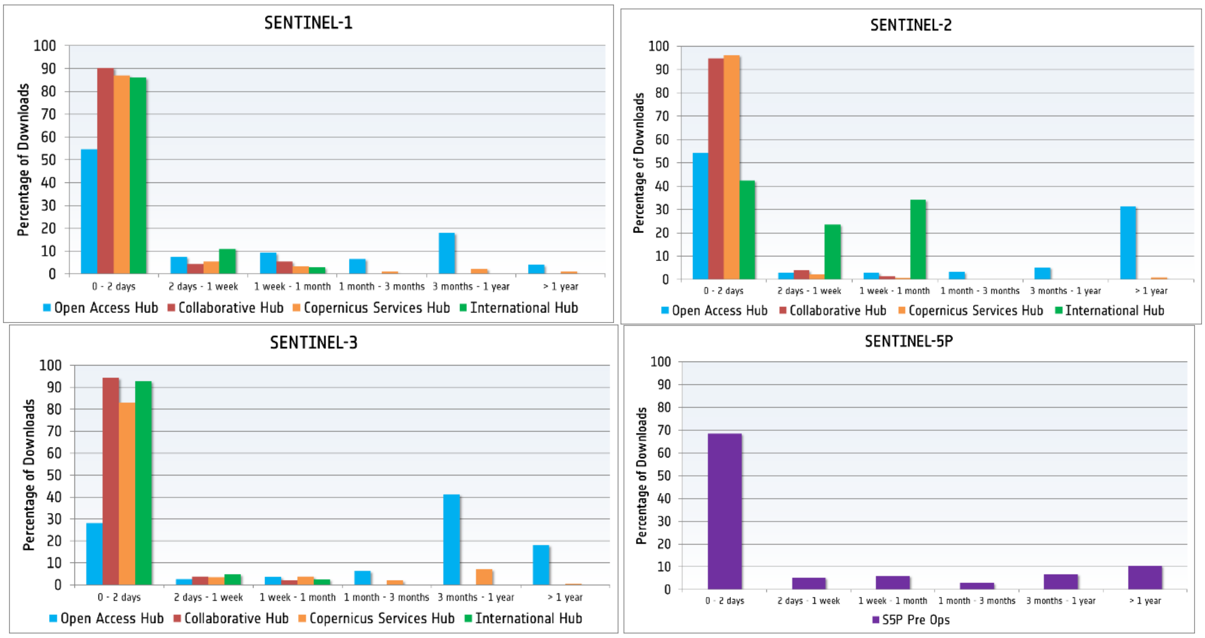


Figure 66: Percentage of Y2021 downloads per user-level data age range each Sentinel mission and per Hub

However, it is interesting to note that this preference for fresh data is distinctly more marked on ColHub, from which around 90% of the data downloaded in Y2021 was from the time range 0-2 days, irrespective of the mission. Users of ServHub also mostly showed the same marked preference, and this year there was no notable difference for Sentinel-3 data: during past years the Sentienl-3 downloads from ServHub were distributed over more than one range and only 40% were on the 0-2 day range.

A slightly different bias is seen from the IntHub users, for whom the freshness of the Sentinel-2 data again appears to have been less critical. Whereas approximately 90% of the Sentinel-1 and Sentinel-3 data which IntHub users downloaded was from the 0-2 day range, for Sentinel-2 this dropped to 42% of downloads, with the remainder of the data downloaded falling in either the 2day-1week or 1week–1month time ranges. This is also a very similar pattern to that which was seen for Sentinel-2 downloads from IntHub in Y2020, in which only 54% of Sentinel-2 data downloaded was from the 0-2 day range and the rest was evenly split between the 2days–1week and the 1week–1month ranges.

On both the ColHub and the IntHub, no downloads were made of data older than 1 month. For the IntHub, this was inevitable given that the rolling policy removes all user-level data from the Hub after 3 weeks, and the interfaces for retrieving the historic data are not available for the IntHub. On ColHub, the rolling policies vary according to the Hub node: node 2 and node 3 of ColHub have respectively 2 and 3 weeks, while node 1 has a 1 year rolling policy.

On the Open Hub, the preference for newer data is still clear (except for Sentinel-3) but it is less pronounced. Downloads for user-level data in the 0-2 days category accounted for 55% for Sentinel-1, 54% for Sentinel-2, and as much as 68% for Sentinel-5P. For Sentinel-3, however, the most downloaded range was user-level data between 3months - 1year, constituting around 41% of the total Sentinel-3 downloads from the Open Hub, and as much as 18% were downloads of Sentinel-3 data older than 1 year, while only 28% of the Sentinel-3 downloads from the Open Hub were in the range 0-2 days. Another notable deviation from the norm is that the second highest portion of Sentinel-2 downloads (31%) was actually of data older than 1 year, which is conceivably linked to users within the major 'Land' user group needing to compare data for specific crop seasons across the years for agricultural applications.

The greater uptake of older user-level data on the Open Hub compared with the other hubs is possibly due to the open registration policy and the continuing growth in the number of new users registering, which has already been discussed. As new users discover the service, there will likely be some who need historical data over the areas they are interested in.

For Sentinel-5P, 68% of downloads from the dedicated Hub were in the 0-2 days range. The remaining 32% of the data Sentinel-5P users downloaded was fairly evenly split between all of the other time ranges, with a small weighting in favour of data older than 1 year (10%)

2.3.7 Dedicated Access Points

Copernicus Atmosphere Environment Monitoring Service (CAMS)

In order to feed the Copernicus Atmosphere Monitoring Service (CAMS) data assimilation chain with atmospheric component measurements from the Sentinel-5P TROPOMI with the best timeliness available, CAMS has been provided with access to the Sentinel-5P Payload Ground Segment internal dissemination point (ftp server).

During Y2021, a total of 11.2 TiB of data was downloaded by CAMS, corresponding to the relevant production of Sentinel-5P L2 data for Carbon Monoxide, Methane, Nitrogen Dioxide, Sulphur Dioxide, Ozone and Formaldehyde.

All Near Real Time Level-2 user-level data are also routinely provided to EUMETSAT for redistribution via EUMETCast, since 29 August 2019.

2.3.8 Data Hub Relays

The flow of user-level data downloaded from ColHub to the Collaborative national mirror sites is summarised in Figure 68. Data is either downloaded directly from the ESA nodes by the national mirror site or it is downloaded by one of the partners participating in the Data Hub Relay (DHR) network, and from there either exchanged between the other network partners or relayed directly to a national mirror site. During the reporting period, the user-level data exchanged in the DHR Network were from all the missions, including Sentinel-5P which was introduced this year in the exchanges between relays.

The DHR Network was initially set up in late 2016. The number of relays had grown to 7 by the end of Y2018, but, two relays were decommissioned in Y2019, , and in Y2020 two of the relays were operated on a best efforts basis. During Y2021, a new node in Greece was added, and the two nodes in the UK which had previously either been deactivated or was working on a best efforts basis, were both re-activated.

So at the end of Y2021, the team of DHRs consists of 6 nodes and there were DHR partners in the following member states:

- Norway, operated by MET;
- Austria, operated by ZAMG;
- The Czech Republic, operated by CESNET;
- 2 nodes in UK operated by AIRBUS and STFC
- Greece, Operated by NOA

Moreover, on 1 September 2021, a project dedicated to the support of Collaborative Data Hub Software Maintenance and Evolution Services started, in order to be ready for Digital Twin Earth.

During Y2021, the disseminated volume from ColHub nodes jumped from 13.12 PiB in Y2020 to 42.08 PiB in Y2021 and reached an average daily volume of 70.64 TiB. The decrease in the volume of data exchanged between the DHRs in Y2021 as compared with Y2020, shown in Figure 69 below, is a consequence of the fact that two of the six relays were operating on best efforts for a quarter, and therefore the exchange of the data on these nodes was reduced for a period.

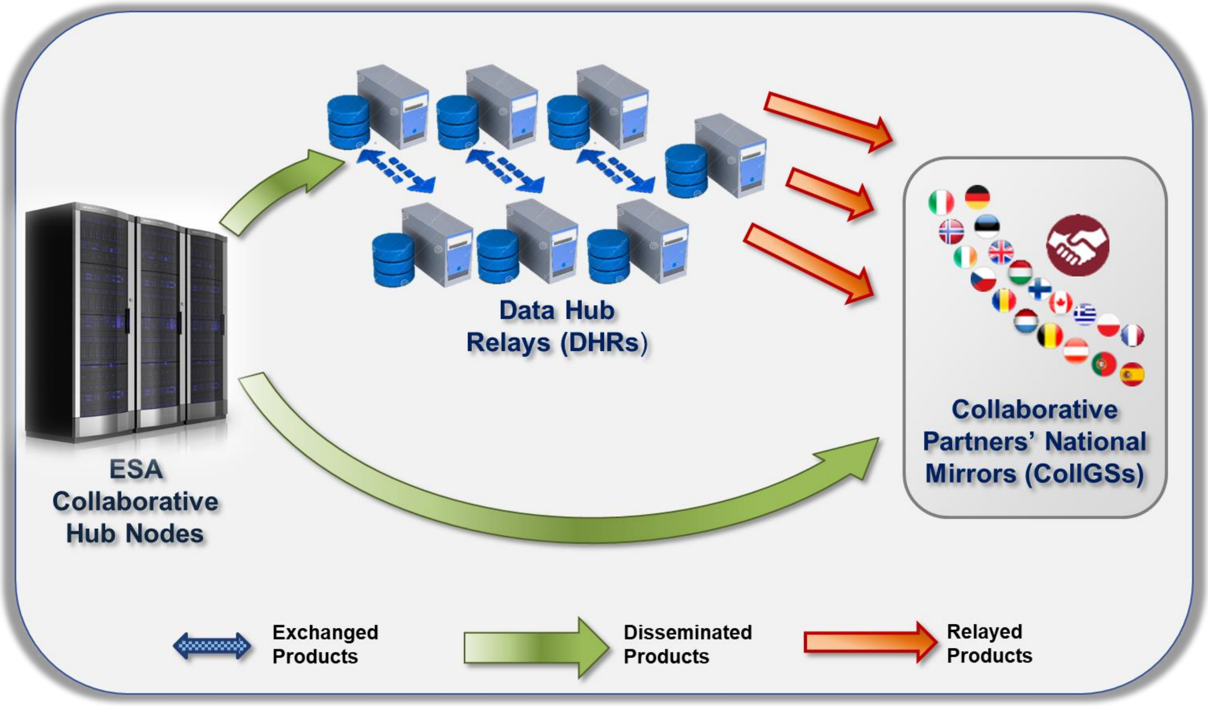


Figure 67: Schematic showing general data flow of user-level data from the Collaborative Data Hub to the Collaborative National Mirrors, highlighting the terminology used

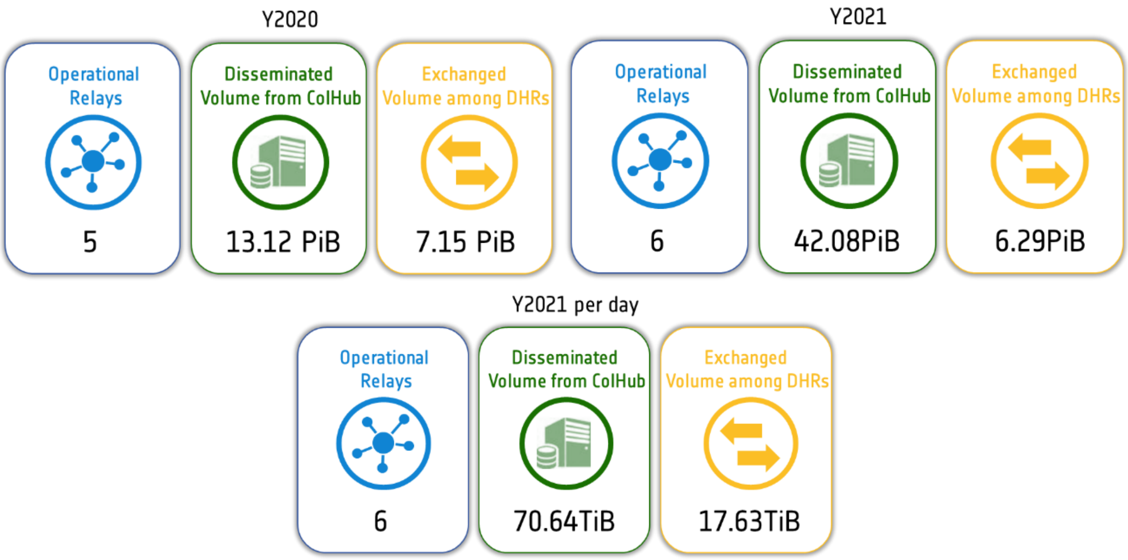


Figure 68: Overall Data Hub Relay statistics for Y2021 vs 2020, with Y2021 per day averages

Overall, the Network continued to demonstrate the importance of having alternative data sources to support ColHub in the dissemination of Sentinel user-level data towards the Collaborative Ground Segment partners. 55% (23.18 PiB) of the volume downloaded from ColHub was delivered directly to Collaborative mirror sites, whereas 45% (18.90 PiB) was delivered via the DHR Network. This percentage split shows the extent to which the DHRs reduce the load on ColHub.

Figure 70 below presents the evolution of the DHR network data volumes since the beginning of DHR operations (i.e. between December 2016 to 30 November 2021). It shows the monthly volumes of disseminated user-level data from ColHub to the Collaborative mirror sites (blue columns), from

ColHub to DHRs (in orange) and the volumes exchanged between DHRs (in grey). The graphs give an overview of the trend in the data flow from ColHub and through the DHR Network. Overall, there has been a marked rise in the number and volume of data moved around the network of Collaborative Ground Segment access points in the first 3 years since the start of DHR operations. However, during Y2020 there was a considerable decrease in activity, due to the reduced number of DHRs participating on a full operational basis in the DHR network. In Y2021, as would be expected with two nodes reactivated and an additional node joining the network, the overall activities increased again and the volumes surpassed even the levels seen in Y2019. In September 2021, there was a particularly notable peak in the volume of data being passed around the network, with nearly 55 flowing around and out (in September the overall volumes reached 5.30PiB). By November 2021, 4.2PiB of data was being passed around the network, up 117% from the 1.92 PiB which was recorded in November 2020. The number of user-level data and the volumes involved in Copernicus data dissemination is growing each year, and the involvement of the DHR Network remains an important part of the overall dissemination architecture for Sentinel data. The data volumes, as reported in Figure 70 above, give an idea of the 'effort' made each day by the Network: an average of 53.75 TiB of data is disseminated to the Relays each day, composed of an average of about 89,000 user-level data.

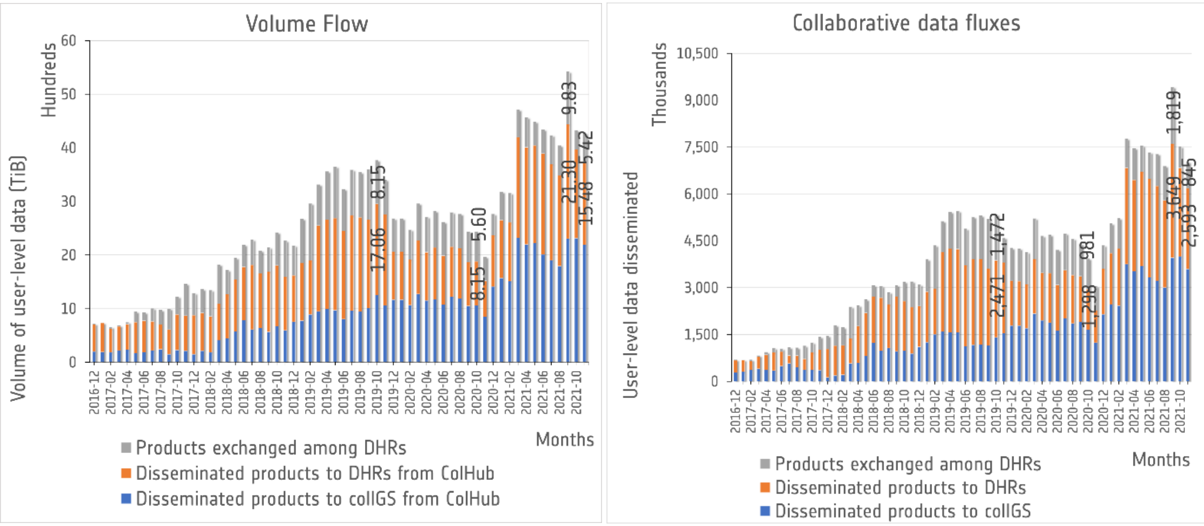


Figure 69: Total data flows in terms of Volume (left) and number of user-level data (right) during the last 5 years

3 User Activity

3.1 Active Users

For the purpose of this report, an 'active user' is defined as a user who is both registered and who has performed at least one complete download within the reporting period (Y2021). However, users who did not perform a complete download were not necessarily 'inactive': if a user chooses to extract only a specific granule or tile from a user-level data, this is not counted by the system as a complete download and hence users who only made partial downloads would not be classed as active users. In addition, users may have downloaded only user-level data metadata from the Sentinel archive, for instance to create an independent catalogue for future use. Moreover, an 'active user' is defined strictly on the basis of downloads and does not include users who log into their accounts or perform searches via the GUI.

For each of the four hubs, the total number of active users, together with this figure as a percentage of each hub's total number of registered users, is presented in Figure 73. The variation in these figures generally reflects the different use constraints of the hubs. For example, given that the ColHub and IntHub were established for the use of national institutions, with each partner institution using only one user account, it was expected each of these partners would use their accounts during the period. This is shown to be the case: 100% of registered users were active users.

At the other end of the scale, the Open Hub is open worldwide to anyone who wishes to register an account. It therefore has far more registered users and, as expected, a lower percentage of active users – 17% this period. This is a slightly lower percentage than the 19% calculated for Y2019, but in terms of absolute numbers, there were 18% more active users in Y2021 than in Y2020 (see Figure 74).

