

## Review document on Copernicus products related to the hydrological water balance

### Project Identification

<b>Project Full Title</b>	Water Scenarios for Copernicus Exploitation
<b>Project Acronym</b>	Water-ForCE
<b>Grant Agreement</b>	101004186
<b>Starting date</b>	01.01.2021
<b>Duration</b>	36 months

### Document Identification

<b>Deliverable number</b>	D3.2
<b>Deliverable Title</b>	Review document on Copernicus products related to the hydrological water balance
<b>Type of Deliverable</b>	Report
<b>Dissemination Level</b>	Public (PU)
<b>Work Package</b>	WP3
<b>Leading Partner</b>	Vrije Universiteit Brussel & Antea Belgium nv

### History of Changes

Date	Version	Comments
10/05/2021	V1.0	First Concept
07/06/2021	V2.0	Final Report

## Abstract

The Horizon2020 project Water scenarios For Copernicus Exploitation (Water-ForCE) will develop a Roadmap for Copernicus Inland Water Services, aiming to better integrate the entire inland water cycle within the Copernicus Services.

The current report describes the detailed inventory of relevant water quantity products provided by the Copernicus Services. It forms the basis for the requirement analysis and gap assessment in Work Package 3, which will culminate in recommendations on future products and technical requirements for future Sentinel sensors. As such, the report is developed by - and through - the eyes of end users.

The Copernicus Services already offer an extensive amount and a high variety of relevant data products and tools. Moreover, most of these are freely available. Nonetheless, the analysis pointed out several bottlenecks which inhibit users to obtain a clear and complete picture of all products made available by the Copernicus Services:

1. There is a strong lack of data-awareness with the wider community. This is underlined by how many parameters requested during our recent user-uptake event, were actually already provided by the Copernicus Services. Trainings and free online tutorials could reduce this issue. The NASA Arset trainings are considered to be an example of good practice.
2. The General search engine of Copernicus Services is too limited. The CMEMS and C3S data portals and especially NASA's Earthdata portal were considered examples of good practice.
3. The lack of harmonization / standardization between the layout and functionalities of the data portals for each Copernicus Service.
4. Quasi similar products, which only slightly differ in e.g. spatiotemporal resolution, are scattered amongst different Copernicus Services.
5. Users did not yet find their way to the five Data and Information Access Services, even though they requested the related services.

Users also request more elaborated products (e.g. discharge or subsurface parameters such as soil maps and groundwater). When products were present, they can still lack the high spatiotemporal resolutions required for certain end users. This needs to be further investigated during the requirement analysis of Work Package 3.

The conclusions resulted in five recommendations to facilitate future development of the Roadmap.



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# 1. Introduction

## 1.1 Water-ForCE

The **Horizon2020** project [Water-ForCE](#) (Water scenarios For Copernicus Exploitation) will develop a Roadmap for Copernicus **Inland Water Services**, aiming to better integrate the entire inland **water cycle within the [Copernicus Services](#)**. It will address current disconnects between remote sensing / in-situ observation and the user community. Clarity in terms of the needs and expectations of both public and private sectors, as well as the wider research and business innovation opportunities will be delivered. The Roadmap will advise on a strategy to ensure effective uptake of water-related services by end users and further support the implementation of relevant directives and policies.

The Water-ForCE consortium is led by the University of Tartu (Estonia) and consists of 20 organisations from all over Europe. It connects experts in water quality and quantity, in policy, research, engineering and service sectors. Through close collaborations with these communities, Water-ForCE will:

- Analyse EU policies to identify where the Copernicus Services can improve monitoring programs and how the Copernicus data can be more effectively used in developing and delivering the next versions of the directives.
- Specify the requirements for future Copernicus missions (e.g. optical configuration of Sentinel-2E and onward, hyperspectral sensors).
- Optimize future exploitation for inland water monitoring & research and, consequently, (a) enlarge the service portfolio and (b) improve the performance of current Services.

The project is divided in eight work packages (WP), each of them focusing on a specific problem and/or target of the Copernicus Service (Figure 1). The following report is part of **WP3** which focusses on **Water quantity**.

## 1.2 Context WP3

The general objective of WP3 is to provide insights into products that are relevant to inland water services, thereby supporting integrated water resource management and improving coverage of EU policies regarding water quantity. Hence, WP3 will shed light upon current and upcoming Copernicus's Earth Observation (EO) products and services that focus on water storage and the flux components.



Based on (a) an inventory, (b) a requirement analysis that leads to (c) a gap assessment, WP3 will culminate in recommendations on future products and technical requirements for future Sentinel sensors. The final output of WP3 will be used as input for the Roadmap, to be developed in WP6.