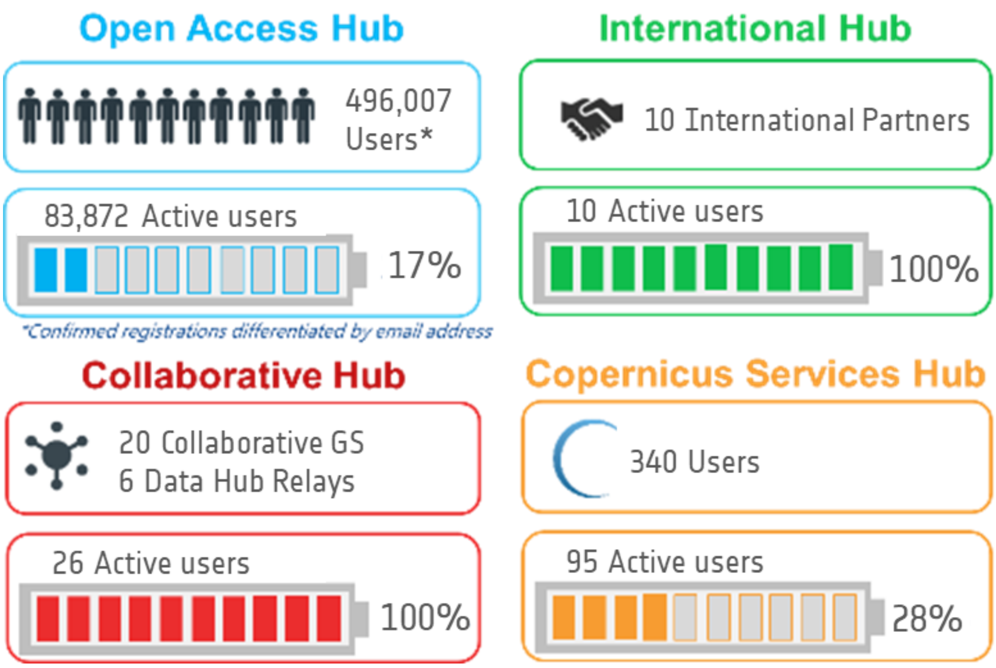


Figure 72: Registered and Active users per hub during Y2021

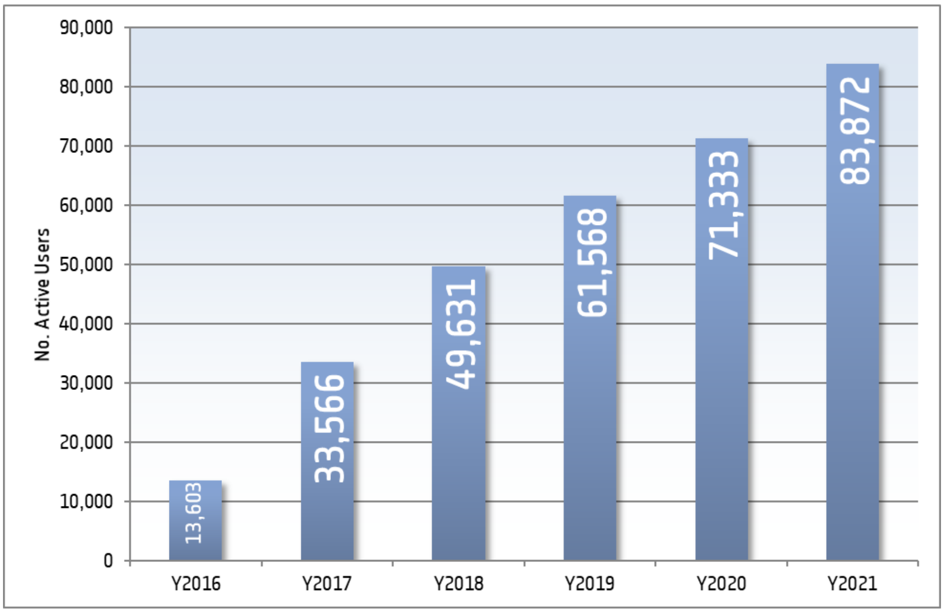


Figure 73: Growth in numbers of active users on the Open Hub between Y2016 and Y2021

3.2 User downloads profile

This section examines the distribution of user downloads across each of the hubs and for all active Sentinels during Y2021. Sentinel-5P is not yet included as it is still only available on the dedicated Hub, which all users access with the same password so no differentiation of accounts is possible.

Figure 75 shows, for each hub and each mission, the download ranges observed among the active users during Y2021. The overall trends remain similar to those of the past years and are generally as would be expected. For the ColHub and IntHub, almost all active users were downloading in the range '>1,000 user level data', and this corroborates with the assumption that the Collaborative mirror sites and international partners would routinely retrieve all, or a significant proportion of, the published user-level data in order to make them available on their national sites. In both cases, the few users in the lower categories are likely to be due to the arrival of new users whose services are not yet fully operational (see section 4).

The opposite trend is observed on the Open Hub: for example, a large majority (74%) of Sentinel-2 active users downloaded between 1-9 user-level data during the year. Given the global and open nature of the Open Hub, this behaviour is also expected: a large proportion of users who register are casual or specialist users, who would only need to download one or a few user-level data during the year.

As in Y2020, the number of Sentinel-2 users on the Open Hub who downloaded in the '1-9' range exceeded the number of Sentinel-1 and Sentinel-3 users who downloaded in that range 49,326 users for Sentinel-2 compared with 17,419 for Sentinel-1 and 10,563 for Sentinel-3. Overall, there were more active users who downloaded 1-9 Sentinel user-level data than there had been in Y2020.

It is also worth highlighting that the scale used in the bar chart for the Open Hub below is different to the scale used for the other hubs. The number of active users on the Open Hub is measured in thousands, while for the other hubs it is just measured in single units. So although only a small proportion of the total number of active users on the Open Hub downloaded more than 1,000 user-level data, there were actually many more users who downloaded in that range than on all the other hubs put together: 1,256 for Sentinel-2,508 for Sentinel-1 and 413 for Sentinel-3. This suggests that many large, systematic users, who may not have access to the other ESA hubs, are regular users of the Open Hub.

Concerning ServHub, 44% of users downloaded more than 1,000 user-level data, a slightly lower proportion than the 49% of active users who downloaded in this range in Y2020. In Y2021, the proportion downloading in the other ranges was as follows: 32% in the '1-9' category, 13% in the '10-100' category' and 11% in the '100-1000' category. It is suggested that this relatively more even distribution across the download ranges may be explained by the differing needs of each Copernicus Service: whereas some of the Services, such as the security and emergency services, may only need a few very specific user-level data related to precise locations and time windows, others such as the marine and land services may require the routine and continuous monitoring of large areas of interest.

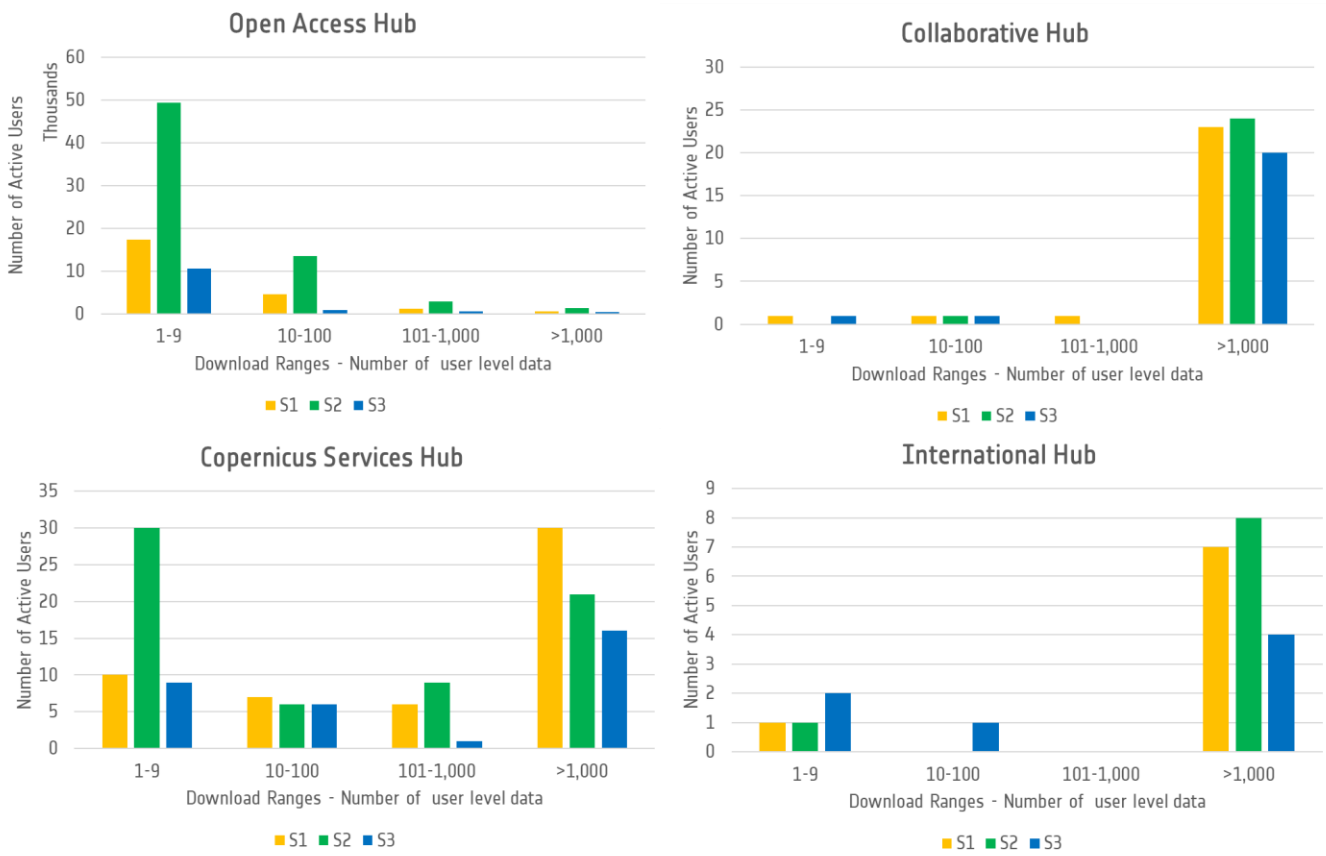


Figure 74: Y2021 Download Ranges for each Data Access System Hub

3.3 Open Hub Active Users focus

3.3.1 Monthly Active Users

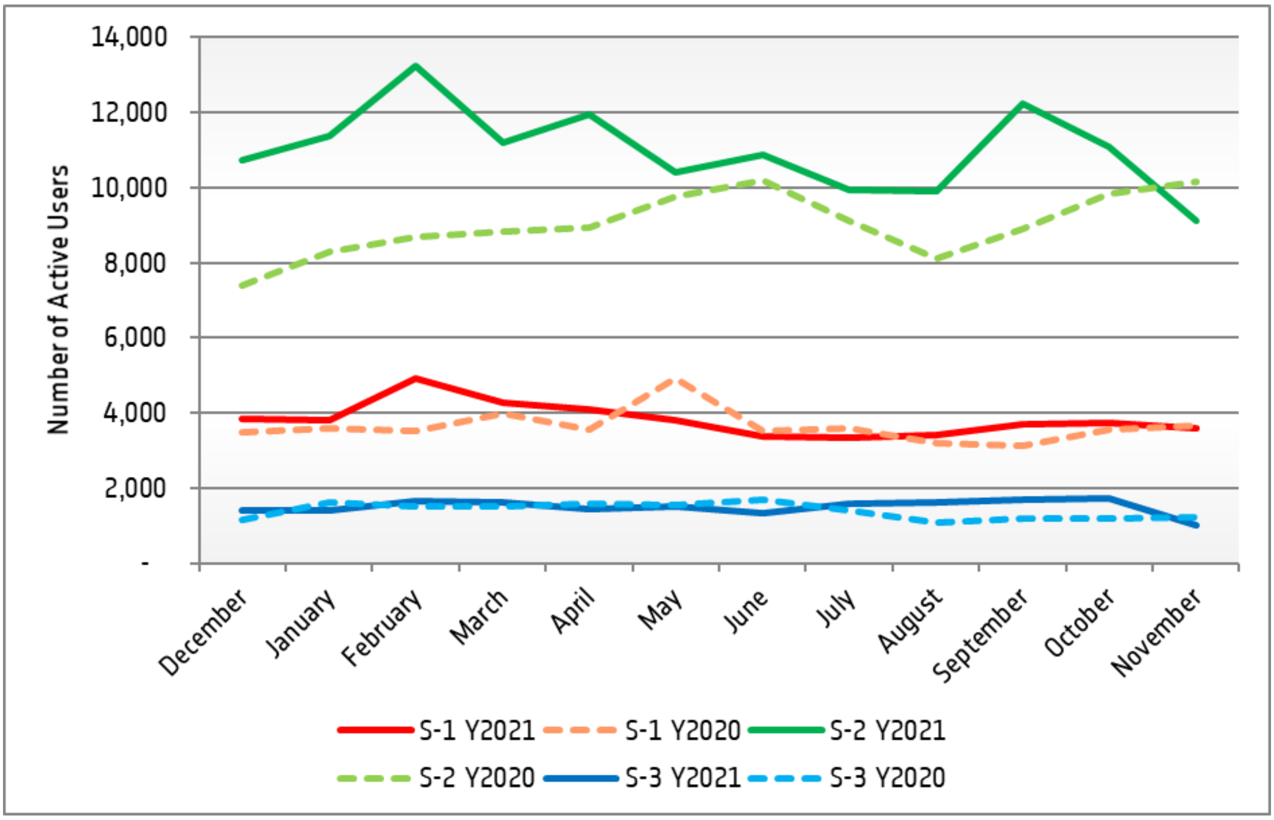


Figure 75: Active user trend per mission in Y2021 and Y2020

The graph in Figure 76 shows the number of active users on the Open Hub on a monthly basis throughout Y2021 for each Sentinel mission (i.e. the number of users that downloaded at least one user-level data from a particular Sentinel mission in the month). For comparison, the graph also shows the equivalent plots for Y2020, shown as dotted lines.

For Sentinel-1, there were some months during Y2021 in which the number of active users was slightly higher than it had been in the equivalent month in Y2020, and some months in which it was slightly lower. In general, however, the number of active users per month was very similar in both years and relatively steady, ranging between 3,000 to 5,000 active users per month. In fact, **the average number of active users/month during Y2021 was 3,837, which is close to the 3,650 average during Y2020 and 3,386 in Y2019.** These trends suggest that the number of active users for Sentinel-1 remains fairly stable, as seen in Y2020. There was, however, a noticeable peak in the number of active users in February 2021, which is matched by a peak in Sentinel-2 active users that month. It is speculation, but this may have been linked to the eruption of Mount Etna on 16 February 2021 which blew out a fountain of lava and ash into the sky, generating widespread interest in and need for aerial images of Sicily. Interestingly, for instance, there was a similar peak in the number of Sentinel-2 active users in September 2021, the month in which the eruptions from Mount Cumbre Vieja began in La Palma, and there was also a less dramatic but still noticeable increase in the number of Sentinel-1 active users for the month.

Overall, the number of active users of Sentinel-2 user-level data was higher in Y2021 than in Y2020, for all months of the year except November when there was a sharp drop in the number of active users. This drop resulted in the number of active users at the end of Y2021 being less than it had been at the start of Y2021, and it will be important to check whether the trend recovers in Y2022. Nonetheless, Sentinel-2 continued to be the mission with the highest number of active users per month throughout the year, and in February 2021 there were as many as 13,217 active users. **The average number per month was 10,994, which is 22% higher than the average of 9,021 during Y2020.** Sentinel-2 was the mission with the highest percentage rise between Y2020 and Y2021.

Concerning Sentinel-3, Figure 76 shows a stable, almost constant number of active users throughout the beginning of the year, with a very gradual increase starting to happen in the second half of the year, so that in December 2020, there were 1,412 active users of Sentinel-3 user-level data, while by October 2021 there were 1,757 and in the overall comparison with Y2020, **the average number per month rose 8% during Y2021,** up to 1,529 from 1,409 in Y2020. However, as for Sentinel-1 and -2 it is again noted there was a notable decrease in the number of active users in November. Looking at the three missions together, there was a decrease respectively of 2%, 10% and 16% for Sentinel-1, -2 and -3 with respect to the previous month.

3.3.2 Active users per continent and country

The registration phase includes the collection of user information (e.g. user country, thematic domain and usage type) selected by the user from a set of predefined lists. There is no active verification of the information entered, so the statistics presented here rely on the self-registered data.

Table 24 below shows the number of active users on the Open Hub broken down by continent, for Y2020 and Y2021. It also shows, for both periods, the proportion for each continent of the overall number of active users, and the percentage increase between Y2020 and Y2021. The graph in Figure 77 highlights this growth in active users on all continents, also including Y2015, Y2016, Y2017, Y2018 and Y2019 to gauge the overall trends.

Once again, there was a rise in the number of active users in all continents during the year. The highest increase was in the number of active users from Oceania, up 46% to 3,988 active users, and for the first time the number of active users from Oceania was higher than the number from Africa, even though there was also a massive 30% increase in the number of active users in Africa. The number of active users from Asia also rose significantly, up 27% compared to Y2020, to 23,987. Europe, North America and South America + Antarctica all experienced similar level growth, at 12%, 14% and 8% respectively.

The highest number of active users was still in Europe, where there were more than 31,000 active users in the year, representing 43.8% of the total number of active users in Y2021. Asia was the second most active continent, with 33.6% of the total number of active users for Y2021.