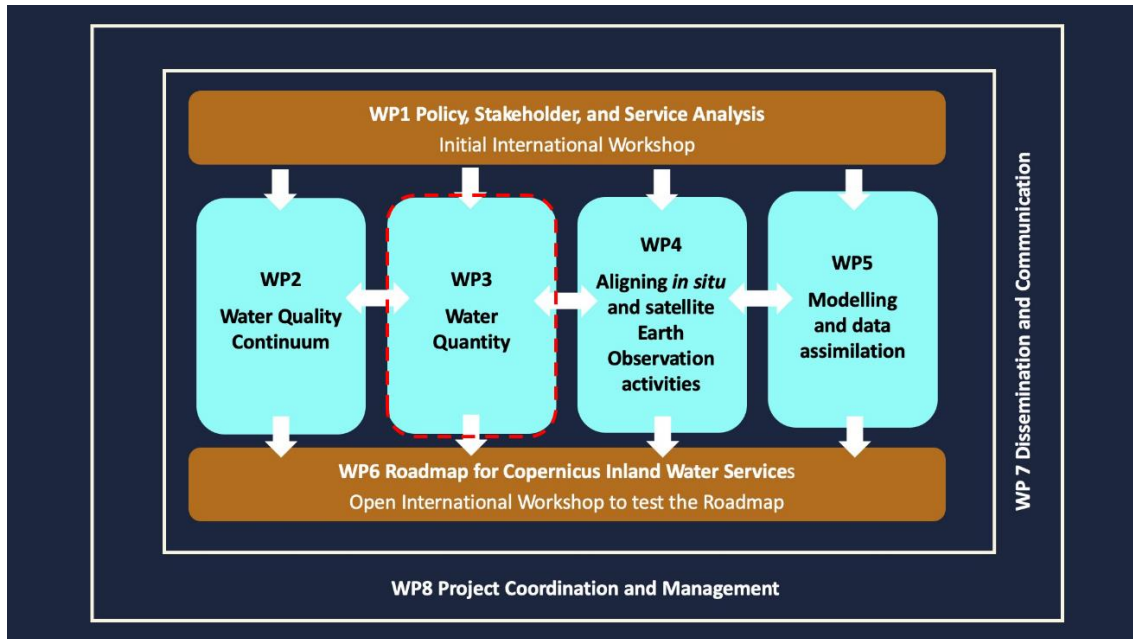


Figure 1 : Organizational structure of the different work packages in the Water-ForCE project.

Work package 3 is subdivided in several tasks, each with their own associated deliverables:

- **T3.1/D3.1:** Creating an international inland water quantity remote sensing working group.
- **T3.2/D3.2:** Create an inventory of Copernicus products related to the hydrological water balance. This comprises mapping of current Copernicus Services and EO products.
- **T3.3/D3.3:** A Water Management Analysis including a state-of-the-art gap analysis with recommendations on Copernicus and other services supporting water management, focused on flood, drought, water allocation, SDG6 and water accounting. The analysis will be based on the inventory of T3.2.
- **T3.4/D3.4:** Compile a review document on the use of models and satellite EO observations for water resources modelling.
- **T3.5/D3.5:** Assess the technical requirements for future Sentinel sensors to fulfil water quantity monitoring and research requirements.

More information on the timelines of these tasks/deliverables and the general work package planning can be found [here](#).



### 1.3. Objectives & context T3.2

This report forms the output of Task 3.2. It builds upon the [output of D3.1 \(Workshop\)](#) that highlights disconnects between user needs and data availability/accessibility. The workshop provided initial insights on data awareness by end users.

The objective of T3.2 can be described as follows:

- **To raise public awareness** on Copernicus Services and its (EO) data products.
- **To present an overview** of both currently available, as well as planned Copernicus water quantity data products.

Task 3.2 delivers a **detailed inventory** of the existing and planned (EO) data products in the Copernicus portfolio on water storages in and fluxes between all components of the inland hydrological cycle. Groundwater aspects are covered as well, to ensure an appropriate representation of the hydrological water balance. In addition, other sources such as the National Oceanic and Atmospheric Administration ([NOAA](#)) and the Japan aerospace exploration agency ([JAXA](#)) are analysed, as this allows a comparison regarding data availability and usability.

Task 3.2 forms the basis for T3.3 and, hence, has to be seen as an intermediate output of WP3.

### 1.4. Content of the report

This report accompanies [the inventory of D3.2](#). To facilitate future research in WP3 as well as in other work packages, the current report starts with a delineation of the Copernicus Platform and respective Services (§2). This is followed by a short introduction of other, external data platforms (§3). The inventory is described and summarized in Chapter §4, while being analysed in Chapter §5, thereby providing a step up to the actual gap assessment in T3.3. The conclusions are presented in Chapter §6, while initial recommendations for developing the final roadmap are presented in chapter §7.

Please note that, as the present report will form the basis of the requirement analysis and gap assessment in T3.3, it is **developed by - and through - the eyes of end users**.



## 2. Copernicus

A detailed explanation - in the language of your choosing - of the Copernicus Programme and related Services can be found on the [Copernicus website](#). The sections hereafter provide a summary of respective webpages on the Copernicus Programme (§2.1), Copernicus Services (§2.2) and Data Access (§2.3).

### 2.1 Copernicus Programme

Copernicus is the European Union's continuous Earth Observation programme. It offers information services that draw from satellite Earth Observation (EO) and in-situ (non-space) data, to benefit all European citizens.

The Copernicus Programme is funded, coordinated and managed by the European Commission and is implemented in partnership with (a) the EU Member States, (b) the European Space Agency ([ESA](#)), (c) the European Organisation for the Exploitation of Meteorological Satellites ([EUMETSAT](#)), (d) the European Centre for Medium-Range Weather Forecasts ([ECMWF](#)), (e) EU Agencies and (f) [Mercator Ocean International \(MOI\)](#).

The objective of the Copernicus program is to monitor our planet and its environment in order to better understand Earth's processes and establish a sustainable management strategy for the use of natural resources. The programme has been specifically designed to meet user requirements via its free and open access to data products as well as tools for analysis, visualization and learning resources.

To achieve its objectives, Copernicus employs a three-pronged approach, leading to three key components:

1. [The Space Component](#) provides a collection of satellite based, Earth Observation (EO) data by the **Sentinel satellite missions as well as other Contributing Missions** that are operated by National, European or International organisations and provide a wealth of data on its own. The European Space Agency (ESA) is responsible for the development of the space segment component of the Copernicus Programme and operates the Sentinel-1 and Sentinel-2 satellites. ESA will deliver the land mission from Sentinel-3 and will operate Sentinel-5P. EUMETSAT is responsible for operating the Sentinel-3 satellites and delivering the marine mission and will also operate and deliver products from the Sentinel-4, and -5 instruments, and the Sentinel-6 satellites. ESA and EUMETSAT will coordinate the delivery of data from upwards of 30 satellites that form the Contributing Missions.
2. [The In-Situ Component](#) provides a collection of in-situ data from **in-situ monitoring networks** (e.g. ground based weather stations, ocean buoys and air quality monitoring networks) to provide robust integrated information and to supplement, calibrate and validate the data from satellites. The in-situ networks





are managed by Member States and international bodies and make data available to the Services by agreement. The European Environment Agency is leading the work for Copernicus to catalogue the in-situ requirements of the Copernicus Services, develop frameworks and pilot agreements to ensure access to all the relevant data in a timely and sustainable way.

3. The six [Copernicus Services](#) produce **value-added products** by transforming the wealth of satellite and in-situ data into timely and actionable information through processing and analysing it. The six Services are further elaborated in the following section (§2.2).

## 2.2 Copernicus Services

The Copernicus Services offer EO products and tools, that meet specific end-user needs. They **transform** satellite and in-situ data **into value-added information**: (a) Datasets stretching back for years and decades are made comparable and searchable, ensuring the monitoring of changes, (b) patterns are examined and used to create better forecasts, (c) maps are created from imagery, (d) features and anomalies are identified and (e) statistical information is extracted. Hence, the Copernicus Services support a wide range of interdisciplinary subjects and have a huge potential to address societal challenges. The implementation and operation of Copernicus Services have been delegated by the European Commission to dedicated service providers - the Copernicus Entrusted Entities - through a series of "Delegation Agreements". A general overview of the Copernicus Services and the institutions charged with their coordination is given in Figure 2.

These value-adding activities are streamlined through the six thematic streams of Copernicus Services; as presented in the following figure.







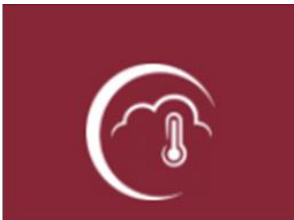
[Copernicus Atmosphere Monitoring Service \(CAMS\)](#)



[Copernicus Marine Environment Monitoring Service \(CMEMS\)](#)



[Copernicus Land Monitoring Service \(CLMS\)](#)



[Copernicus Climate Change Service \(C3S\)](#)



[Copernicus Security Service](#)



[Copernicus Emergency Management Service \(CEMS\)](#)



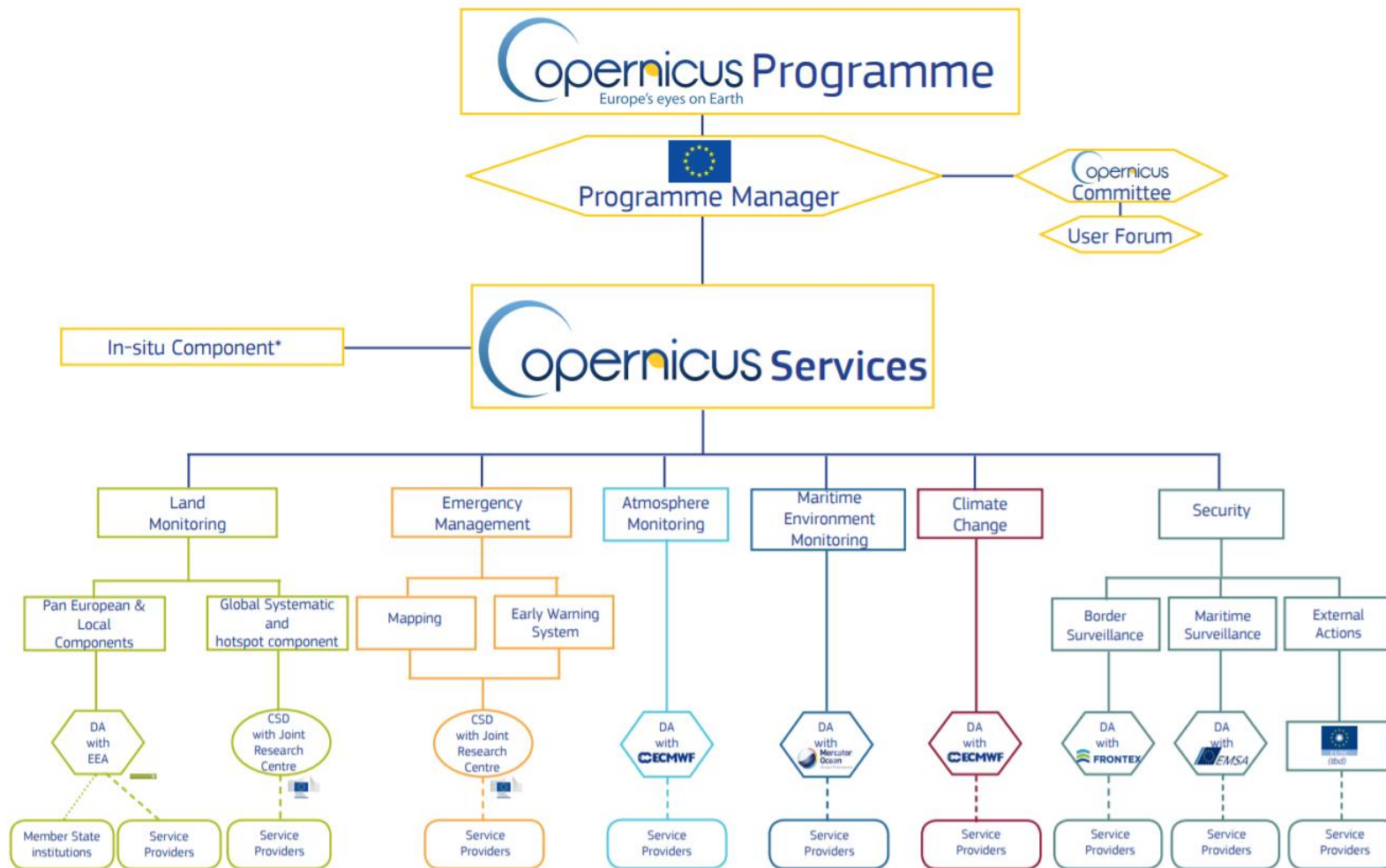


Figure 2: Structure of the Copernicus monitoring service portal. (Source: [https://www.copernicus.eu/sites/default/files/documents/Copernicus\\_Programme\\_Services.pdf](https://www.copernicus.eu/sites/default/files/documents/Copernicus_Programme_Services.pdf))