Continent	Y2021	Overall % Y2021	Y2020	Overall % Y2020	% Increase Y2020-Y2021
Europe	31,262	43.8	27,972	39.2	12%
Asia	23,987	33.6	18,836	26.4	27%
South America + Antarctica	8,780	12.3	7,680	16.0	14%
North America	12,341	17.3	11,427	10.8	8%
Africa	3,609	5.1	2,771	3.9	30%
Oceania	3,988	5.6	2,727	3.8	46%

Table 24: Open Hub active users for Y2021 and Y2020, per continent

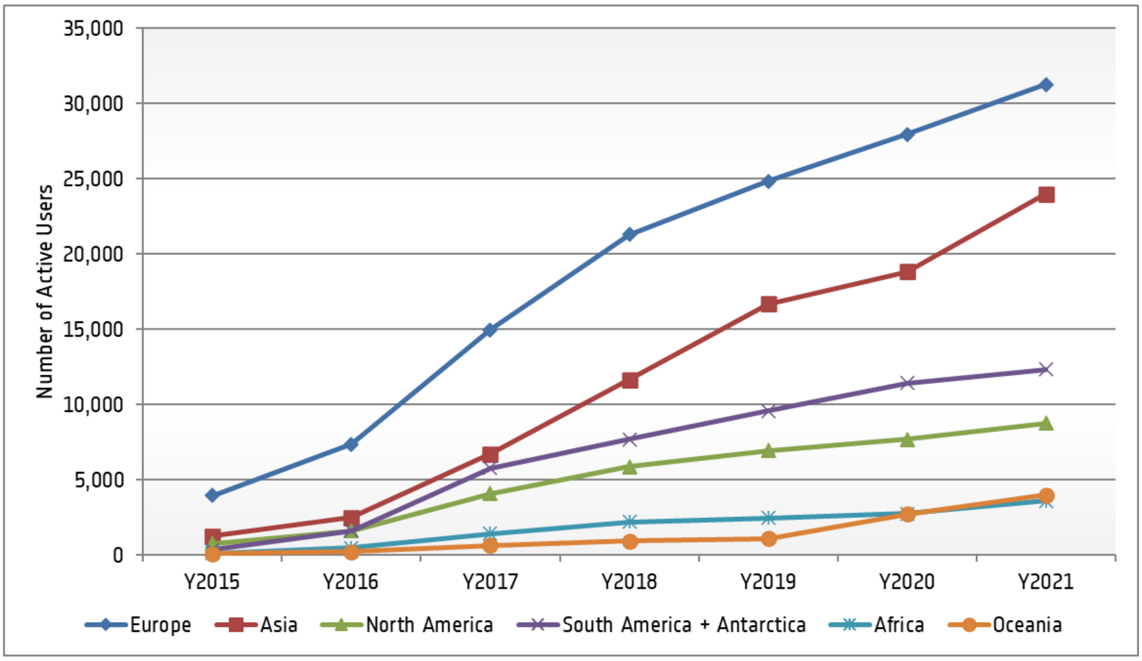


Figure 76: trend in Open Hub active users from Y2015-Y2021, per continent

It is highlighted that in Europe, North America, South America and Oceania (Australia), national mirror sites are available as an alternative and more local source for the user-level data, and that the numbers presented here may be far from the total number of active users of Copernicus Sentinel data in those continents. As far as it is known, there are not currently any local Copernicus Sentinel data access sites in Asia or Africa.

It is also recalled that the total numbers of active users per continent do not necessarily match the volume of data downloaded by users in each continent. For instance, a user who downloads just one user-level data in the year counts as one active user in exactly the same way as a user who downloads more than 1,000 user-level data in the year. The active user statistics always need to be read in conjunction with the data download statistics, therefore, in order to generate a picture of the level of user activity within a continent.

The set of tables below provide a further breakdown of the Open Hub active users, this time on the basis of individual nations. The 'Top 10' active user countries are provided for all three Sentinels, both on a global and European level (specifically ESA and/or EU member states). The number of users who downloaded a user-level data from each mission during Y2021 is provided for each country, as well as the percentage increase since Y2020 and any change in the position in the list.

Four ESA/EU member states, Germany, Italy, France and Spain, appear in the top 10 rankings for each Sentinel mission, both in the global tables and in the

Europe-only tables, with France appearing again in the global top 10 for Sentinel-2 active users this year. The UK dropped out of the global Sentinel-2 top 10 for the first time since the start of operations. In the Europe-only tables, the lists are very similar to those seen in Y2020, with only slight rearrangements in the order of the countries. One notable change is in the Sentinel-2 top 10, where Portugal has re-entered and Norway has dropped out. In terms of growth in the number of active users in the ESA/EU member states with respect to Y2020: for Sentinel-1, the highest increase was in the number of active users in Romania (up 22%); while for Sentinel-2 it was in Greece (as last year) with an increase of 33%; and for Sentinel-3 it was in France, with an increase of 24% in the number of active users. There were, however, also some significant decreases in the numbers of active users in some European countries. For Sentinel-1, it was Portugal which saw the biggest drop, with 35% fewer active users in Y2021 than in Y2020. For the most part, the number of Sentinel-2 active users increased but in Romania the number fell by 20%. For Sentinel-3, the highest decrease was 17% and this was again in Portugal.

In the global tables, three non-European nations also appear in the top 10 for each mission: China, India, and the United States. China is now the country with the most active users for each missionwith 3,057, 6,747 and 1,247 active users respectively for Sentinel-1, -2 and -3. Having previously not appeared in the global Sentinel-2 top 10, Australia jumped into 4th place with 3,551 active users in the year, whereas the number of Australian active users of Sentinel-1 data was half the number it had been in Y2020. Russia had disappeared from the top 10 for both Sentinel-1 and Sentinel-3 in Y2020 but in Y2021 Russia appears again in the top 10 for Sentinel-3, with 261 active users.

The highest rises in the numbers of active users were in the non-ESA/EU nations: for example, the number of users in China who downloaded Sentinel-2 and -3 data rose for both missions by 61% to 6,747 and 1,247 respectively. The global lists also saw the highest decrease in active users, with the 52% decrease in the number of Sentinel-1 active users in Australia. It is encouraging to note that in the global top 10 for Sentinel-3, the majority of countries saw an increase in the number of active users, unlike in Y2020 when there was a 50/50 split in countries Sentinel-3 gaining active users and losing them.

Sentinel-1 - Global				
Country	Active Users Y2021	% increase from Y2020	Ranking Y2020	Change
China	3,057	43	1	0
India	1,423	3	3	^1
Italy	1,204	3	5	^2
Germany	1,181	-3	4	0
United States	1,105	13	5	0
Australia	776	-52	2	˅4
United Kingdom	741	-7	7	0
France	733	0	8	0
Spain	718	3	9	0
Indonesia	645	1	10	0

Table 25: Y2021 Top 10 Global Countries: Sentinel-1

Sentinel-2 - Global				
Country	Active Users Y2021	% increase from Y2020	Ranking Y2020	Change
China	6,747	61	1	0
Spain	3,629	11	2	0
Brazil	3,567	8	3	0
Australia	3,551	N/A	N/A	N/A
Germany	3,425	6	4	˅1
Italy	2,806	9	5	˅1
United States	2,757	15	6	˅1
India	2,411	8	7	˅1
Mexico	1,987	18	9	0
France	1,749	N/A	N/A	N/A

Table 26: Y2021 Top 10 Global Countries: Sentinel-2

Sentinel-3 - Global				
Country	Active Users Y2021	% increase from Y2020	Ranking Y2020	Change
China	1247	61	2	^1
United States	964	18	1	˅1
Italy	757	0	3	0
Germany	747	-1	4	0
Spain	714	5	5	0
France	522	24	8	^2
India	507	-14	6	˅1
United Kingdom	442	-2	7	˅1
Brazil	375	-7	9	0
Russian Federation	261	N/A	N/A	N/A

Table 27: Y2021 Top 10 Global Countries: Sentinel-3

Sentinel-1 - ESA/EC				
Country	Active Users Y2021	% increase from Y2020	Ranking Y2020	Change
Italy	1,204	3	2	^1
Germany	1,181	-3	1	˅1
United Kingdom	741	-7	3	0
France	733	0	4	0
Spain	718	3	5	0
Poland	585	10	6	0
Greece	327	2	8	^1
Netherlands	313	-2	7	˅1
Romania	235	22	10	^1
Portugal	192	-35	9	˅1

Table 28: Y2021 Top 10 ESA/EU Countries: Sentinel-1

Sentinel-2 - ESA/EC				
Country	Active Users Y2021	% increase from Y2020	Ranking Y2020	Change
Spain	3,629	11	1	0
Germany	3,425	6	2	0
Italy	2,806	9	3	0
France	1,749	12	5	^1
United Kingdom	1,634	0	4	˅1
Poland	1,610	27	6	0
Greece	1,221	33	7	0
Netherlands	942	3	8	0
Portugal	649	N/A	N/A	N/A
Romania	539	-20	9	˅1

Table 29: Y2021 Top 10 ESA/EU Countries: Sentinel-2

Sentinel-3 - ESA/EC				
Country	Active Users Y2021	% increase from Y2020	Ranking Y2020	Change
Italy	757	0	1	0
Germany	747	-1	2	0
Spain	714	5	3	0
France	522	24	5	^1
United Kingdom	442	-2	4	˅1
Poland	247	3	6	0
Greece	214	23	8	^1
Netherlands	185	-14	7	˅1
Portugal	130	-17	9	0
Romania	110	-9	10	0

Table 30: Y2021 Top 10 ESA/EU Countries: Sentinel-3

3.3.3 Users per declared uses and thematic domains

This section discusses the type of use which registered users of the Open Hub intend to make of the Copernicus data, in terms of the usage type (Research, Education, Commercial, other) and application domain. It is stressed that users are only asked to categorise their intended use of the data when they first register for access to the Open Hub; users are asked to state their user country, thematic domain and usage type from a set of predefined lists during the registration process. The information may therefore be limited in several ways: there is no independent verification performed of the information provided; users are only able to select one application domain and one usage type from the choices available, meaning that users with multiple domains/usages are not reflected; no further information is obtained from users selecting 'Other' options; and users are not currently given the chance to update their selection, so any developments in the use to which they put the data are also not reflected. Even so, and as in previous years, an analysis of the information is still considered helpful in that it provides a broad overview of the uses which users intend to make of the data at the point at which they register.

Figure 78 summarizes the active users and data downloads in terms of the intended onwards use for the data. The circle chart shows the overall percentage split of active users between the four available choices for their intended usage type: Research, Education, Commercial and Other. The chart shows that by the end of Y2021, the vast majority of active users were those who had selected 'Research' (46.8%) and 'Education' (44.5%) for their usage type, and only 3.8% were those who had selected 'Other' when they registered for an account. This is an almost identical split to that recorded in previous reporting years.

It is, then, extremely interesting to see from the bar graph that although only 4.9% of the active users were those who had selected 'Commercial' on registration, those 4.9% downloaded as much as 67% of the total number of user-level data downloaded overall in Y2021.

On the other hand, the large 'Research' user group made only 29% of the total number of downloads, and the ' Education' user group even fewer, having made just 3% of the total number of downloads in the year. It seems very likely, therefore, that the 'Commercial' user group is largely composed of mass downloaders, possibly wishing to replicate the data collection on their own infrastructure, while those who download the data for the purpose of education, tend to be the users who download only the specific user-level data they need, probably via the GUI.

It is also interesting to note that there was a big increase in activity from the Commercial user group during the year with respect to Y2020: in Y2020, the number of downloads made by the Commercial user group constituted 41% of the total number of downloads, whereas in Y2021 the proportion rose to 67%. This increase in the proportion of downloads made by the Commercial users appears largely to be accounted for by the Commercial users making a significantly higher proportion of the Sentinel-3 downloads in Y2021 than they had in Y2020, up to 33.36% from 11.66% during Y2020.

The 'Other' user group again accounted for only 2% of the total number of downloads, half the proportion their downloads constituted in Y2020.

Figure 79 breaks down the totals for the number of active users and downloads in Y2021 according to the seven thematic domains which users can choose from when they register for an account on the Open Hub. The circle chart shows that users who selected 'Land' as their application domain continued to be by far the largest group of active users, accounting for 59.1% of the total number of active users in Y2021. Next in order were 'Other' with 12%, 'Climate' with 8%, 'Marine' and 'Atmosphere' both with 7%, 'Emergency' with 6% and 'Security' with 1%.

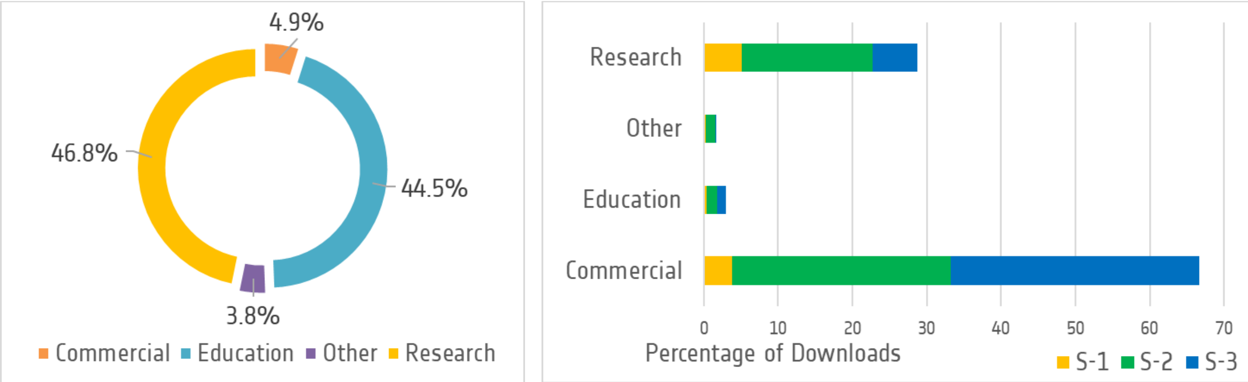


Figure 77: Percentage of Open Hub active users per declared usage type in Y2021, and the percentage of downloads (by number) performed for Sentinels -1, -2 and -3 for each usage type during Y2021

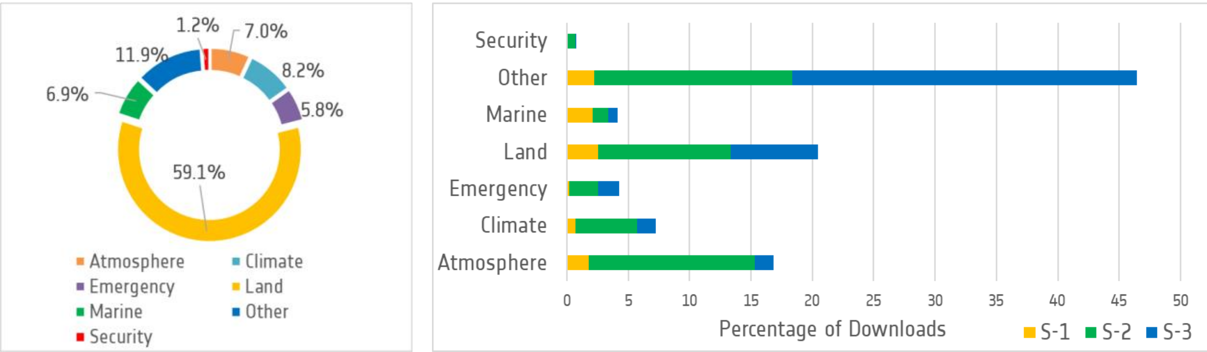


Figure 78: Percentage of Open Hub active users per declared thematic domain in Y2021, and the percentage of downloads (by number) performed for Sentinels -1, -2 and -3 for each thematic domain during Y2021

For the first year since the start of operations, ‘Other’ became the application domain for which the majority of downloads was made, with 46% of the total number of downloads in Y2021 made for ‘Other’ applications, up from 27% in Y2020. The majority of the ‘Other’ downloads were made for Sentinel-3 data, unlike in Y2020 in which Sentinel-2 data was the most downloaded for the ‘Other’ application domain. Combined with the statistics on the user groups, this suggests that the change in the lead application domain this year may have been brought about by the activity of the mass-downloading commercial users, who are probably not able to categorise their application domain using the categories currently provided on registration because their main aim is to make the data available to their onwards users.

Although ‘Land’ remained the application domain with the highest number of active users, this year those active users only made 21% of the total number of downloads made in the year. It is also interesting to note that Sentinel-2 downloads continue to comprise the majority of the ‘Land’ downloads, with 11% of all downloads being made for Sentinel-2 ‘Land’ applications, but Sentinel-3 downloads are starting to constitute a similar proportion of the ‘Land’ downloads, with 7% of all downloads being Sentinel-3 data for ‘Land’ applications.

The proportion of data downloaded for ‘Marine’ applications fell again, this time from 5% of all downloads in Y2020 to 4% in Y2021. This appears again to have been due to a reduction in the proportion of Sentinel-3 data downloaded for ‘Marine’ applications, as was noted last year, with Sentinel-3 data for ' Marine' applications constituting less than 1% of the total downloads in Y2020.

Yet again, although the 'Atmosphere' user group constituted only 7% of the total number of active users in Y2021, they made a high proportion (17%) of the total number downloads in Y2021. The proportion of active users who made downloads for 'Emergency' applications rose from 4% in Y20202 to 7% in Y2021. There was, however, no increase in the proportion of downloads made by the 'Emergency' active users, with the downloads still constituting less than 5% of the overall downloads made in Y2021. The proportion of downloads made for 'Security' applications increased but remains marginal.

4 Data Dissemination Partners

The access to Copernicus Sentinel data which ESA provides through the Copernicus Sentinel Data Access System is complemented by an ever-growing number of national and commercial re-distributors which also provide online access to the data. These redistribution points include the national mirror sites which are provided in the framework of the Collaborative Ground Segment, and the sites which are provided by international partners in the framework of international agreements. Tables 32 and 33 below set out the links to these national and international data access sites. Please note that the list may not be comprehensive and the content of each site is outside the responsibility of ESA and the Serco-led consortium.

It is also highlighted that each data dissemination partner follows its own strategy for the Copernicus Sentinel user-level data it chooses to make available through its site, and the length of time for which it makes the data available. Some sites offer a complete mirror of all available user-level data from one or more of the Sentinel missions, while others offer a very specific subset of user-level data types and/or coverages of particular geographical regions. The objectives of each site are not detailed here but the reader is invited to investigate each in detail via the URLs provided.

Category: Collaborative National Mirror Sites		Annual Report Section: 4.1
Category	Partner	Access URL(s)
Collaborative National Mirror Sites	Austria	https://data.sentinel.zamg.ac.at https://www.sentinel.zamg.ac.at
	Belgium	https://www.terrascope.be
	Canada	ftp://ftp.neodf.nrcan.gc.ca
	Czech Republic	https://dhr1.cesnet.cz https://dhr2.cesnet.cz
	Estonia	https://ehdatahub.maaamet.ee
	Finland	https://finhub.nsdc.fmi.fi
	France	https://peps.cnes.fr
	Germany	https://code-de.org/
	Greece	https://sentinels.space.noa.gr
	Hungary	https://fir.gov.hu/
	Ireland	https:/eobrowswer.speir.ichec.ie
	Italy	https://collaborative.mt.asi.it/
	Luxembourg	http://www.lsa-datacenter.lu
	Norway	https://colhub.met.no https://satellitedata.no/
	Poland	https://copernicus.imgw.pl https:/dane.sat4envi.imgw.pl
	Portugal	https://ipsentinel.pt/
	Romania	https://dhus.rosa.ro/
	Spain	Not available
	Sweden	https://digitalearth.se
	UK-1	UK1: site: https://www.ceda.ac.uk/ JASMIN site: https://jasmin.ac.uk/
	UK-2	https://geobrowser.satapps.org

Table 32: Collaborative National Mirror sites

Category: International Partners' Sites		Annual Report Section: 4.2
Category	Partner	Access URL(s)
International Partners' Sites	**Australia –** Geoscience Australia (GA)	https://copernicus.nci.org.au/
	Brazil – Brazilian Space Agency (AEB) and the National Institute for Space Research of Brazil (INPE)	https://sentinel-hub.inpe.br/#/home https://brazildatacube.org
	Chile – University of Chile	http://www.datoscopernicus.cl
	Colombia	Not available
	India – Indian Space Research Organisation (ISRO)	https:// bhoonidhi.nrsc.gov.inc
	Serbia – Biosense Institute	https://biosens.rs/
	Ukraine – State Space Agency of Ukraine (SSAU)	http://sentinel.spacecenter.gov.ua
	United States – National Aeronautics and Space Administration (NASA)	Alaska Satellite Facility (Sentinel-1) https://vertex.daac.asf.alaska.edu
		NASA OceanColor Web (Sentinel-3) https://oceancolor.gsfc.nasa.gov
		Level-1 and Atmosphere Archive & Distribution System (LAADS) Distributed Active Archive Center (DAAC) (Sentinel-3) https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurement/olci/
		GES DISC (Sentinel-5P) https://disc.gsfc.nasa.gov
		HLS (derived products from Sentinel-2) https://lpdaac.usgs.gov/products/hlss30v015/
	United States – National Oceanic and Atmospheric Administration (NOAA)	https://coastwatch.noaa.gov
	United States – US Geological Survey (USGS)	https://eros.usgs.gov/sentinel-2

Table 33: Sentinel Data Dissemination Partners

4.1 Collaborative Ground Segment Agreements

ESA Member States and other Copernicus Participating States are complementing the exploitation of the Copernicus Sentinel missions and supporting the redistribution of Copernicus Sentinel data by establishing additional data access points (mirror sites) and, in some cases, developing new user-level data. These are the users of the ColHub which are described in this report, and their national mirror sites are part of the expanding network known as the Collaborative Ground Segment (CollGS).