## 2.2.1 Copernicus Land Monitoring Service (CLMS)

Declared operational in 2012, the Copernicus Land Monitoring Service provides geographical information on land cover and - changes, land use and other variables at a global, European and local level. The specific user products are categorised according to their spatial coverage (Figure 3 **Fout! Verwijzingsbron niet gevonden.**). For instance, water quantity related products like the area of surface Water Bodies and the Water Level products can be found under the theme 'Water' in the [Copernicus Global Land Service \(CGLS\) webpage](#) because these products cover the whole world. However, to obtain specific products for Europe or a certain nomenclature of territorial unit for statistics (NUTS) area, one is referred to the Pan-European or the local portal. The land service also provides data visualisation-, analysis- and training tools which help users to meet their specific needs.

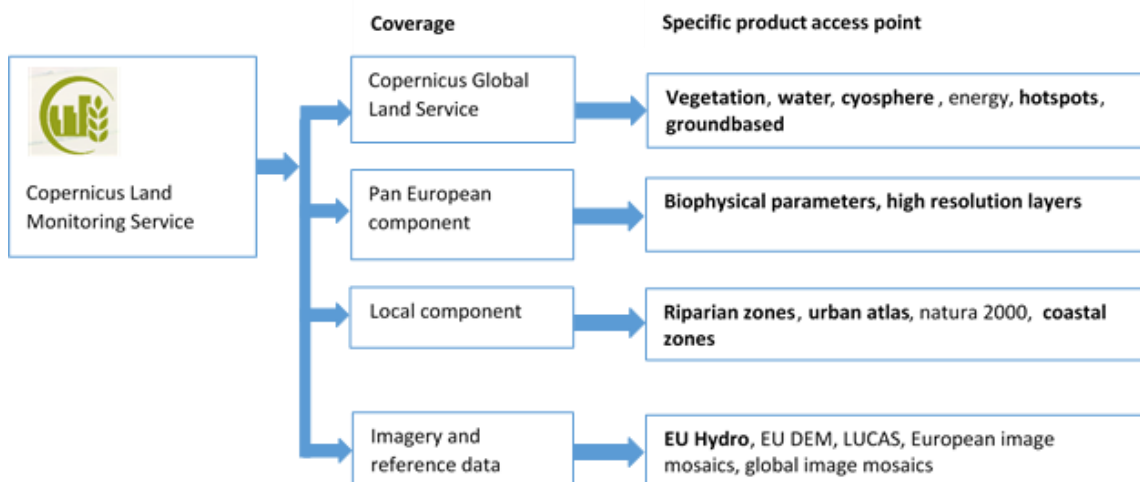


Figure 3: Structure of the Copernicus Land Monitoring Service portal. The specific product access points in bold include products related to water quantity.

## 2.2.2 Copernicus Marine Environment Monitoring Service (CMEMS)

The Copernicus Marine Environment Monitoring Service provides regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas.

CMEMS describes analysis, reanalysis and forecast products. The data products are easily accessible either via the catalogue or the data search tool. One can search for products based on temporal coverage, area of interest (global ocean, European seas) and/or based on the parameters required e.g. parameters which describe sea ice. Each product is provided with a comprehensive list of metadata, which is uniform for all products, hence facilitating the comparison between products.

Each data product can be visualized by the “product view” tool accessible on the product’s webpage allowing a visualization of how different variables can spatially change. The tool is comparable to the map viewers available in other services. However, the CMEMS product view tool gives users the chance to view all the datasets associated with the particular product and products can be accessed in a variety of formats.

Note that the marine environment falls **outside the scope** of this project since the goal is to develop a **Roadmap for inland water services**. Hence, only certain data products from coastal zones were taken into account in the inventory. Additionally, sea ice parameters are covered as well since they are considered an important component of the water storage cycle.

### 2.2.3 Copernicus Atmosphere Monitoring Service (CAMS)

The Copernicus Atmosphere Monitoring Service (CAMS) provides continuous data and information on atmospheric composition at global and regional scales.

This service describes the current situation (analysis), the prediction of the situation a few days ahead (forecast), and provision of consistent retrospective data records for recent years (re-analysis). CAMS focuses on five main areas:

- Air quality and atmospheric composition
- Ozone layer and ultra-violet radiation
- Emissions and surface fluxes
- Solar radiation
- Climate forcing

Even though these five main areas might seem to have no direct relation to water quantity, some datasets can be found containing information on e.g. water storage data products (water storage in column, clouds...).

### 2.2.4 Copernicus Climate Change Service (C3S)

The Copernicus Climate Change Service offers past, present and future climate data for Europe and the world. The Climate Data Store (CDS) is the heart of C3S, where one can obtain various data products and tools. Data searches can be based on spatial and/or temporal requirements or the need of a specific data type, for instance forecast data or in-situ observations.

Moreover, users have the option to target specific domains, e.g. one can request satellite observation data which focusses on land hydrology only leaving out land cryosphere and biosphere. The general metadata for each product is well described, however information such as processing level is often not available. Though the information offered is free of charge, registration and login are required to submit a data request.



The C3S website also offers user applications which can be used to monitor or evaluate trends (these applications are not covered in the inventory). The Climate Data Store Toolbox contains a wealth of resources for users. It provides training resources, practical guides for new users/beginners and a toolbox editor which allows users to personalize their applications and the application gallery - containing sample source codes for creating e.g. plot maps or to calculate trends. To use the toolbox, (basic) knowledge on programming languages - such as Python - is required. As stated earlier, the Climate Data Store plays an important role in the access of some datasets from the Copernicus Emergency Management Service.

## 2.2.5 Copernicus Emergency Management Service (CEMS)

The Copernicus Emergency Management Service came into operation in 2012. It offers relevant actors and interested users accurate and timely geo-spatial remote sensing data for the management of natural and man-made disasters and humanitarian aid.

This service contains two components:

1. **The On demand mapping Service**, which provides detailed geospatial information (maps) within hours or days after a request to support immediate emergency activities. Additionally, it provides geospatial information for disaster preparedness, risk reduction and recovery. The use of the on demand mapping is limited to authorised and associated users. **The general public can only access these products after a specified time.**
2. **The Early Warning & Monitoring Service** (Figure 4) offers continuous critical geospatial information at the global and European level for: monitoring of floods (European flood awareness system – [EFAS](#) / Global flood awareness system – [GloFAS](#)), droughts (European drought observatory – [EDO](#) / Global drought observatory – [GDO](#)) and fires (European forest fire information system – [EFFIS](#)). In the inventory, focus was placed on the drought and flood products as these have a direct effect on water quantity. The **EFAS products are free to use**, including the map viewer, in contrast to GloFAS for which a log in and registration is required.

The set-up of the European and global drought observatory system feels user-friendly: simple and clear; especially in comparison to the set-up of the flood awareness system. Additionally, the data products and tools of EDO and GDO are easily accessible and their usage is explained. This is especially useful for new users.

The Copernicus Emergency Management Service works in close collaboration with C3S in terms of data access. For instance, river discharge products from EFAS and GLOFAS can be accessed easily through the CDS.



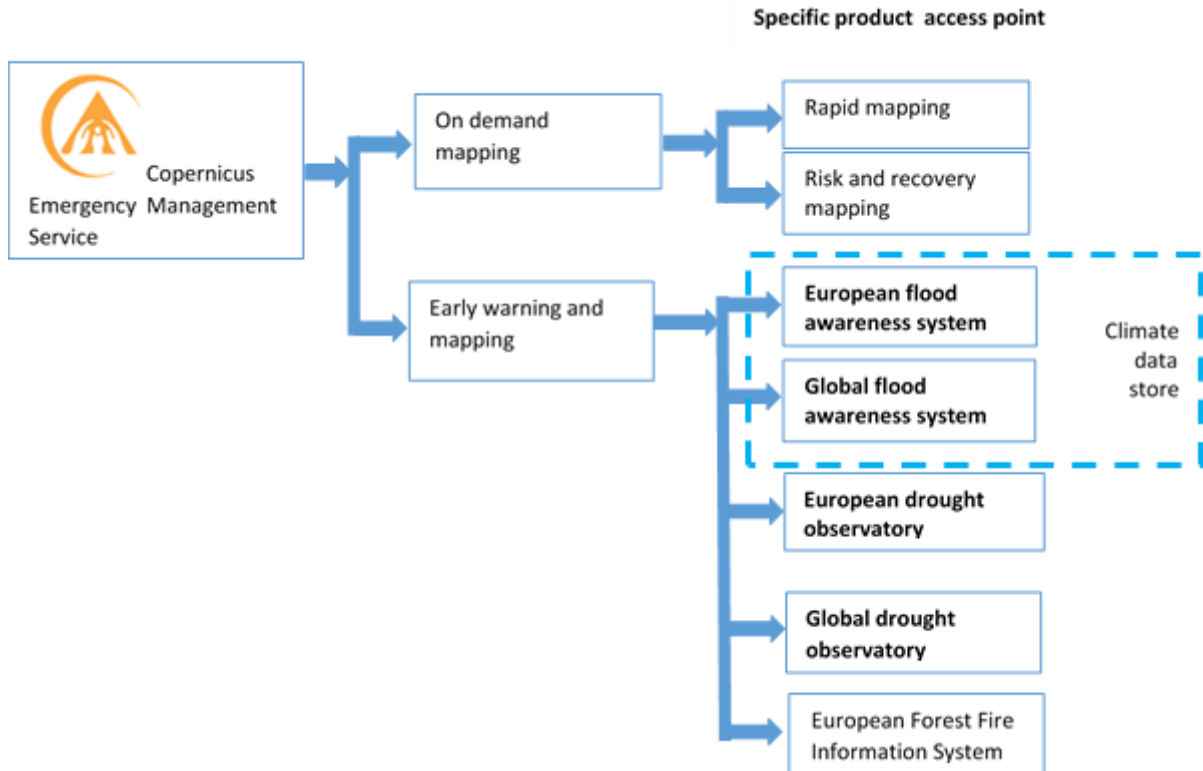


Figure 4: Structure of the Copernicus Emergency Management Service. The specific product access points in bold include products related to water quantity.

### 2.2.6 Copernicus Security Service

The Security Service of the Copernicus program supports the European Union by providing valuable information for crisis prevention, preparedness and response. It offers data products concerning 3 key security areas: border surveillance, maritime surveillance and Support to EU External Action.

This service does not offer relevant data products for the objective of D3.2 and is therefore not discussed further.



### 2.2.7 Data Access

The technological prowess of Copernicus, especially in terms of availability and accessibility, has made Copernicus the largest space data provider in the world, currently delivering 12 terabytes per day.