A total of 20 CollGS agreements had been signed with ESA by the end of Y2021. Following the signature of an agreement, ESA passes a dedicated set of credentials to the national contact point to enable it to access the ColHub. ESA also provides technical support to the national contact point to help it optimise its access to the data.

Table 34 summarises the status of the 20 current CollGS agreements, listed in order of the date on which the agreement was signed with ESA. It is highlighted that the UK's Collaborative Ground Segment consists of two mirror site initiatives: UK-1 indicates the site operated for the academic community; UK-2 indicates the site operated independently and aimed at commercial users.

The CollGS partners provide information about the activity on their national mirror sites via an annual questionnaire which ESA sends out. The statistics presented in this section are based on the 16 partners who both had active national initiatives during Y2021 and who provided the requested information.

By the end of the reporting period, most of the CollGS partners had transferred their sites into operations. The Hungarian site was still under final testing during Y2021 and was not yet been opened to the public, although it it is now open to the public at the time of writing this Report. The implementation of the Spanish site has been delayed, primarily due to the COVID situation. It should also be explained that the Polish Copernicus data access service is divided into two parts: the national operator provides users with the newest data (last 30 days), whereas the rest of the data, the whole archive of Sentinel data for Poland, is accessible through the Sat4Eniv project, on the webpage https:/dane.sat4envi.imgw.pl. The statistics presented here cover only the site run by the national operator, and so do not represent the full uptake of data from the Polish CollGS.

For the sites which had already been opened prior to Y2021, there was an average growth in the number of users registered on their sites of 67%.

There was an 26% drop in the average volume of data published on a CollGS site during the year compared with Y2020: in Y2021, the average volume published on a site was 1.47 PB, whereas in Y2020 it had been 1.99 PB. Interestingly, however, the total volume of data *downloaded* from all of the sites during the year was actually 163% higher in Y2021 than in Y2020, with a total of 6.23 PB downloaded and an average of 0.44 PB per CollGS, which is 13% higher than the same value in Y2020 (see Table 36). This may indicate that there has been some fine-tuning of the data offer on the various CollGS sites, tailoring it more closely to the user needs.

Overall, however, it is highlighted that the data download volumes discussed in this section are only one way of measuring the 'output' of a particular Collaborative Ground Segment. In fact, several CollGS sites now provide on-demand processing of data, and/or online visualisation and processing and the tools needed to support this. While these cutting-edge uses of Copernicus Sentinel data are not explored further in this section, the interested reader can explore the individual Collaborative Ground Segment portals. The executive summaries of the 'Collaborative Ground Segment Workshops' also highlight such initiatives on a per partner basis and are available to download here:
https://sentinel.esa.int/web/sentinel/missions/collaborative/workshop

Progressive Number	CollGS Partner	CollGS Agreement Signature Date	Opened Mirror Site? (yes/no)	Operation start date
1	Greece	May 2014	Yes	6 Feb 2015
2	Norway	Sep 2014	Yes	18 Oct 2016
3	Italy	Oct 2014	Yes	28 May 2016
4	Germany	Nov 2014	Yes	07 Mar 2017
5	Finland	Jan 2015	Yes	24 May 2016
6	UK-1	Mar 2015	Yes	1 May 2015
	UK-2	Mar 2015	Yes	1 Sep 2016
7	France	Mar 2015	Yes	1 May 2015
8	Sweden	June 2015	Yes	1 Oct 2019
9	Canada	Sep 2015	Yes	22 Sep 2015
10	Portugal	Oct 2015	Yes	24 Feb 2017
11	Austria	Feb 2016	Yes	27 May 2016
12	Estonia	Sep 2016	Yes	1 Jan 2019
13	Luxembourg	Apr 2017	Yes	1 May 2019
14	Belgium	Sep 2017	Yes	27 Sep 2017
15	Ireland	Oct 2017	Yes	19 Feb 2018
16	Romania	Dec 2017	Yes	30 Nov 2018
17	Czech Republic	Jan 2018	Yes	15 Mar 2017
18	Poland	Mar 2018	Yes	1 Jan 2020
19	Hungary	October 2019	No	Not yet public
20	Spain	November 2019	No	Not yet public

Table 34: Collaborative Ground Segment mirror sites summary

CollGS Partner	Overall Number of Registered Users since Start of Operations	% Increase since Y2020	% of Registered Users from the National Country	Number of Active Users in Y2021	% of Registered Users who were Active in Y2021
Austria	1,868	4.0%	79.0%	79	4.0%
Belgium	3,444	277.0%	15.7%	138	4.0%
Canada	21	5.0%	-	7	33.3%
Czech Republic	511	61.0%	93%	181	35.4%
Estonia	322	31.0%	88.2%	100	31.0%
Finland	599	18.6%	-	87	14.5%
France	8,580	22.9%	51.3%	-	-
Greece	804	4.4%	65.7%	34	4.2%
Hungary	61	455.0%	72.0%	24	39.3%
Luxembourg	223	48.0%	-	85	38.1%
Norway	810	36.0%	-	200	24.7%
Poland	43	34.0%	98.0%	35	81.4%
Portugal	810	36.0%	93.5%	53	6.5%
Romania	84	17.9%	-	21	25.0%
Sweden	10	-95.0%	-	10	100%
UK-1	2,453	30.7%	77.6%	89	3.6%
UK-2	1,328	8.0%	63.9%	44	3.3%

Table 35: Summary of national mirror site users

Table 35 presents the data on the registered and active users on the national mirror sites, as reported in the annual questionnaires. On this and subsequent figures and tables in the section, statistics are only shown for the CollGS partners which provided their reports, and if the statistics were not provided, this is shown as '-' .

It should be noted that, while it is interesting to look at the statistics as a whole, the figures from each CollGS will necessarily be different, partly due to the different start dates for each site but also because partners can impose their own restrictions on registering and accessing the data: some of the CollGS are completely open to all types of users, while others are only open to a few selected users.

In line with the agreement on reporting, the CollGS partners categorise their own users according to the same fields used by ESA. Figures 80 and 81 below show the percentage of registered users from each national mirror site assigned to each 'usage category' (research, commercial, education, other) and to each 'usage field' (specific field for which the data is used e.g. land, marine, atmosphere etc).

Usage Category

13 out of the 16 partners which provided data had 'Research' as their top category of user and 'Research' users accounted for 46% of all CollGS users. In fact, the category represents over 50% of users of the national sites in Belgium, Estonia, Finland, Greece, Hungary, Luxembourg, Norway, Poland, Sweden and UK-2. In Greece, the number of users which fall into the 'Research' category reaches 66%.

Overall, 7% of the CollGS users were from the 'Commercial' user group, which is consistent with Y2020. Most notably, however, commercial users constituted 20% of the users of the Luxembourg mirror site and 18% of the users of the UK-2 site.

22% of the CollGS users were from the category 'Education', but this was the largest category of users for the Czech mirror site (63% of users) and the Romanian site (61%) .

Usage Field

By the end of Y2021, the group of registered users which ascribed themselves to the 'Land' category was still the largest group of users on most of the CollGS sites, and accounted for 40% or more of users of the sites in Austria, Belgium, Czech Republic, France, Norway, Poland, Portugal, Romania and UK-2. 'Marine' accounted for a high proportion of users from Canada where 64% of the registered users ascribed themselves to the 'Marine' category.

'Other' was actually the highest group of registered users of the Luxembourg and UK-1 sites, in particular accounting for about 50% of the users of the UK-1 site.

The Hungarian site was the only site on which the majority of the registered users ascribed themselves to the category of 'Security'. Canada was the only site on which the majority of registered users ascribed themselves to the category of ' Marine', with 64% of the users registering themselves as Marine users. 20% of the registered users of the Luxembourg site and 19% of the Greek site considered themselves 'Atmosphere' users.

Taking into account all users for all partners, the top usage fields were 'Land', accounting for 40% of users, 'Other' (17%), 'Marine' (9%) and 'Atmosphere' (8%).

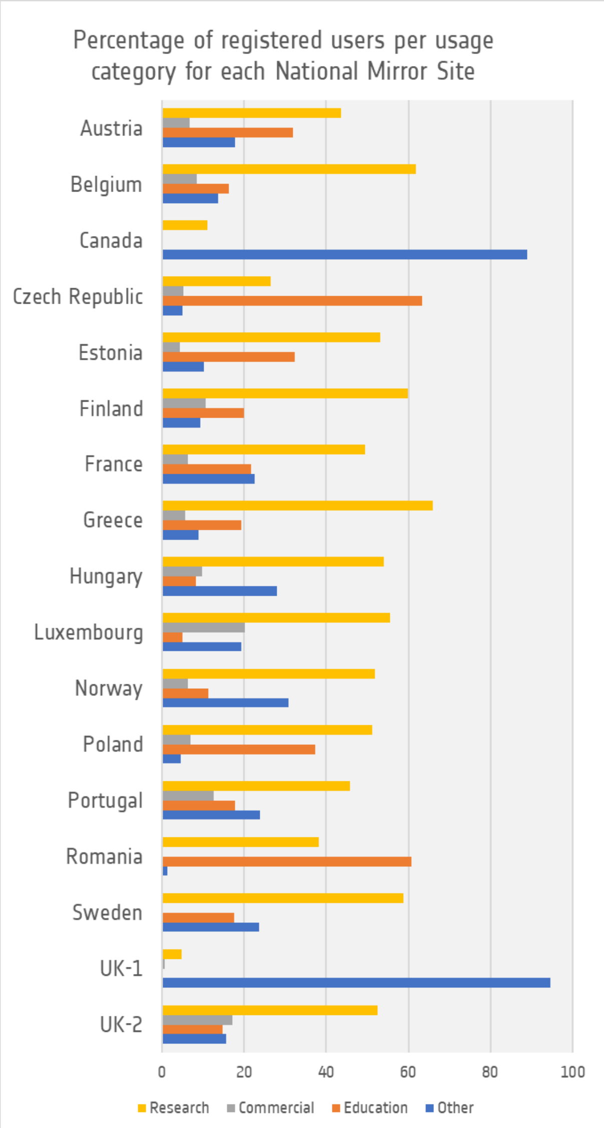


Figure 79: Percentage distribution of mirror site users by usage category

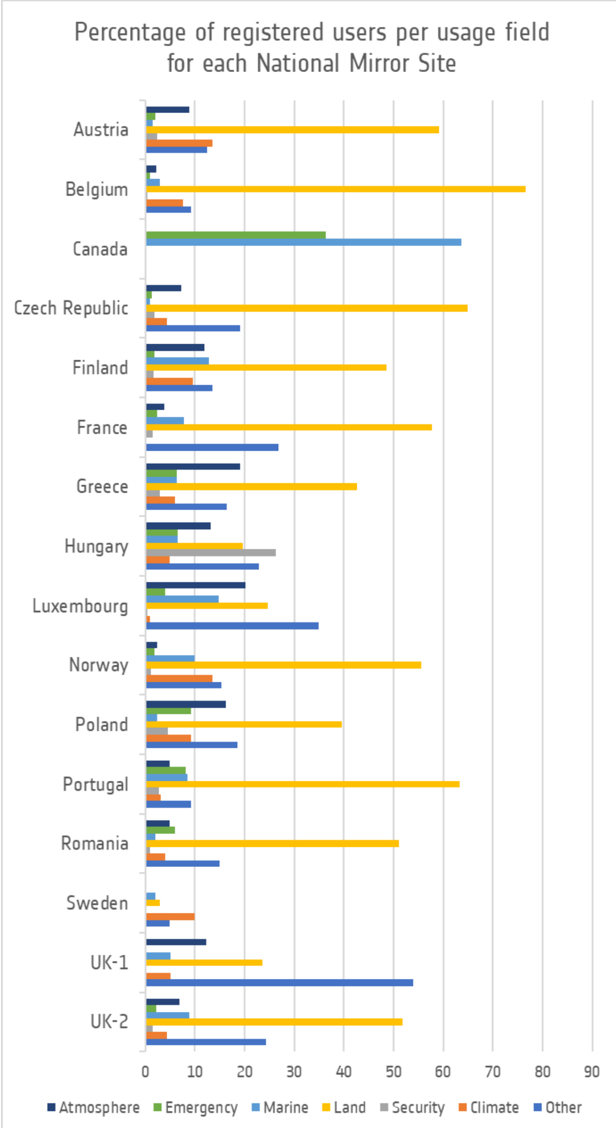


Figure 80: Percentage distribution of mirror site users by usage field

CollGS Partner	Y2021 Published Volume (TB)	% Increase from Y2020	Y2021 Downloaded Volume (TB)	% Increase from Y2020
Austria	6,352.0	-5%	186.0	0%
Belgium	218.7	22%	0.6	-21%
Canada	44.0	-2%	39.0	-38%
Czech Republic	272.2	492%	189.3	284%
Estonia	36.1	N/A	19.3	N/A
Finland	166.0	37%	41.0	-62%
France	3,886.0	13%	4,563.2	269%
Greece	518.2	-3%	18.0	51%
Hungary	43.0	-70%	-	N/A
Luxembourg	7,404.0	-27%	232.0	-44%
Norway	2,608.0	-51%	1,077.3	108%
Poland	250.6	38%	13.5	125%
Portugal	164.0	7%	0.1	12%
Romania	45.7	99%	0.5	-20%
Sweden	10.0	-83%	-	N/A
UK-1	1,737.0	-16%	10.0	245%
UK-2	1,076.0	-52%	0.5	-83%
TOTAL	**24.96 PiB**	**-26%**	**6.23 PiB**	**163%**
Average Y2021	**1.47 PiB**	**-26%**	**0.44 PiB**	**13%**

Table 36: Overall publication and dissemination volumes on mirror sites

Table 36 above reports, where available, the total volume of Copernicus Sentinel data both published on and downloaded from the mirror sites during Y2021, together with the percentage change with respect to Y2020. Overall, this year is more varied than the last, with a number of decreases as well as increases reported. In particular, as already mentioned, the total data volume published in the year (24.96 PiB) was 26% lower than in Y2020. This may be due to the missing input usually provided by the German mirror site which, in general, is one of the mirror sites which makes the largest collection of data available for its national users.

The greatest individual increases in publication volumes were seen in Czech Republic (492% increase), Poland (438%) and Romania (99%). The greatest individual decreases were seen on the Sweden (-83%) and Hungary (-70%) sites.

In terms of volumes of downloads made by users, the overall sum of 6.23PiB was 163% higher than the Y2020 total. This increase in absolute values is largely due to a rise in the reported volume of downloads from the French and Norwegian sites: in Y2020, users of the French CollGS downloaded 1.21 PiB of data, but in Y2021 this volume jumped to 4.46 PiB. It is interesting to note that the data downloaded was predominantly from Sentinel-1 (63%), even though the publication volumes were mostly focused on Sentinel-2. The downloads from Norwegian site almost doubled in Y2021 and they were mostly focused on Sentinel-1 mission, even if the publication was evenly spread.

The other partners which showed enormous growth in download volume between Y2020 and Y2021 were the Czech Republic (up 284%), UK-2 (up 245%) and Poland (up 213%).

The majority of mirror sites showed lower download volumes than the volumes published. The exception to this was only the French site, which supported a higher download volume (4.46PiB) than published volume (3.79PiB).

CollGS Partners	Y2021 Published Volume (TB)				Y2021 Downloaded Volume (TB)			
	Sentinel-1	Sentinel-2	Sentinel-3	Sentinel-5P	Sentinel-1	Sentinel-2	Sentinel-3	Sentinel-5P
Austria	1,899.63	3,805.60	646.81	-	53.00	42.00	91.00	-
Belgium	52.34	166.38	-	0.02	0.16	0.45	-	0.02
Canada	41.00	0.02	3.00	-	38.41	-	0.66	-
Czech Republic	10.38	20.29	11.96	12.40	20.91	15.15	0.24	0.00
Estonia	20.80	8.20	7.10	-	14.20	4.70	0.40	-
Finland	76.38	21.64	66.66	1.21	11.19	1.88	0.03	28.15
France	1,857.00	2,029.00	-	-	2,890.20	1,673.00	-	-
Greece	241.39	196.00	45.60	35.23	8.43	6.33	2.57	0.67
Hungary	8.00	5.00	9.00	21.00	-	-	-	-
Luxembourg	2,698.09	4,705.95	-	-	21.74	210.72	-	-
Norway	1,038.00	1,371.00	199.00		986.00	88.00	3.30	
Poland	53.63	71.88	72.71	52.35	0.34	1.24	11.44	0.48
Portugal	132.89	9.67	21.93	-	0.05	0.04	0.00	-
Romania	22.48	10.96	12.29	-	0.43	0.02	-	-
Sweden	-	10.00	-	-	-	N/A	-	-
UK-1	1,351.00	5.00	280.00	101.00	0.02	1.22	0.03	9.10
UK-2	766.00	310.00	-	-	0.27	0.18	-	-
TOTAL	**10,269.01**	**12,746.59**	**1,376.06**	**223.21**	**4,045.35**	**2,044.94**	**109.66**	**38.42**
% increase/ decrease	**-35%**	**-24%**	**-25%**	**-71%**	**98%**	**24%**	**-54%**	**860%**

Table 37: Y2021 Publication and dissemination volumes per Sentinel on mirror sites

Table 37 breaks the publication and download volumes down by Sentinel mission, where this information was available. 8 sites published more Sentinel-1 data than any other mission in Y2021, and these were Canada, Estonia, Finland, Greece, Portugal, Romania, UK-1 and UK-2, a similar list to that seen in Y2020. Of these sites, it is noted that the Canadian site started to publish also other missions in addition to the Sentinel-1.

7 sites published more Sentinel-2 data than any other mission: Austria, Belgium, Czech Republic, France, Luxembourg, Norway, and Sweden. Of these sites, the Swedish site was the only one which published only Sentinel-2 data

Only the polish site published more Sentinel-3 data than data from the other Sentinels, as well as Sentinel-2 data.

3 sites started to publish Sentinel-5P data in Y2021 (Belgium, Czech Republic and Greece) and the Hungarian site was the only site which published more Sentine-5P data in Y2021 than data from any other Sentinel.

As would be expected given the lower figure for the overall data volume published this year, the average volume of user-level data published in Y2021 per national mirror decreased for all the missions: 35% decrease for Sentinel-1; 24% for Sentinel-2; 25% for Sentinel-3; and 71% for Sentinel-5P. However, it is again recalled that the comparison with last year's statistics this year may be misleading, given the missing input from the German mirror site for this year.

In terms of download volumes, Figure 82 shows that there was some very interesting user activity. For instance, although UK-1 published mostly Sentinel-1 data, 88% of the volume of data downloaded by users was Sentinel-5P data. A similar disparity between the published and downloaded volumes was seen on the

Austrian, Czech, Finnish, Norwegian and Polish sites, from which the overwhelming majority of the data downloaded by users was Sentinel-3 data, Sentinel-1, Sentinel-5P, Sentinel-1 and Sentinel-3 respectively.

No downloads are reported for Sweden and Hungary, and this is in line with the scope of the Swedish site, which is not aimed at users who wish to download the data but instead offers online hosted processing services, and reflects the fact that the Hungarian site was not open to the public during Y2021.

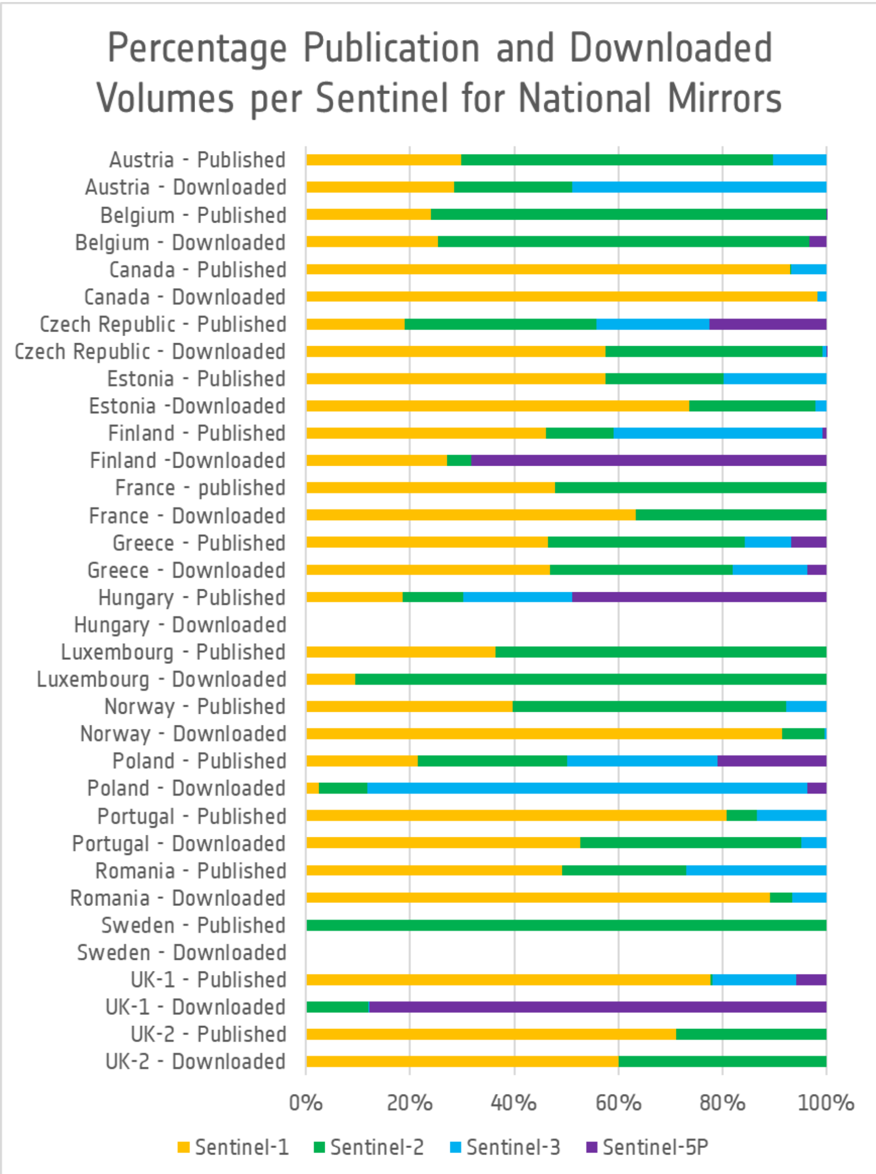


Figure 81: Percentage publication and dissemination volumes per Sentinel on mirror sites

4.2 International Technical Agreements

The Copernicus programme has a strong international dimension. In support of the international data sharing principles of the Group for Earth Observation (GEO), and in line with the Copernicus programme's policy of full, open and free-of-charge access to Copernicus data and information, the European Commission has entered into 10 Cooperation Arrangements with international partners to advance the mutually beneficial exchange of satellite data, in-situ data and support for calibration/validation activities.

ESA is entrusted with ensuring the exchange of satellite data under these cooperation arrangements, and for that purpose enters into technical operating arrangements (TOAs) with the agencies nominated by the partner countries. Under the TOAs, the nominated agencies are able to download Copernicus Sentinel data from IntHub, and transfer the data to their national data access sites for use by their own user communities.

No new TOAs were signed during Y2021.

Table 38 below presents an overview of the international partner sites which have already been established, or which are in the process of being established. The partners are listed in order of the date on which they signed the TOA with ESA.

International Partner	TOA signature date	Date started distributing Sentinel data from the site	Purpose of the national data access site
United States National Aeronautics and Space Administration (NASA)	18-Feb-2016	12-Dec-2015	The aim of NASA's mirror site is to re-use and re-disseminate Copernicus Sentinel data, to increase distribution capacity, and maximise the benefits to Earth Science research and applications. The site is primarily intended to enable users to download the data. NASA started distributing Sentinel-1 user-level data from its Alaska Satellite Facility data portal, Vertex, on 12 December 2015. In addition, Sentinel-3 OLCI data is made available as part of the OceanColor Web; all user-level data from 16/02/2016 to the present being available for re-dissemination. As well as the Sentinel-1 and -3 user-level data, during 2018 data from the Sentinel-5P mission began to be published on the NASA Sentinel Gateway (NGS). The relevant websites are: S1: https://vertex.daac.asf.alaska.edu S2 (HLS which are data derived from Sentinel-2): https://lpdaac.usgs.gov/products/hlss30v015/ S3:https://oceancolor.gsfc.nasa.gov and https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/olci/ S5P: https://disc.gsfc.nasa.gov

United States US Geological Survey (USGS)	19-Feb-2016	16-Feb-2017	USGS provides storage and redistribution of Sentinel-2 data on its Earth Resources Observation and Science (EROS) Center. The current USGS Sentinel-2 archive is only a partial representation of all available acquisitions from ESA however. USGS also makes available Full Resolution Browse (FRB) images in Georeferenced Tagged Image File Format (GeoTIFF) for Sentinel-2 tiles. This user-level data is a simulated natural colour composite image created from three selected bands (11, 8A, 4) with a ground resolution of 20 meters. USGS develops algorithms and processing methodologies in order to enhance the interoperability and synergistic use of Landsat and Sentinel-2 data streams. https://eros.usgs.gov/sentinel-2
United States National Oceanic and Atmospheric Administration (NOAA)	1st signed 7-Mar-2016 - update signed 19-Dec-2017	01-May-2016	NOAA provides access to satellite data for understanding and managing oceans and coasts. It makes available the oceanographic user-level data from the Copernicus Sentinel missions. Data is made available on the CoastWatch – OceanWatch site. For Sentinel-1, published user-level data include those over the US, Arctic and Antarctic. The data is then processed into wind speed and the original data is not generally mirrored. NOAA publishes a collection of Sentinel-2 MSI over a limited region.Sentinel-3 marine data has also been made available from May 2016, received from EUMETSAT's Multicast Terrestrial. The site is primarily intended to enable users to download the data and to visualise it online. https://coastwatch.noaa.gov
Australia Geoscience Australia (GA)	24-Mar-2016	26-Jun-2015	GA publishes Copernicus Sentinel data on its data access site 'Sentinel Australasia Regional Access' (SARA). SARA is primarily intended to provide free and open download access to data from Copernicus Sentinels 1-3, primarily for users in Australasia, South-East Asia, the South Pacific, the Indian Ocean and the Australian Antarctic Territory. For the Sentinel-3 Land user-level data, the site provides a 60 day rolling archive of Global S3 user-level data, which is reduced to a subset cut to the Australasia region of interest (ROI) after that period. Limited provision of Sentinel 5P data from the Australasia ROI is now also being trialed. SARA is hosted at the National Computational Infrastructure and operated by the Regional Copernicus Data Hub consortium formed by GA, the New South Wales Office of Environment and Heritage, Queensland Department of Environment and Science, Western Australian Land Information Authority and the Commonwealth Scientific Industrial Research Organisation.

			https://copernicus.nci.org.au
Serbia The BioSense Institute – Research Development Institute for Information Technologies in Biosystems	25-Jan-2019	Mid-Oct 2019	BioSense has established a regional data access mirror site/analysis hub to improve access to and the exploitation of Copernicus Sentinel data in the Republic of Serbia and the wider Balkan area. The relevant websites are: https://biosens.rs and https://agrosens.rs.
Brazil Brazilian Space Agency (AEB) and the National Institute for Space Research of Brazil (INPE)	14-Mar-2019	Site not in operations by end Y2021	INPE is setting up a regional data access/analysis hub, to facilitate the access to and exploitation of Copernicus Sentinel data in Brazil.
Ukraine State Space Agency of Ukraine (SSAU)	28-Mar-2019	1-Jan-2020	SSAU has established a regional data access mirror site, the 'Data Hub System – Ukraine', to facilitate access to and the exploitation of Copernicus Sentinel data in Ukraine. SSAU publishes on the Data Hub System – Ukraine all available Copernicus Sentinel data over Ukraine and the immediately surrounding regions. The site is primarily intended to enable users to download the data. http://sentinel.spacecenter.gov.ua/
India Indian Space Research Organisation (ISRO)	11-Apr-2019	26-Jan-2020	ISRO has established a regional data access site called Bhoonidhi, which provides access to all data from Sentinels -1 and -2 over India and the immediately surrounding regions, together with data from other EO missions, such as Landsat-8.The site is primarily intended to enable users to download the data. https://bhoonidhi.nrsc.gov.in
Chile University of Chile	20-Aug-2019	27-Sep-2019	UdeChile, through the Center for Mathematical Modelling (CMM) and its specialised units, in particular the HPC Center and its Image Processing Working Group, operates a regional data access/analysis mirror site to improve access to and the exploitation of Copernicus Sentinel data, initially in Chile and later also in the Latin American region. Currently the site maintains a window of 60 days of all Sentinel-1 and -2 data tiles which intersect the Chilean territory.

			The site is primarily intended to enable users to download the data. www.datoscopernicus.cl
Colombia Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IDEAM)	26-Dec-2019	2018	IDEAM is in the process of establishing a regional data access/analysis site to facilitate access to and the exploitation of Copernicus Sentinel data in the Latin American region. The current area of interest is limited to Colombia. The initial aim of the site is to provide data to create annual reporting of deforestation of the country.

Table 38: International Partners summary

The international partners which have opened their national data access sites provide annual feedback on the use of their sites and the uptake of Copernicus Sentinel data. The input received for Y2021 is summarised below. Where information was not available this is shown as 'N/A'.

Table 39 presents information about the number and type of users on each of the operational sites.

Unfortunately, no statistics are available this year for the Serbian national data site. BioSense spent 2021 restocking the archive with Copernicus Sentinel data over the Balkan regions, after the hard disk failure during the previous year which had resulted in a total data loss for the site. BioSense was able to restock the latest year and a half (from 1 January 2020), but they faced errors with the GUI and were not able to get their instance of the DHuS working properly during the year. However, thanks to collaboration with other CollGS partners (in particular, those which use the same software for the dissemination and which faced the same issue during past years), they will be able to conclude the preliminary action for starting the service within the 2022.

By the end of Y2021, the Brazilian site was in the pre-operational testing phase, so only a few statistics are included in this Report. , INPE worked closely with the DHuS support team throughout the year, however, and since December 2021 (just outside the reporting period) the synchronizing software has been working correctly in the operational environment, so they will be able to open the external access in Y2022.

It should also be noted that for USGS and NASA, the figures presented under 'Principal user categories' are calculated on the basis of the proportion of downloads which were made by each category of user, while for the other partners the percentages show the proportion of their registered users which fall into each category.

International Partner	Operation start date	Number of active users in Y2021	% increase in active users since Y2020	Principal user categories (percentages of registered users unless otherwise stated
Geoscience Australia (Australia)	26-Jun-15	6,959 *	3.4%	National or regional institutions and bodies: 11% European Union institutions and bodies: 0.1% National or regional public authorities in the European Union or Copernicus participating states: 0% Other international national or regional institutions or public authorities: 3% Research and education organisations: 35% Commercial and private bodies – SMEs: 23% Commercial and private bodies – non SMEs: 3% Charities and non-governmental organisations: 2% Intergovernmental and international public organisations: 0.1% Natural persons for non-commercial purposes: 22% Other: 0.2%
NASA (USA)	12-Dec-15	N/A	N/A	*[percentages are of download proportions]* Research: inc. government: 5.8% Commercial: 10% Education: 7.9% Other: US Organization and foreign users: 76.3%
NOAA (USA)	01-May-2016	N/A	N/A	NOAA National Centres for Coastal Ocean Science NOAA National Weather Service Ocean Prediction Centre NOAA Satellite Analysis Brance US Navy CoastWatch/OceanWatch
USGS (USA)	16-Feb-17	57,297	1.8%	*[percentages are of download proportions]* Academic Institution: 55% Private Business: 18% General Public: 13% Other: 5% Non-profit Organization: 3,4% Non-US Federal/National Government: 3,3% US Federal Government: 0,2% Tribe/Narion/Indigenous Group: 0,02%
University of Chile (Chile)	27-Sep-19	383	7.9%	Research: 40% Commercial: 6% Education: 33% Other: 21%
SSAU (Ukraine)	01-Jan-20	59	51.3%	Research: 16% Education: 83% Other: 1%
ISRO (India)	26-Jan-20	112	-32.5%	N/A
IDEAM (Colombia)	01-Dec-18	N/A	N/A	N/A
AEB (Brazil)	14-Mar-19	N/A	N/A	N/A
BioSense (Serbia)	N/A	N/A	N/A	N/A

Table 39: International Partner general characteristics and statistics for Y2021

* Active users - as user information is not recorded for all downloads, the total number of active users value is based on unique IP addresses. In addition, a review of previous calculations of this value indicates it has been overestimated in the past. A corrected value for this year has been supplied above and when compared to the (corrected) value for last year (6731) indicates an increase of 3.4% in "active users" this year.

International Partner	Total Published Volume in Y2021 (TB)	% Change in Published Volume from Y2020	Total Published Volume since start of data distribution (TB)	Total Downloaded Volume in Y2021 (TB)	% Change in Downloaded Volume from Y2020	Total Downloaded Volume since start of data distribution (TB)
Geoscience Australia (Australia)	1,955	-0.02	5,181	4,436	0.2	15,322
NASA (USA)	N/A	N/A	N/A	16,627	-0.07	31,399
NOAA (USA)	418.7	77	1,336.7	51.3	474	124.3
USGS (USA)	N/A	N/A	N/A	498.13	N/A	N/A
University of Chile (Chile)	137.0	97	326.0	1.5	0	2.6
SSAU (Ukraine)	111	-2.6	226	3.5	6	3.8
ISRO (India)	165	1.7	244	64	0.07	98
IDEAM (Colombia)	N/A	N/A	N/A	N/A	N/A	N/A
AEB (Brazil)	81.2	100	81.2	-	-	-
BioSense (Serbia)	N/A	N/A	N/A	N/A	N/A	N/A

Table 40: International Partner publication and download statistics for Y2021

Table 40 above summarises, per partner, the volumes of published and downloaded data by the end of Y2021 and, where applicable, also the percentage change with respect to the end of Y2020. The changes which took place on the Chilean site are particularly striking: there was a 97% increase in the volume of data published on the site during the year, while a 8% increase in the number of active users which engaged with the site compared to the number in Y2020.

Also notable this year, the volume of data which NOAA published was 77% higher than in Y2020, and the amount of data downloaded increased by 474%.

In Table 41, the overall volumes of user-level data published and downloaded in Y2021 are broken down by Sentinel, to show the focus of each site in terms of the Sentinel missions which are made available to their users, and the respective interest of the users.

More information about the Commission's international cooperation on EO data exchange under Copernicus can be found at:

https://www.copernicus.eu/en/international-cooperation-area-data-exchange

International Partner	Y2021 Published Volume (TB)				Y2021 Downloaded Volume (TB)			
	S-1	S-2	S-3	S-5P	S-1	S-2	S-3	S-5P
Geoscience Australia (Australia)	272	592	1,051	40	2,144	1,599	693	N/A *
NASA (USA)	N/A	N/A	N/A	N/A	16,627.1	N/A	N/A	1128
NOAA (USA)	77.4	54.6	286.7	N/A	23.83	0.36	27.1	N/A
USGS (USA)	N/A	-	N/A	N/A	N/A	498.13	N/A	N/A
University of Chile (Chile)	64.86	50.05	22.17	N/A	0.85	0.39	0.24	N/A
SSAU (Ukraine)	52.14	37.06	22.18	N/A	1.83	1.67	0.003	N/A
ISRO (India)	15	150	N/A	N/A	16	48	N/A	N/A
IDEAM (Colombia)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AEB (Brazil)	55.5	25.7	N/A	N/A	-	-	N/A	N/A
BioSense (Serbia)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 41: International Partner published and download volumes, per Sentinel mission for Y2021

* While Sentinel 5P data is now being published on GA's site, download statistics are not yet being recorded.