The vast majority of data/information delivered by Copernicus is made available and accessible to any citizen, and any organisation around the world on a free, full, and open basis.

One can access data and information through the following methods:

1. The data delivered by the **Copernicus Space Component** can be downloaded from [ESA's and EUMETSAT's data points](#).
2. For the data collected by the **In-situ Component** (Observational or Spatial data), one is referred to the access points mentioned on the [in-situ website](#).
3. The [respective webportals](#) of the Entrusted Entities for the **Copernicus Services**. The data and information delivered by the Copernicus Services are made available to users through the websites of the service in question. In most cases, data and information can be browsed/discovered without prior registration, but registration is required for downloading.  
Note that [the Copernicus Services Catalogue Webpage](#) allows one to **freely browse** the entire Copernicus Services catalogue **by encoding relevant keywords**.
4. For users who do not wish to transfer data to their own systems, data is available through the five **DIAS** ([Data and Information Access Services](#)) allowing users to **process and analyse Copernicus data and information in the cloud**. Since June 2018, five DIAS platforms provide access to Copernicus Sentinel data, as well as to the information products from the six operational Services of Copernicus, together with cloud-based tools (open source and/or on a pay-per-use basis). Each of the five competitive platforms also provides access to **additional commercial satellite or non-space data** sets as well as premium offers in terms of support or priority. Thanks to a single access point for the entire Copernicus data and information, DIAS allows the users to develop and host their own applications in the cloud, while removing the need to download bulky files from several access points and process them locally.

Figure 5 provides an overview of the conventional data access hubs (above-mentioned points 1 to 3), while Figure 6 presents the DIAS (above-mentioned point 4).







Figure 5: Overview of Copernicus Conventional Data Access Hubs. (Source: <https://www.copernicus.eu/en/accessing-data-where-and-how/conventional-data-access-hubs>)

### THE DIAS & WHERE TO REACH THEM

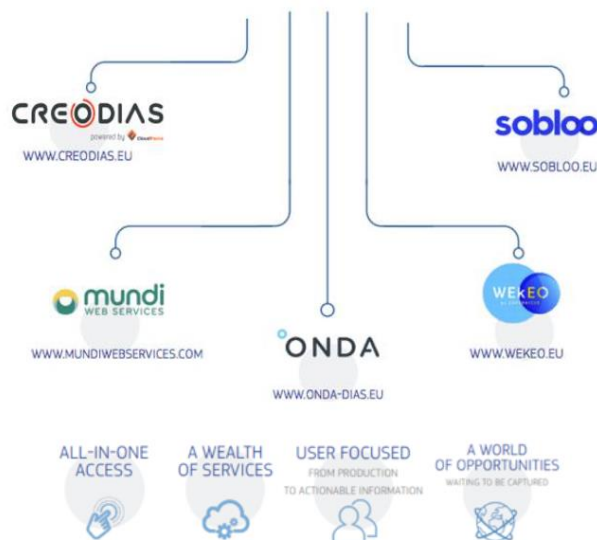


Figure 6: The five Data and Information Access Services. (Source: <https://www.copernicus.eu/en/access-data/dias>)



## 3. External EO data platforms

Although the Copernicus Services offer an extensive amount and highly diverse set of data products, the output of the workshop (D3.1) made clear that users often use other data platforms. Possible causes for this were discussed in D3.1. A link from the Copernicus website with direct access to platforms like [NOAA](#), [JAXA](#) and [ESA](#) was in high demand. Therefore, those three platforms are included in the inventory for comparison on data products and usability. A brief introduction of these data providers can be found in the subsections below.

### 3.1 ESA

In addition to playing a fundamental role in the management and coordination of the Copernicus Programme, ESA also offers a unique set of data products under the [climate change initiative \(CCI\)](#) program. These data products were developed as a response to the United Nations Framework Convention on Climate Change (UNFCCC) and the Global Climate Observing System (GCOS) need for data on essential climate variables. As such, ESA is included in the list of "external" data platforms.

The data products offered by ESA can be accessed through the CCI open data portal. All products are available on the climate data dashboard which provides a clear visual overview of the data products offered by ESA. Classification of the products is not explicit, however, based on colour codes the products are grouped as shown in Table 1.

Table 1: ESA CCI data products

Group	Data products
<b>Group 1</b>	Aerosol, cloud, greenhouse gases and ozone
<b>Group 2</b>	Ocean color, sea level, sea surface salinity and sea surface temperature
<b>Group 3</b>	Above ground biomass, Antarctic ice sheet, fire, glaciers, Greenland ice sheet, lakes, land cover, permafrost, snow and soil moisture

Products in group 1 are related to the atmospheric composition, group 2 considers ocean physics and biogeochemistry, whereas group 3 is related to land products. Products related to water quantity are mainly included in group 3.

Each product contains a dataset(s) with an individual access site which is hosted by the Centre for Environmental Data Analysis ([CEDA](#)). Here, one finds detailed information on a product in addition to its metadata.

Data access is completely open and neither login nor registration is required. ESA also offers users a CCI Climate Analysis Toolbox ([Cate](#)) which is a cloud-enabled computing environment for analysing, processing and visualising all ESA CCI datasets. Cate works by mashing ECV data and other data sources into a common data model. CCI is also



linked to Copernicus, meaning certain datasets can be accessed also through the Climate Data Store e.g. land cover maps.

## 3.2 JAXA

The Japan aerospace exploration agency is the Japanese core performance organization mandated with aerospace research and technological developments.

Through its Earth Observation research centre, JAXA receives data from both Japanese and foreign Earth Observation satellites, which are then processed, inspected and analysed. The data are then made public to academia, research institutes and public organizations which use it to meet their needs.

JAXA is unique in the way it provides data products; that is, it provides both standard and research data. Standard data products are those which have been calibrated and validated whereas the research products have neither been calibrated nor validated and are only meant for research purposes. To access JAXA data, a login and registration is required.

The data products are provided by various data portals. For instance through the Globe Portal System ([G-portal](#)), users can access products which are derived from the satellites: Global Change Observation Mission – Climate (GCOM – C), Global Change Observation Mission – water (GCOM – W), Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Measurement (GPM).

Through the JAXA Satellite Monitoring for Environmental Studies ([JASMES](#)) portal, users can access not only satellite observations but also information on the current status of the climate variables such as solar radiation reaching the Earth's surface (photosynthetically available radiation - PAR), cloudiness, snow and sea ice cover, dryness of the vegetation (water stress trend), soil moisture, wild fire, precipitation, land and sea surface temperature.

The [Shikisai portal](#) contains operational information, product processing status, use cases and links related to the Global Change Observation Mission – Climate (GCOM – C).

## 3.3 NOAA

The National Oceanic and Atmospheric Administration is an agency of the United States of America which is charged with the observation, research on and monitoring of the climate, weather, oceans and coast.

The information acquired from the observations and studies is analysed and further disseminated to different communities for the benefit of people and the environment.



NOAA's work is divided into several thematic areas. These include: weather, climate, oceans & coasts, fisheries, satellite research, marine & aviation, charting, sanctuaries and education.

For the climate area, NOAA runs the National Centre for Environmental Information ([NCEI](#)) which provides access to archived oceanic, atmospheric and geophysical data. The data provided by NCEI covers the climate normal of the United States, analysis products, re-analysis products and sectoral in a bid to meet the needs and applications of different users. The NCEI runs several programmes through which it helps to collect and disseminate climate data products and tools.

### 3.3.1 Climate Data Record (CDR) program

The mission of the [Climate Data Record \(CDR\) program](#) is to develop and implement a robust, sustainable, and scientifically defensible approach to produce and preserve climate records from satellite data. CDR is a timeseries of measurements of sufficient length, consistency, and continuity to determine climate variability and change. The CDR program has CDR's for three domains as shown in Table 2. Each CDR product has an individual page with further information on the product, relevant documentation, metadata and guidelines on how to download the data. Data access is free of charge.

Table 2: The climate data record \* highlighted products are taken into account for the inventory.

Domain	CDR
<b>Atmosphere</b>	AVHRR aerosol optical thickness, <b>AVHRR cloud properties – NASA, AVHRR cloud properties PATMOS-x, cloud properties ISCCP</b> , Extended AVHRR polar pathfinder (APP-x), <b>hydrological properties</b> , ocean heat fluxes, ocean near surface atmospheric properties, outgoing longwave radiation – daily, outgoing longwave radiation – monthly, Ozone – ESRL, <b>Precipitation – CMORPH, Precipitation - GPCP Daily, Precipitation - GPCP Monthly, Precipitation - NEXRAD QPE, Precipitation - PERSIANN-CDR</b> , Solar Spectral Irradiance, Total Solar Irradiance.
<b>Oceanic</b>	Ocean Heat Content, Sea Ice Concentration, sea surface temperature – optimum interpolation, Sea surface temperature – pathfinder, sea surface temperature - WHOI
<b>Terrestrial</b>	AVHRR surface reflectance, leaf area index and FAPAR, Normalized difference vegetation index, <b>snow cover extent (northern hemisphere)</b>

### 3.3.2 Climate data online program

The [climate data online program](#) is another program ran by NOAA where users can find global historical and climate data and tools to manipulate the data. The data provided here is free of charge.



Here, two categories of data are found (Table 3); current data products which are accessible within the climate data online search interface and the legacy applications which belong to an old access system and are accessible using legacy servers.

All data products except global marine data and global climate station summaries are captured in the inventory. Similar to the climate data record products, each climate data online product has its own individual page where further information can be found.

*Table 3: Data products from the Climate data online program*

<b>Data type</b>	<b>Data product</b>
<b>Current data</b>	Daily summaries, global marine data, global summary of the month, global summary of the year, local climatological data, normals annual/seasonal, normals daily, normals monthly, precipitation 15 minute, precipitation hourly, weather radar (II), weather radar (level III)
<b>Legacy applications</b>	Climate indices, global climate station summaries, global hourly data, global summary of the day, national solar radiation database, regional snowfall index

The NOAA and NCEI websites contain a lot of information. As such, a [data search tool](#) is also an important way of searching data products. This gives a good overview of products available in the NCEI.



## 4. Inventory

In this chapter the inventory of the Copernicus data products and - for comparison - the inventory of external platforms, is explained. The following subsections will give more information on the characteristics of the included data products and on how to use the inventory in practice.

### 4.1 Demarcation & Characteristics

Data providers offer a variety of both products and services. The inventory focusses solely on data products (datasets, timeseries or maps). It does not include any applications or tools<sup>1</sup>. The data products included in the inventory are all:

- Products relevant for developing inland water services and, hence, are limited to inland and coastal zones.
- Related to water quantity and thus the hydrological cycle. They address among others: the water storages in- and fluxes between all components of the hydrological cycle.
- Referring to datasets, indices, projections, in-situ observations or forecasts. Hence, the inventory is not strictly limited to raw EO datasets: it also includes derived, value-added products as these often are more suitable for downstream users.
- Data products on a global, European, regional or local scale.
- Data products accessible from the [Copernicus Services](#) website and/or data platforms from NOAA, JAXA and ESA.