5 Data Access System perfomance analysis

Performance analysis plays a key role in the continuous improvement of the Sentinel Data Access System. The approach and the results from this continuous analysis process are described in this section.

5.1 Service Availability

Service availability is defined as the percentage of a given time period during which it is possible for users to search the catalogue and retrieve user-level data from the system. The service availability of each of the data hubs is constantly monitored and presented to users in the statistics panel of each data hub. The number of user-level data published and downloads made in the previous 24hrs is also provided for each hub, to broaden the view of the current performance of the hub.

Table 42 below presents the overall availability for each of the four hubs for Y2021. For comparison, the table also sets out the corresponding values recorded for Y2020, Y2019, Y2018, Y2017, Y2016 and Y2015 where available. For the Open Hub, it is highlighted that the availability values are calculated using the combined availability of each access instance, i.e. the Graphical User Interface (GUI) and the API Hub. For the ColHub, the redundancy provided by the second and third nodes (in operation from 27 July 2017 and 13 March 2018 respectively) is taken into account: no downtime is recorded unless all three nodes are simultaneously down (which in fact did not happen during the period).

In general, the achievements regarding availability confirm the impressive results of Y2019 and Y2020: each Hub achieved over 99% overall availability, and all the hubs showed an improvement on the availability recorded during the previous years.

Hub	Y2021	Y2020	Y2019	Y2018	Y2017	Y2016	Y2015
Open Access Hub	**99.39**	99.10	99.34	98.48	98.95	95.11	96.62
Collaborative Hub	**100**	100	100	100	98.04	98.19	96.09
Copernicus Service Hub	**99.90**	99.23	99.60	98.50	98.60	99.35	N/A
International Hub	**99.99**	99.99	99.95	99.90	98.89	99.59	N/A

Table 42: Overall availability of each hub during reporting years Y2015 – Y2021

Month	Open Access Hub	Collaborative Hub	Copernicus Services Hub	International Hub
Dec-20	97.56	100	99.36	100
Jan-21	99.57	100	100	100
Feb-21	98.79	100	99.7	100
Mar-21	99.78	100	100	100
Apr-21	99.62	100	99.97	100
May-21	99.1	100	100	99.82
Jun-21	100	100	100	100
Jul-21	99.73	100	100	100
Aug-21	99.09	100	100	100
Sep-21	100	100	100	100
Oct-21	99.38	100	99.83	100
Nov-21	99.96	100	99.95	100
Y2021	**99.39**	**100.00**	**99.90**	**99.99**

Table 43: Monthly availabilities during Y2021 per hub (green shading indicates >98% availability; yellow shading indicates 95-98% availability; red shading indicates <95% - not present)

Table 43 breaks the overall availability figures down by month for each of the hubs.

The highest overall availability was 100% recorded for ColHub. 100% service availability was also recorded for ColHub in the previous years. This result was achieved due to the 3 nodes operating in parallel, which provide sufficient redundancy to safeguard service continuity: as long as one of the nodes remained operational, users could switch to that node to retrieve the data if a problem arose on one of the other nodes. A period of simultaneous downtime never happened during Y2021, and in fact it has not occurred since the opening of the second node for the ColHub in July 2017. The 3-node structure also enables the service team to carry out maintenance on the nodes without disrupting the service availability.

The IntHub – hosted on the NOA/GRNET infrastructure – again achieved 99.99% overall yearly availability, , stable from Y2020. In fact, for eleven months of Y2021, no downtime was recorded on the Hub at all; small periods of unavailability were recorded only in May 2021.

As can be seen from Table 43, only OpenHub monthly availability went below 99% In December 2021 and this was the result of a series of extended unscheduled maintenance activities due to the outage between the two T-Systems data centres, which impacted the Open Hub as described further below.

Praiseworthy, from a user point of view, all the hubs have not been impacted by the fire incident in OVH taking place on March 2021.

The previous years of infrastructure upgrades and lessons learnt have created a system which is operationally robust, notwithstanding the ever-increasing pressures which are placed on the system through user activity and data publication. Below is a list and description of the scheduled upgrade and maintenance activities which took place in Y2021:

- 01/12/2020 07:00-17:30 - During this planned maintenance due to infrastructure security patching, some service interruptions have been occasionally experienced by the following access points: the Copernicus Open Access Hub - including API Hub and Copernicus Sentinels POD Data Hub (on 1 Dec 20); the Collaborative Data Hub Node1 (on 2 Dec 20); the Copernicus Services Data Hub (on 2 Dec 20). The International Access Hub, the Collaborative Data Hub - Node-2 and Node-3 and the Sentinel-5P Pre-Operations Data Hub have not been affected by the maintenance.
- 15/12/2020 08:30-16:30 - Infrastructure maintenance for updating the data hub software

on Sentinel-5P Pre-Operations Data Hub, during which a 30 minutes downtime has been experienced preventing the end-users from querying and downloading data. Also, the user level data publication on the catalogue has been temporarily suspended for the duration of the maintenance.

- 16/02/2021 07:00-17:30, 17/02/2021 07:00-17:30 – Planned Infrastructure security maintenance which caused the publication delay of all Copernicus Sentinel-1, Copernicus Sentinel-2 and Copernicus Sentinel-3 user level data on the following access points: Copernicus Open Access Hub, Collaborative Data Hub Node-1, Copernicus Services Data Hub. Any service interruptions have been occasionally experienced by these access points, as well. The International Access Hub, the Collaborative Data Hub - Node-2 and Node-3 and the Sentinel-5P Pre-Operations Data Hub have not been affected by the maintenance.
- 23/02/2021 07:00-17:30 – Planned Infrastructure Security maintenance caused service interruptions on the Copernicus Open Access Hub (also including API Hub and Copernicus Sentinels POD Data Hub).
- 24/02/2021 07:00-17:30 – Planned Infrastructure Security maintenance caused service interruptions on the following data hub instances: Collaborative Data Hub Node-1, Copernicus Services Data Hub. The International Access Hub, the Collaborative Data Hub - Node-2 and Node-3 and the Sentinel-5P Pre-Operations Data Hub have not been affected by the maintenance.
- 24/06/2021 04:00-16:00 An OVH network maintenance involved the full NASHA Roubaix zone, the core infrastructure hosting the data hub services. During this period there were some service interruptions and publication delay for all Sentinel-1, Sentinel-2 and Sentinel-3 user level data on the access points: Copernicus Open Access Hub (also including API Hub and Copernicus Sentinels POD Data Hub), Collaborative Data Hub Node1, Copernicus Services Data Hub and International Access Hub. To perform this maintenance and as a precautionary measure, the Sentinel-2 dataflow was stopped to prevent any loss or corruption of data during the maintenance window. This caused a backlog in publication of S2 user level data.
- 06/09/2021 06:00-14:00 An exceptional maintenance on the ONDA-DIAS Catalogue to improve the Solr response time of the queries, delayed the retrieval of Offline data on DHuS Services. During the maintenance window no service downtime have been reported on DHuS Services. Activities have been performed without perturbation on the nominal publication flow. The Offline catalogue back-online correctly.
- 14/10/2021 06:00-15:00 . Maintenance activity to permit the necessary configuration updates in view of increasing the data retention period for immediate access. During the maintenance window short interruptions and publication delay have been experienced for all Sentinel-1/2/3 user level data on SciHub, ApiHub, CopHub, ColHubNode1, DiasHub Node1.
- 25/11/2021 08:00-16:00: Infrastructure maintenance with the aim to improve the download experience on SciHub and ApiHub. During the maintence window short download interruption have been experienced.

Several unexpected anomalies were also experienced during Y2021. The most significant of these anomalies were:

- 22/12/2020 08:00-17:05/21:30 - Unscheduled downtimes were experienced by the following access points: the Copernicus Open Access Hub (SciHub access point for 13h:30m, the APIHub for about 11 hours), the Copernicus Services Data Hub (for about 1 hour) and the Collaborative Hub-Node1 (for about 9 hours). The incident was caused by a link outage between the two T-Systems data centres. The Copernicus Services Data Hub, International Access Hub, and the Collaborative Data Hub - Node 2 and Node 3 were available in the meantime but user level data publication was temporarily suspended.
- 11/01/2021 10:30-12:30 – Extraordinary maintenance activities whereby a series of virtual machines have been migrated to a different server and this caused a degradation of the service response times on the Open Access Hub.
- 10/03/21 01:10-12 Mar 21 11:00 – Fire Incident at OVH Strasbourg. Connection lost with our facilities at 1:00 a.m. UTC on 10 March 2021.

Sentinel-2 and Sentinel-5P user level data publication was not impacted. S-1, S-2 and S-3 Off-line data could not be ordered. Copernicus resources were hosted in a building that was not been damaged by the fire but to prevent any possible incident the power was cut off as precaution. On 12 March Sentinel-1 and Sentinel-3 fresh data publication was restored; On 14 March Sentinel Historical Archive Access was resumed.

- 02/05/21 22:07-17:30 - 03/05/2021 01:30 and 05/05/2021 15:46-17:46. Unscheduled infrastructure maintenance caused downtime episodes affecting both the SciHub and API Hub access points due to the completion of the Data Access services migration to the cloud. At the time of migration to the new infrastructure, the involved VMs have been affected by an unpredictable problem involving the database: "Too many open files". Problem has been fixed by tuning some SO kernel configurations.
- 17/05/2021 16:17-17:22. Unscheduled maintenance due to a problem which affected the DNS GRNET.GR Domain Name resolution of the Greek Complementary Centre. This problem affected the International Access data Hub, the ColHub Node3, the Africa Cast Hub, the Sentinel-5P Hub, the Sentinel-5P ExpertHub and the DiasHub Node.
- 02/08/21 10:46/11:03 and 11:19/12:27 on 03/08/2021 01:56/02:46 and 02:55/06:20 on 05/08/2021 01:39/02:10 and 02:14/02:26 Unexpected downtime affecting the SciHub access points due to a high number of session generated by a rogue user accounts. Episodes occurred mainly during the night (CEST Local time) and service have been restored between the mentioned time window. Ingestion and Publication of user level data continued nominally without perturbation.
- 13/10/21 07:30-08:30 Unpredicted network issue during OVH cloud maintenance caused downtime affecting SciHub and API Hub CopHub ColHub node 1 and node2.
- 21/10/2021 02:09-06:31 Sporadic download issues on Copernicus SciHub Access Hub were observed due to a high number of sessions generated by rogue user scripts during several intervals
- 29/10/2021 07:05 – 07:20 Short unavailability on SciHub due unexpected service downtime due to database client-server communication failures. During this period access to the service was affected. New data publication and Download were not possible.

5.2 Network Analysis

Infrastructure upgrades

In Y2021 a major infrastructure upgrade took place with the transfer of the Data Access system to the cloud being completed on 30 April 2021 (see Section 1.2.2)

Data traffic loads

Since no new Copernicus missions were launched in Y2021 there were no particular increases of traffic load predicted for Y2021 other than the usual rise due to the ever-increasing number of active users and consequently more downloads being requested from the system.

The graph in Figure 83 shows the daily average (in green) load over a 3 month reporting period on the link from April 1st to June 30th from the legacy infrastructure. It shows the average aggregated load on thenetwork which included dissemination to via commodity internet and GÉANT (for academic users) . The aggregate traffic statistics show peaks up to 32Gbps from the core centre (T-Systems).. After the decommissioning of the centre the traffic goes down to zero Gbps.

Figure 84 shows the daily outgoing traffic from the cloud infrastructure (OVH), during the period from 30 May 2021 to 30 October 2021, with the blue lines showing the MAX and the green line showing the AVERAGE transmit rate reached on each particular day. This demonstrates that the user requests have been managed and the maximum peaks did not overpass the 55Gbps of usage (except for few days in summer 2021).

A decrease of traffic was seen after the summer months, with the average load that went from an average of 43 Gbps at the end of August and become around 35 Gbps at the end of October.

Comparing Figure 1 and b, it can be seen that the network capacity during Y2021 has benefit from the the infrastructure change to cloud and the overall maximum outgoing traffic rose of 83% from 30Gbps to more than 55Gbps.

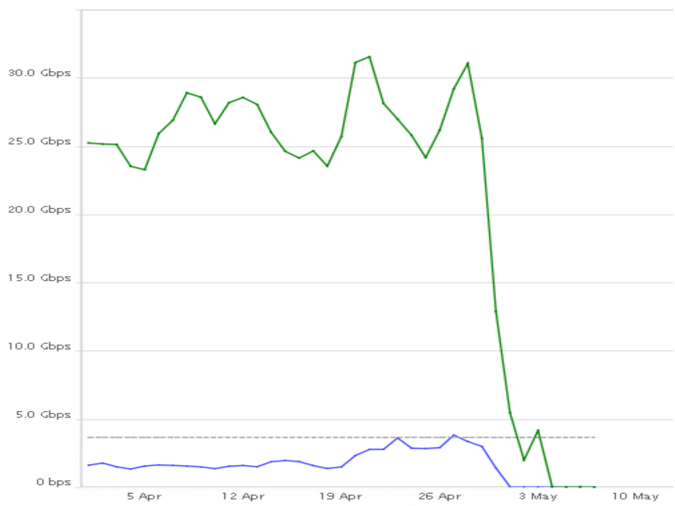


Figure 82: Average T-Systems outgoing traffic (in green) from 01/04/2021 to 10/05/2021

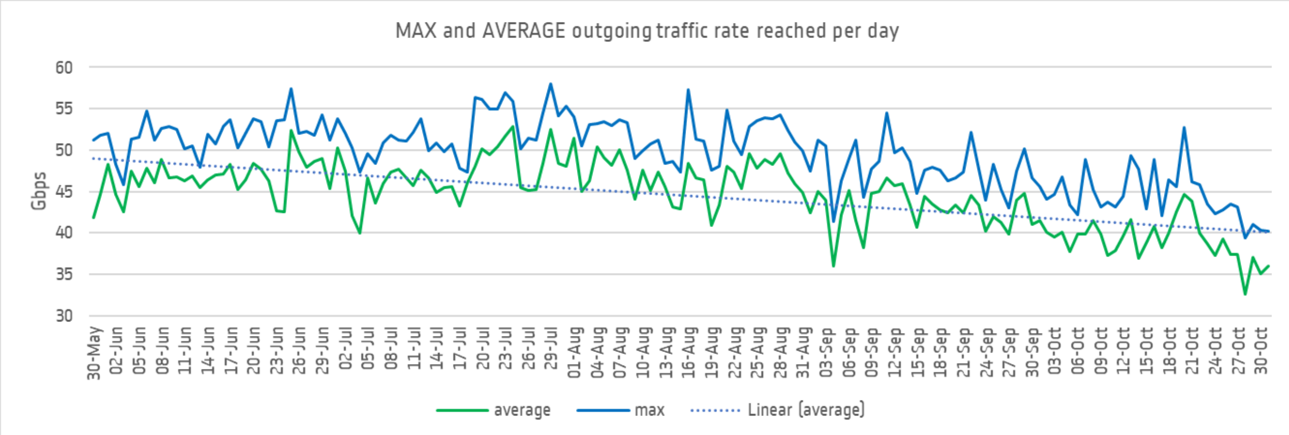


Figure 83: Max (in blue) and average (in green) outgoing traffic in Gbps reached each day from 30/05/2021 to 30/10/2021

Effective bandwidth

Figure 85 below presents for each hub the percentage of completed downloads performed in Y2021 in the following four effective bandwidth ranges: <10Mbps, 10-50Mbps, 50-100Mbps and >100Mbps. The effective bandwidth is calculated using the time it takes to download a user-level data and the volume of that downloaded user-level data. The effective bandwidth depends on many factors, such as the actual network bandwidth available to the user, the performance required to save the user-level data on the user's disk, as well as the concurrent activities on the hub at the time the download is made. Figure 81 shows the effective bandwidth on each hub, taking into account all of the completed downloads during Y2021, as well as providing the combined statistics for all of the hubs together. This provides an approximate overview of the rates at which users of the hub were able to download the Sentinel user-level data.

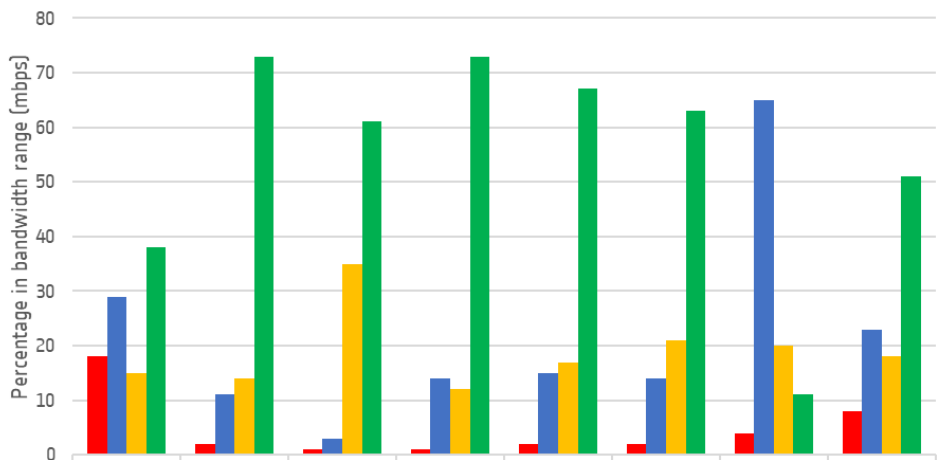
This year, 38% of the effective bandwidth associated to the users of Open Hub was higher than 100 mbps.

For all hubs except the IntHub, the most frequently experienced (or equal highest) effective bandwidth was >100 Mbps. This indicates that users of the Open Hub, ServHu, Diashub and ColHub were for the most part able to download user-level data at a very fast rate.

For ServHub and ColHub Nodes 1 and 2, more than 65% of downloads took place at >100 Mbps; and for both the OpenHub and ColHub Node 3 over 40% of downloads occurred at >100Mbps: 56% and 48% respectively.

For the Open Hub, the most frequently experienced effective bandwidth was >100Mbps range, with 38% of downloads from the Open Hub taking place in this range. This is lower than the 56% registered for Y2020. The percentage of downloads taking place at 50-100 Mbps returned the quite the same as Y2019, 15%. Again due to the diversity of users, it is not possible to identify a single reason for the down in downloads taking place at >100Mbps on the Open Hub, and it is likely to be the result of a combination of factors. One potential contributing factors could be the increase of people smart-working from home in which the connection bandwidth is lower than the ensured download rate in the enterprises premises.

Overall, the statistic which takes all hubs into account shows an encouraging and sustained improvement: 51% of all downloads were made at an effective bandwidth of >100 Mbps; the equivalent figure in Y2020 was 60% and in Y2019 was 45%. Moreover, 69% of downloads during Y2021 were made at speeds of over 50Mbps, down from 81% in Y2020 and up from 68% during Y2019.



	Open Access Hub	Collaborative Hub-node1	Collaborative Hub-node2	Collaborative Hub-node3	Copernicus Services Hub	Dias Hub	International Hub	All Hubs
< 10 mbps	18	2	1	1	2	2	4	8
10 -50 mbps	29	11	3	14	15	14	65	23
50 - 100 mbps	15	14	35	12	17	21	20	18
> 100 mbps	38	73	61	73	67	63	11	51

Figure 84: Effective bandwidth range per Hub for all completed downloads during Y2021 after the transfer to cloud

5.3 Publication Timeliness

Publication timeliness is a measure of the time it takes from the data being sensed by the satellite to the user-level data being published on a data hub. The timeliness depends on the end-to-end design of the mission, from the point in the orbit at which the image was sensed to the geographical position of the receiving antenna, and then to the priority given to each user-level data in the processing and publication chain. The publication timeliness can be affected by a disturbance at any point in this production and publication chain.

User-level data are categorized as either Near Real Time (NRT) or Short Time Critical (STC) or Non-Time Critical (NTC).

The expectation for **Sentinel-1 and Sentinel-2** user-level data is that they will be published within 24 hours from sensing.

For **Sentinel-3**, the annotated timeliness provides an indication on the expected availability date and it is:

- **NRT** user-level data are intended to be made available to the users less than 3 hours after acquisition of the data by the sensor;
- **STC** user level data are expected in less than 48 hours and
- for **NTC** user-level data the latency is 30 days from sensing, allowing consolidation of some auxiliary or ancillary data.

Sentinel-5P NRT user-level data shall be available for users to download within 3 hours from sensing while for the **Sentinel-5P Offline** user-level data, the timeliness threshold depends on the level:

- **Level-1B** shall be available to users to download within 12 hours of sensing, and
- **Level-2** within 14 days.

In this section, only user-level data which were published within 7 days of sensing are included in the calculations (with the exception of Sentinel-3 NTC, which has a 1 month timeliness). This is to remove as far as possible the risk of distorting the figures with retrospectively processed data, and to be able to report the performance measured on the routine dataflow, given that user-level data published after 7 days are either the result of reprocessing or exceptionally serious anomalies.

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mission	Average timeliness for NRT user level data	Increase/ decrease since Y2020	Average timeliness for NTC user level data	Increase/ decrease since Y2020	Average timeliness for STC user level data	Increase/ decrease since Y2020
S1	4h 20m	n/a	10h 20m	+ 4h 55m	-	
S2	-		7h 15m	- 35m	-	
S3-OLCI	2h 20m	- 40m	1d 6h 0m	- 20m	-	
S3-SLSTR	3h 00m	=	1d 12h 0m	+ 5h 40m	-	
S3-SRAL	2h 0m	- 40m	25d 11h 0m	- 48m	1d 7h 0m	+ 1h 40m
S3-SYNERGY	-		2d 3h 20m	+ 11h 40m	17h 40m	+ 8h 40m
S5P-L1B	-		6h 0m	- 3m	-	
S5P-L2	2h	- 15m	1d 18h 0m	- 1d 7h 37m	-	

Table 85: Average publication timeliness on the Open Hub over Y2021 for user-level data, and comparison with Y2020

As for last year, it is highlighted that the Y2021 average publication timeliness figures have been calculated considering the availability of data on Open Access Hub over the last three months of the reporting period.

Table 85 above shows the average sensing-publication timeliness for the user-level data on the Open Hub during Y2021, and the change with respect to the Y2020 values

Sentinel-1

As reported in Chapter 1, since 23 February 2021, for Sentinel-1, the same processing is performed for L1/2 user level data tagged NRT and NTC. The annotated timeliness depends on the geographical area covered by the user level data (giving priority on the European covered areas) and it is not anymore an indication of a different data quality. Data is processed only once and made available to all users of all the Hubs.

Figure 87 shows the average monthly timeliness for Sentinel-1 NRT after the production scenario change and the monthly average publication timeliness on the Open Hub for Sentinel-1 NTC user-level data during Y2021. The dotted orange lines show the monthly timeliness during Y2020 for comparison and the dotted red lines shows the threshold of expected time for user level data availability. For the NRT user level data the comparison with the previous year is not relevant because of the change but it shows that the <24 hour target was achieved, on average, throughout Y2021. For the Sentinel-1 NRT user-level data, a 3 hour sensing-publication average was achieved for all months, apart from some months in which the average rose up to 6 hours and the overall average between all months is 3hours and 25 minutes.

Sentinel-1 NTC user-level data were on average available for download within 10h 20m from sensing; this represents a small deterioration in the timeliness with respect to the average timeliness for Y2020. It is highlighted, however, that in comparison with the threshold, the publication timeliness of both Sentinel-1 NTC user-level data on the Open Hub calculated for Y2021 were well below the expected 24 hours.

It can be seen that the monthly publication timeliness trend was similar to the that shown in Y2020, with a peak in February and another in November in which the timeliness reached 17h and 20h respectively. This year the average publication timeliness was 9 hours, an half with respect to the average timeliness during the other months of Y2020.

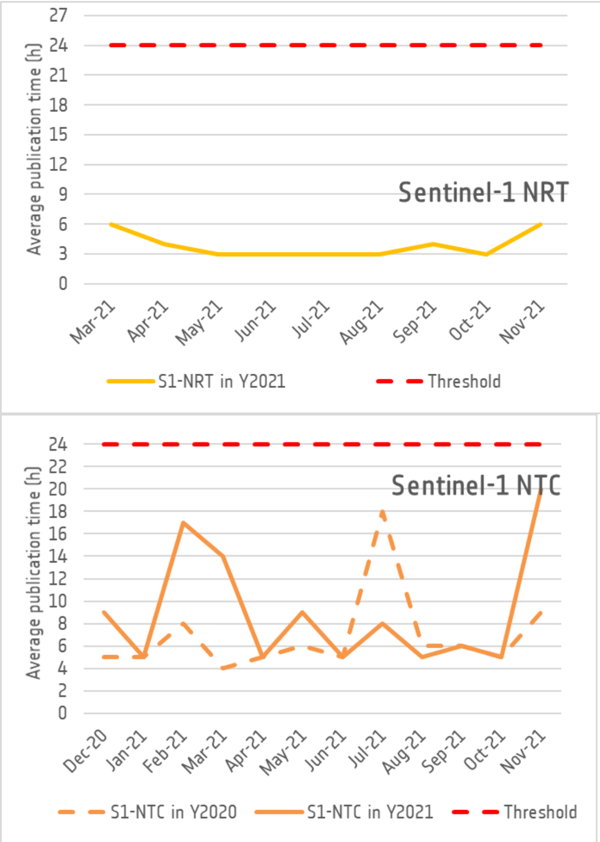

Figure 86: Monthly Average Publication Timeliness on the Open Hub for Sentinel-1 user-level data during Y2021,(NRT are reported only after the scenario change).

Sentinel-2

The Sentinel-2 NTC user-level data timeliness in Y2021 was on average 7h 15m and this is 35minutes faster with respect to the last year. Figure 88 shows the average monthly timeliness for Sentinel-2 and it shows that the trend fluctuates though with less extreme peaks. Again, for all months the 24 hour threshold was respected. The best average timeliness achieved was the 5 hours recorded for two months, February 2021 and October 2021. The worst case was the average timeliness of 11 hours recorded for May 2021. So, in summary, for Sentinel-2, the graph indicates that outside some months, the performances in terms of timeliness were stable in a range of 5 and 8 hours .

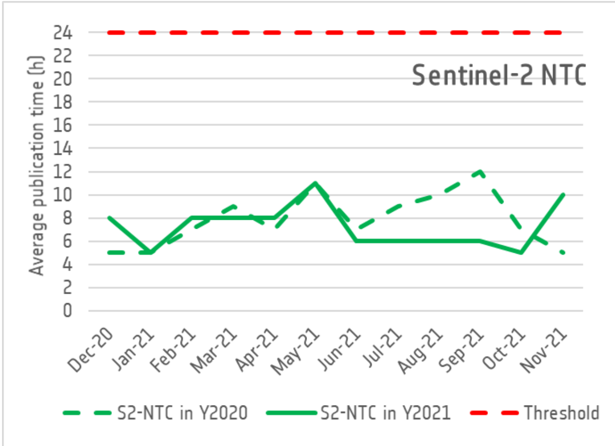

Figure 87: Monthly Average Publication Timeliness on the Open Hub for Sentinel-2 NTC user-level data during Y2021, with Y2020 for comparison

Sentinel-3

Figure 89 shows the monthly publication timeliness for each set of Sentinel-3 user-level data on the Open Hub, with Y2020 for comparison (The dotted red lines indicate the threshold of expected timeliness – note that the 30-days threshold for NTC data are not indicated for a better visualization of results).

For the Sentinel-3 NRT data, the overall Y2021 average was 2h 20m for OLCI, 3h for SRAL and 3h for SLSTR and this represents a decay of 40 minutes for OLCI and SRAL with respect to last year average.

In more details, the target 3-hour NRT timeliness was achieved for each instrument for at least 8 months over Y2021, except for 3 or 4 months in which the publication timeliness registered was between 4 and 7 hours with exception of July 2021 in which the publication timeliness reached 14-15hours for all the instruments.

This was due to an issue occurring at PDGS level on 15 July, which caused a temporary pause in production of Sentinel-3 user-level data, and so delayed publication of the sensed data. For those delayed data, the countermeasures were taken, and the issue was overcome within 6 days from sensing date.

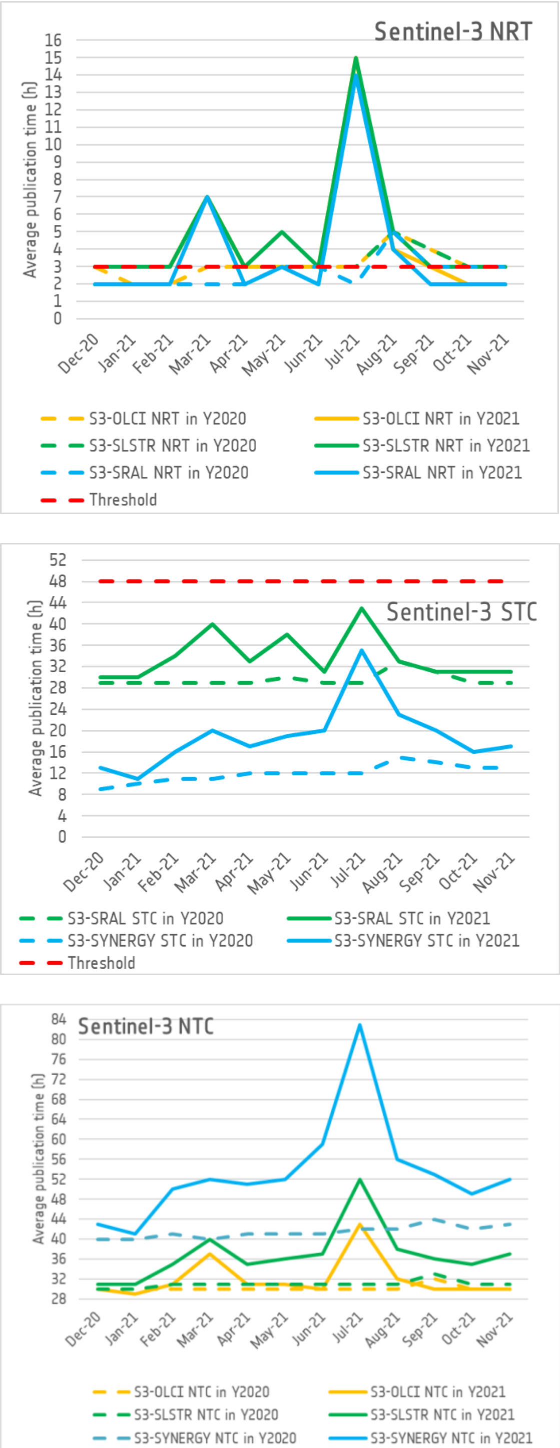

Figure 88: Monthly Average Publication Timeliness on the Open Hub for Sentinel user-level data during Y2021, with Y2020 for comparison

For Sentinel-3 STC and NTC user level data, it can be seen that on average the thresholds were respected in all cases. SRAL NTC user-level data are not shown on the graph due to the far longer timescale in which they are published which would distort the graph, but, as per last year, it is confirmed that an average monthly timeliness of 25d 11h 0m was achieved throughout Y2020, below the 30 days threshold.

Comparing with the previous year, the publication timeliness related to the NTC user-level data of all the Sentinel-3 instruments was almost stable with a small increase/deterioration (<20%) with respect to the previous year especially in July 2021, as already noted for NRT data.

Sentinel-5P

As shown in Table 85, during Y2021 the average time for publication of Sentinel-5P NRT user-level data was 2h, respecting the constraint.

The Sentinel-5P timeliness threshold for the Offline user-level data depends on the level: Level-1B shall be available to users to download within 12 hours of sensing, and Level-2 within 14 days. It can be observed that the average timeliness for Offline data during Y2021 respected the constraints and, moreover, most of the Level-2 OFFL user-level data are currently generated in 3 days, with the exception of the NO2 that is disseminated in about 10 days and the O3_TCL that is generated in 15 days.

5.4 Data Hub Maintenance and Software Improvement

During Y2021, the Data Hub Service Maintenance Team focused on:

- supporting the DHuS Transition to Cloud Infrastructure (see section 1.2.2).
- balancing eviction's mechanism thanks to a proper queue construction. The management of the Eviction's queue has been improved in order to ensure a more balanced mechanism.
- Adding support for Keystone v3 authentication API to interface with Swift Object Storages.

- Implementing a series of implementations and bug fixes aiming to enhance User and Administrator experience.

The DHuS Transition to Cloud Infrastructure has been achieved implementing the serving of online Sentinels user level data through ONDA DIAS Object Storage. This scenario was possible introducing a new DataStore as interface with the new storage. Interfacing the ONDA DIAS OpenSearch Catalogue, user level data online on the DHuS instance are referenced with ONDA DIAS storage information.

Furthermore, some implementations have been developed to enhance User and Administrator experience, such as:

- Update the Upload Panel accessible via Graphical User Interface in order to support the new OData v4 File Scanner;
- Improve the logging verbosity during Synchronization. The Synchronizer's log has been improved adding information about the query performed during the process;
- Add the filtering on 'StatusMessage' property for Orders OData Entity;
- Correct the launch date for S-1B user level data.

In addition, the indexing for 'nbFire' value for Sentinel-3 SLSTR FRP user level data has been added.

5.5 Open Source DHuS Framework

The Data Hub Software (DHuS) is made available as open source software to any interested party and can be easily installed and configured by users wishing to manage a local archive of Copernicus Sentinel user-level data:

(http://sentineldatahub.github.io/DataHubSystem/).

DHuS Releases

In Y2021, two new versions of the Open Source Framework (OSF) software were released. With v.2.7.7-osf, the following main enhanced features were introduced:

- Support for Sentinel Auxiliary POD and RINEX files
- Support for Sentinel-3 SL_2_FRP___ and SY_2_AOD___ data types
- Support for SMOS user level data
- Extraction of further Sentinel-2 metadata

The Open Source DHuS v.2.7.8-osf provided routine bug-fixes and also introduces the extraction and indexing of the number of fires present in Sentinel-3 SLSTR FRP user level data.

Open Source DHuS Downloads

At the close of Y2021, the total number of downloads of all versions of the OSF was 7,393, an increase of 1,538 downloads since the end of Y2020. Within this total, there were 815 downloads of v2.7.7-osf (released in February 2021) and 682 downloads of v.2.7.8-osf (released in June 2021). Overall, therefore, there were 1,497 downloads of the Open Source DHuS versions published in Y2021.

Support to OS Community

Technical support has been provided to the different users (typically institutional agencies and research centres), through a dedicated Role Account (DataHubSystem@serco.com).

As with prior years, During Y2021, the OSF was highlighted at the event 'Collaborative Ground Segment Workshop' which took place online on 18-19 October 2021, and providing the opportunity to the Collaborative Ground Segment partners to express their feedback and future needs towards the OSF.

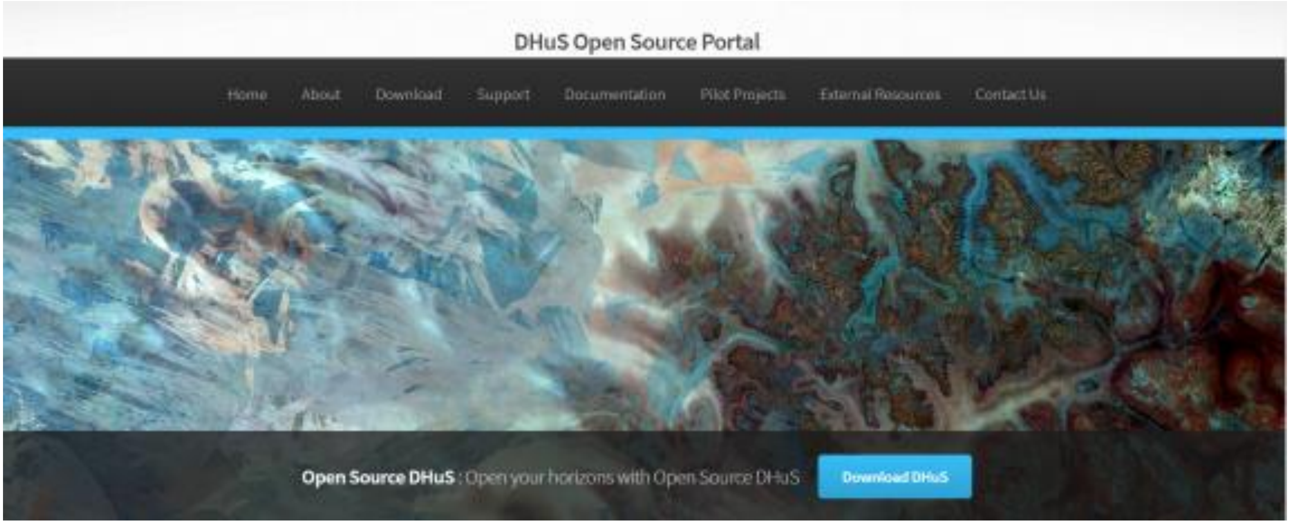

Figure 89: Open Source Dhus portal webpage

6 User Feedback

Feedback from users is constantly monitored in order to determine if the data access service is in line with user expectations and to identify issues as they arise. Users are invited to write to the email address: **eosupport@copernicus.esa.int.** This is the first line contact point for all issues concerning Copernicus satellite data. Issues are directly responded to by the front-line eosupport team if possible. Where this is not possible, they are either referred to the Ground Segment Coordination Desk, or, if the issue is specifically related to data access, it is forwarded to the Sentinel Data Access System operations team for resolution.

6.1 Ticketing Analysis

Feedback and requests received from users of the Open Hub are tracked via a "Ticketing" system, with opened tickets sorted into the following 8 categories:

- *Service Interface:* Technical issue on interfacing to the Service (network, API, scripting, GUI, over quota reached, over quota warning received);
- *User Accounts*: issues relating to the management of user accounts (registration, validation, password reset, credentials loss, deletion, edit profile);
- *Features Request:* Improvements suggested by users about any of the topics of the ticket categories;
- *Products*: Issue on user-level data (production coverage, user-level data quality, external tool usage, user-level data deletion request, download failure, unzipping issue, naming convention information);
- *Web Portals*: News to be published, User Guide update;
- *Bug*: Service malfunctions reported by users and recognized as bugs (the issue is then managed in the maintenance cycle);
- *General*: Miscellaneous requests which do not fit into another category;
- *Junk*: Spam, empty emails, not an issue.

During Y2021, a total of 1,317 tickets were received by the Data Access operations team, with a 5% increase with respect to Y2020. The 'Junk' category - which was the largest category in Y2020 and Y2019 - accounted for 139 tickets (11%).

Of the meaningful categories, the largest proportion of tickets were for 'User Accounts' (608 tickets/46%) and 'Service Interface' (392 tickets/30%), 'Products' (112 tickets/8%) and 'General' (65 tickets/5%.).

In more details, the 'Service interface' category was including support requests for the usage of the nearline user level data interface, introduced in Y2021

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and these tickets were resolved with further support given to interested users, in addition to the already updated user guides. The tickets with 'Products' category were mostly focused on some particular issue in retrieving some specific data from the user interface. It was a consequence of the transfer to the new cloud infrastructure with the the need of preserving the data already ingested in the previous infrastructure and it was resolved by the Data Access team with some adjustment in the configuration of the eviction policy.

As in previous years, very few tickets were received for the remaining categories: in particular, during Y2021 only 1 ticket was raised for 'Web Portals' and zero tickets were raised for either 'Features Requests' or 'Bug'. Figure 91 shows the percentage split between the categories during Y2021.

During Y2021, 100% of the tickets raised were resolved within the reporting period. The time to respond to all tickets is also logged. During the year, the average response time was 21 minutes and 30 seconds. The maximum response time for any ticket was 22 hours 12 minutes.

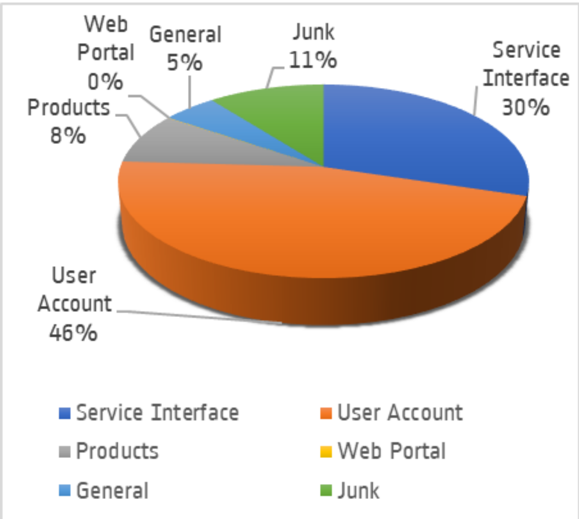


Figure 90: Proportion (percentage) of each category of tickets received from the Open Hub in Y202

7 Y2022 Outlook

During the next year, the Data Access team will manage the standard service evolutions, such as integration of the dedicated S5P Hub into the OVH infrastructure. In addition there will be the new Data Access Service that shall be operated within a broader ecosystem, the Copernicus Data Space, enabling the development of Third-Party services.

The Copernicus Data Space, is expected to encompass a number of supporting services, including in particular:

- Applications, services and data repository
- Cloud infrastructure services (storage, network and processing resources on the cloud) for user data processing and Third-Party applications and services
- User Management Services

Furthermore, in Y2022, the migration of the Sentinel-2 data fetching flow from the new CSC data production interfaces will be completed, starting with a new processing baseline update in Q2 2022.

The POD interface will also change in Y2022 and it will be migrated from FTP to PODIP, as part of ESA's 'Ground Segment Transformation' project, as described in Section 1.2.1 above.

In addition to this evolution of the Data Access infrastructure, Y2022 is the year in which the Data Access team foresees an increase in the support for enhance the cooperation between the Data Hub Relay network nodes and an improvement in the data flows. In more details, the Data Hub Relays will be involved more in the definition of requirements for the development of dedicated software for improve the capabilities of the Data Hub Network in order to be ready for the Digital Twin Earth project planned in the next years (from 2024 on) . In particular:

- Data Flow Network Environment component (DAFNE) providing users with a strong dataflow visualization and control solution in terms of configured synchronizers, evictions and products published within the DHR and Collaborative GS network.
- Transformation Framework component (TF) that allows the capability to trigger parallel processing of Sentinel-2 Level-2A products using Sen2Cor, the CFI provided by ESA, implementing classification and atmospheric correction with the Digital Elevation Model of the Shuttle Radar Topography Mission (SRTM DEM).
- Semantic Framework component (SF) aims to establish an open knowledge base allowing to associate real-world phenomena with relevant Sentinel data and possible processing transformations, accessible to DHR users via natural language search. This is ensured defining a unique vocabulary (indexes, keywords) drawn up based on use cases of interests for DHR users. The first Use Case that will be implemented is a semantic search for earthquake identification.

8 Useful Links

- European Earth observation programme Copernicus: http://www.copernicus.eu/
- Sentinel Online: https://sentinels.copernicus.eu/web/sentinel/home
- Copernicus Open Access Hub: https://scihub.copernicus.eu/
- Collaborative Hub: https://colhub.copernicus.eu/
- International Hub: https://inthub.copernicus.eu/
- Copernicus Services Hub: https://cophub.copernicus.eu/
- GitHub open source framework: https://sentineldatahub.github.io/DataHubSystem/

Annex 1: List of Acronyms

AER	Archive Exploitation Ratio
AOI	Area Of Interest
API	Application Programming Interface
CLS	Collecte Localisation Satellites
CMEMS	Copernicus Marine Environment Monitoring Service
ColHub	Collaborative Hub
CollGS	Collaborative Ground Segment
CSV	Comma Separated Values
DHR	Data Hub Relay
DHuS	Data Hub Software
DIAS	Data and Information Access Service
DLR	German Aerospace Centre (Deutsches Zentrum für Luft und Raumfahrt)
EC	European Commission
EDRS	European Data Relay System
ESA	European Space Agency
EU	European Union
GA	Geoscience Australia
GML	Geography Markup Language
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRD(H/M)	Ground Range Detected (High/Medium Resolution)
GRNET	Greek Research and Technology Network
GS	Ground Segment
GUI	Graphical User Interface
HLOP	High Level Operations Plan
HSQL	HyperSQL (Database)
HTTP	Hypertext Transfer Protocol
IntHub	International Hub
IOCR	In Orbit Commissioning Review
IPF	Instrument Processing Facility
ISRO	Indian Space Research Organisation
LEO	Low Earth Orbit
LRM	Low Resolution Mode
LTA	Long Term Archive
MET-NO	Norwegian Meteorological Institute
MSI	Multispectral Instrument (Sentinel-2 instrument)
MTU	Maximum Transmission Unit
NASA	National Aeronautics and Space Administration
NOA	National Observatory of Athens
NOAA	National Oceanic and Atmospheric Administration
NRT	Near Real Time
NTC	Non-Time Critical
OCN	Ocean (S-1 user-level data category)
OCP	Optical Communications Payload (for EDRS)
OData	Open Data Protocol
OFFL	Offline
OLCI	Ocean and Land Colour Instrument (Sentinel-3 instrument)
Open Hub	Copernicus Open Access Hub
OSF	Open Source Framework

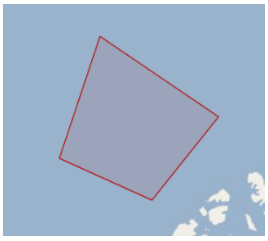
PAC	Processing and Archiving Centre
GS	Payload Data Ground Segment
PLRM	pseudo-LRM
POD	Precise Orbit Determination
PuP	PARC Universal Packet
R&D	Research and Development
RINEX	Receiver Independent Exchange Format
S-1	Sentinel-1
S-2	Sentinel-2
S-3	Sentinel-3
S-5P	Sentinel-5 Precursor
SAFE	Standard Archive Format for Europe
SAR	Synthetic Aperture Radar
SARA	Sentinel Australasia Regional Access
ServHub	Copernicus Services Hub
SLC	Single Look Complex
SLSTR	Sea and Land Surface Temperature Radiometer (Sentinel-3 instrument)
SMOS	Soil Moisture and Ocean Salinity satellite
SRAL	SAR Altimeter (Sentinel-3 instrument)
SSAU	State Space Agency of Ukraine
STC	Short Time Critical
STFC	Science and Technology Facilities Council
SYN	Synergy (Sentinel-3 user-level data type group)
TCI	True Colour Image
TEC	Total Electron Content
TOA	Top Of Atmosphere
TROPOMI	TROPOspheric Monitoring Instrument (Sentinel-5P)
USGS	United States Geological Survey
UTC	Coordinated Universal Time
VM	Virtual Machine
WAN	Wide Area Network
WMS	Web Map Service
XML	eXtensible Markup Language
ZAMG	Zentralanstalt für Meteorologie und Geodynamik

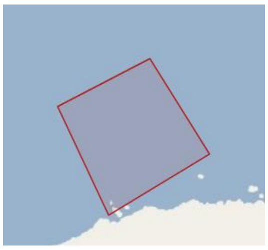
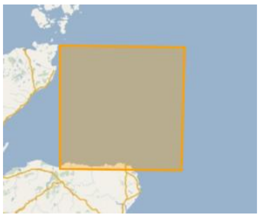
Annex 2: User-level data Type Description

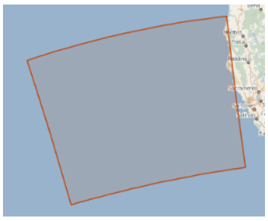
The following table provides:

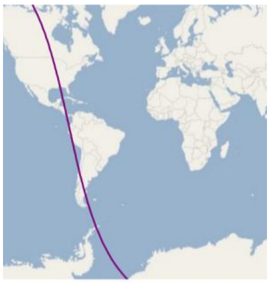
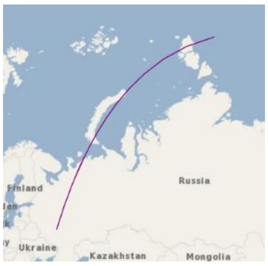
- the description of user-level data types per each mission,
- the image of how their footprints are visualized on the hub,
- the average size of the user-level data based on the calculation of the annual published user-level data. The sizes given are based on the download volume, i.e. the compressed zip file (average compression rates are provided where applicable, i.e. for Sentinel-1 user-level data).
- a short discussion on what new/changed user-level data have appeared in 2018.

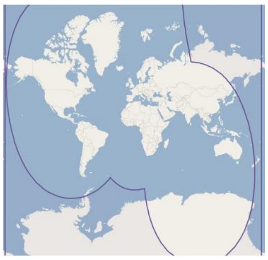
Further information on user-level data can be found on the 'Instrument user guides' following the link: https://sentinel.esa.int/web/sentinel/user-guides/

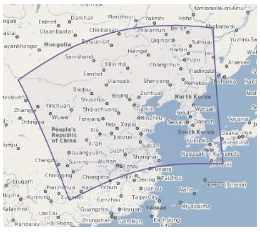
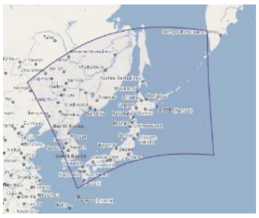
Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
Sentinel-1 (SAR)	L0-RAW	Sentinel-1 Level 0 RAW data		1.3 GiB	
	L1-GRDM	Sentinel-1 Level 1 Ground Range, Multi-Look, Detected: Medium Resolution		200 MiB	
	L1-GRDH	Sentinel-1 Level 1 Ground Range, Multi-Look, Detected: High Resolution		860 MiB	
	L1-SLC	Sentinel-1 Level 1 Single-Look Complex		4 GiB	

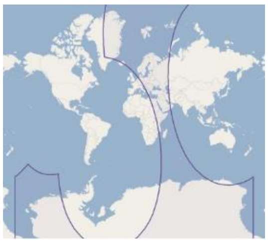
Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
	L2-OCN	Sentinel-1 Level 2 Ocean		5 MiB	
Sentinel-2 (MSI)	MSIL1C	Sentinel-2 Level 1C		480 MiB	
	MSIL2A	Sentinel-2 Level 2A		600 MiB	Global coverage from 13/12/18 (previously Euro-Mediterranean region only)
Sentinel-3 (OLCI)	OLCI L1 FR	Sentinel-3 Level 1 OL_1_EFR___ Full Resolution top of atmosphere radiance		600 MiB	Activation of Sentinel-3B data on 17/12/18
	OLCI L1 RR	Sentinel-3 Level 1 OL_1_ERR___ Reduced Resolution top of atmosphere radiance		690 MiB	
	OLCI L2 Land FR	Sentinel-3 Level 2 OL_2_LFR___ Full Resolution Land & Atmosphere geophysical user-level data		100 MiB	Activation of Sentinel-3B data on the Open Hub on 24/01/19

Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
	OLCI L2 Land RR	Sentinel-3 Level 2 OL_2_LRR___ Reduced Resolution Land & Atmosphere geophysical user-level data		170 MiB	
Sentinel-3 (SLSTR)	SLSTRL1 RBT	Sentinel-3 Level 1 SL_1_RBT___ Brightness temperatures and radiances		480 MiB	
	SLSTR L2 Land	Sentinel-3 Level 2 SL_2_LST___ Land Surface Temperature geophysical parameters	The footprint for this user-level data type depends on timeliness: NRT  NTC 	90 MiB	NRT activation on the Open Hub on 21/03/19
Sentinel-3 (SRAL)	SRAL L1	Sentinel-3 Level 1 SR_1_SRA___ Echos parameters for LRM, PLRM and SAR mode (resolution 20Hz)		25 MiB	Activation of Sentinel-3B data on 11/12/18

Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
	SRAL L1 A	Sentinel-3 Level 1 SR_1_SRA_A_ Echos parameters for PLRM and SAR mode (resolution 80Hz)		2.3 GiB	Activation of Sentinel-3B data on 11/12/18
	SRAL L1 BS	Sentinel-3 Level 1 SR_1_SRA_BS Echos parameters for LRM, PLRM		1.7 GiB	Activation of Sentinel-3B data on 11/12/18
	SRAL L2 Land	Sentinel-3 Level 2 SR_2_LAN___ 1-Hz and 20-Hz Ku and C bands parameters (LRM/SAR/PLRM), waveforms. Over Land	The footprint for this user-level data type depends on timeliness: NTC and STC  NRT (covering only LAND regions) 	36 MiB	Activation of Sentinel-3B data on 11/12/18
Sentinel-3 (SYNERGY)	SY_2_SYN	Surface Reflectance and Aerosol parameters over Land		300 MiB	Activation on the Open Hub from 25/03/19

Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
	SY_2_VGP	1 km VEGETATION-Like user-level data (~VGT-P) - TOA Reflectance		35 MiB	
	SY_2_VG1	1 km VEGETATION-Like user-level data (~VGT-S1) 1 day synthesis surface reflectance and NDVI		70 MiB	
	SY_2_V10	1 km VEGETATION-Like user-level data (~VGT-S10) 10 day synthesis surface reflectance and NDVI		175 MiB	
Sentinel-5P (TROPOMI)	L1B_RA_BD1 L1B_RA_BD2 L1B_RA_BD3 L1B_RA_BD4 L1B_RA_BD5 L1B_RA_BD6 L1B_RA_BD7 L1B_RA_BD8	Radiance user-level data bands 1-8: 1: 270-300nm 2: 300-320nm 3: 320-405nm 4: 405-500nm 5: 675-725nm 6: 2305-2345nm 7: 2345-2385nm 8: 2345-2385nm		1: 500 MiB 2: 2.8 GiB 3: 2.7 GiB 4: 2.6 GiB 5: 2.6 GiB 6: 2,6 GiB 7: 1.5 GiB 8: 1.6 GiB	
	L1B_IR_UVN	Irradiance user-level data UVN module 270-775 nm	-	30 MiB	

Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
	L1B_IR_SIR	Irradiance user-level data SWIR module 2305-2385 nm	-	6 MiB	
	L2_AER_AI	UV Aerosol Index		13 MiB	
	L2_AER_LH	Aerosol Layer Height		120 MiB	NRT and OFFL user-level data available on the S5P Hub from 30/09/19
	L2_CLOUD	Cloud fraction, albedo, top pressure		25 MiB	
	L2_CO	Carbon Monoxide (CO) total column		12 MiB	
	L2_CH4	Methane (CH_4) total column		40 MiB	OFFL user-level data available on the S5P Hub from 01/03/19
	L2_HCHO	Formaldehyde (HCHO) total column		60 MiB	OFFL user-level data available on the S5P Hub from 05/12/18

Mission and Instrument	User-level data types	Description	Footprint on the hub	Average size	New/updated user-level data in Y2019
	L2_NO2	Nitrogen Dioxide (NO_2), total and tropospheric columns		35 MiB	
	L2_NP_BD'x'	Suomi-NPP VIIRS Clouds X = 3, 6, 7		330 MiB	
	L2_O3	Ozone (O_3) total column		25 MiB	
	L2_O3_TCL	Ozone (O_3) tropospheric column	-	1 MiB	OFFL user-level data available on the S5P Hub from 01/03/19
	L2_SO2	Sulphur Dioxide (SO_2) total column		85 MiB	OFFL user-level data available on the S5P Hub from 05/12/18