### 4.2 Structure of the inventory

To facilitate applicability by the wider community, the inventory is developed in Microsoft Excel and accessible on the work package webpage via the link "[D3.2 Inventory](#)". The inventory comprises data products related to the hydrological cycle, all originating from the following Copernicus Services: CMEMS, CLMS, CEMS and C3S. In addition, data products provided by the data providers NOAA, JAXA and ESA are also included as mentioned earlier in **§3. External EO data platforms**.

Table 4 provides an overview of what is listed in the Excel inventory. The inventory is based on information that was publicly available on the websites of respective data

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<sup>1</sup> Tools and applications are defined as means by which data is visualised, analysed and/or processed (e.g. the [CDS Toolbox](#), numerical models or Pythonscripts).



providers and complemented with the input of personal interviews with Services hosts. When searching for a data product on the Copernicus website, in most cases a general overview of data characteristics and metadata is displayed. This overview was used as a basis input source for the inventory. When consulting the inventory, one can observe that not all columns are fully completed because the detailed information for a specific product was not easily accessible: nor in the product description, nor in the data technicalities. Product manuals and additional information documents might provide more detailed info (metadata). However, since this info is not directly visible it is considered a barrier for easy data access (user requirement). This is one type of issue that is highlighted by the inventory.

Table 4 : Overview of product data information provided in the inventory.

Column headers inventory			
A	Data provider (Copernicus, NOAA, JAXA, ESA)	L	Observation/model
B	Abbreviation	M	Temporal resolution
C	Subservice	N	Spatial resolution
D	Product type	O	Processing level
E	Product description	P	Access data
F	Parameter group	Q	File format
G	Parameter	R	Access metadata
H	Specific output parameter	S	Start date
I	Data ID	T	End date
J	Region	U	Datalink
K	Coordinates	V	Product user manual link

The columns "F-G-H-I" mentioned in Table 4, all contain information concerning the type of parameter, however there are important differences:

- Column F: The parameter group - general group to which a parameter belongs.
- Column G: The general parameter to which a more specific parameter belongs.
- Column H: The specific output parameter (most specific classification).
- Column I: The Data ID being the official name of the data product or (if not clear) the keywords by which the product can be found.

As an example: Soil (F) - Soil moisture (G) - Volumetric soil moisture (H) - Soil moisture gridded data from 1978 to present (I).





The D3.2\_Inventory.xlsx file consists out of several tabs. A brief explanation on the nomenclature of the tabs is provided in the table underneath and the first tab of the inventory.

Table 5: Explanation nomenclature tabs inventory.

Tab	Filter	Description
Copernicus_inventory	/	The complete Copernicus inventory (all filters switched off by default)
External_platforms_inventory		The complete inventory of NOAA, JAXA, ESA (all filters switched off by default)
C3S_* / CMEMS_* / CLMS_* / CEMS_* / CAMS_* / ESA_* / NOAA_* / JAXA_*	/	Tabs referring to data of the different data providers or Services (these can contain info, pivot tables...)
*_PT_*	/	Tabs containing Pivot Tables
Copernicus_upcoming		A subset of the "Copernicus_inventory" tab, with only upcoming products + description

## 4.3 Copernicus inventory

### 4.3.1 Copernicus inventory

**The Copernicus inventory can be accessed by the tab " Copernicus\_inventory" in "D3.2\_Inventory.xlsx".**

As explained in **§4.2 Structure of the inventory** each data product can consist out of one or multiple specific output parameters (e.g. a "soil moisture" data product can consist of the variables "soil moisture" and "soil moisture uncertainty"). Each specific output parameter belongs to a parameter and is assigned to a parameter group, the latter often consisting of different parameters. Table 6 presents a general overview of (a) the defined parameter groups and (b) for each Copernicus Service, the number of data products that can be allocated to each group.

The "number of data products" meaning the amount of products (e.g. water level, area of surface water bodies) with different resolutions, regions and sensors: e.g. the specific output parameter "volumetric soil moisture" under the parameter group "Soil" can consist of 3 data products due to the availability of 3 different resolutions.



Table 6: Overview on the number of data products for different parameter groups for each Copernicus Service: Climate Change Service (C3S), Atmosphere Monitoring Service (CAMS), Emergency Management Service (CEMS), Land Management Service (CLMS) and Marine Environment Monitoring Service (CMEMS).

Parameter Group	C3S	CAMS	CEMS	CLMS	CMEMS	Total
Anthropogenic			1			1
Drought	4		8	7		19
Evapotranspiration	45	2				47
Floods			41			41
Geographic zones				10		10
Ground motion				3		3
Humidity	23	1				24
Hydrology	55		5	2		62
Land cover/Land use	10	10		59		79
Precipitation	68	8	19			95
Snow & Ice	159	6	7	10	41	223
Soil	36		11	6		53
Water storage	107	34				141
Waterbodies	24	2	1	19		46
<b>Total</b>	<b>531</b>	<b>63</b>	<b>93</b>	<b>116</b>	<b>41</b>	<b>844</b>

Figure 7 gives a clear overview on the above mentioned parameter groups and the different parameters they cover. It also provides insights on: (a) the distribution of the parameters among the different Services, (b) possible overlaps and (c) disconnects.

As one can observe, certain parameters are only provided by one service. Data on water storage is restricted to the Climate Change Service (C3S) while detailed information on floods is exclusively provided by the Emergency Management Service (CEMS). On the other hand, parameters regarding soil moisture or snow cover are offered by several Services. The CMEMS is only represented by two parameters: snow thickness and sea ice (Snow & Ice parameter group, 41 data products). Please note that CMEMS does offer an extensive amount of data products, but - as discussed in **§4.1 Demarcation & Characteristics** - only parameters related to water storage and/or coastal zones are considered.

Table 6 focusses on currently available data products. However, the Services do plan general product updates in the near future and are developing additional products and tools (pers. comm.).



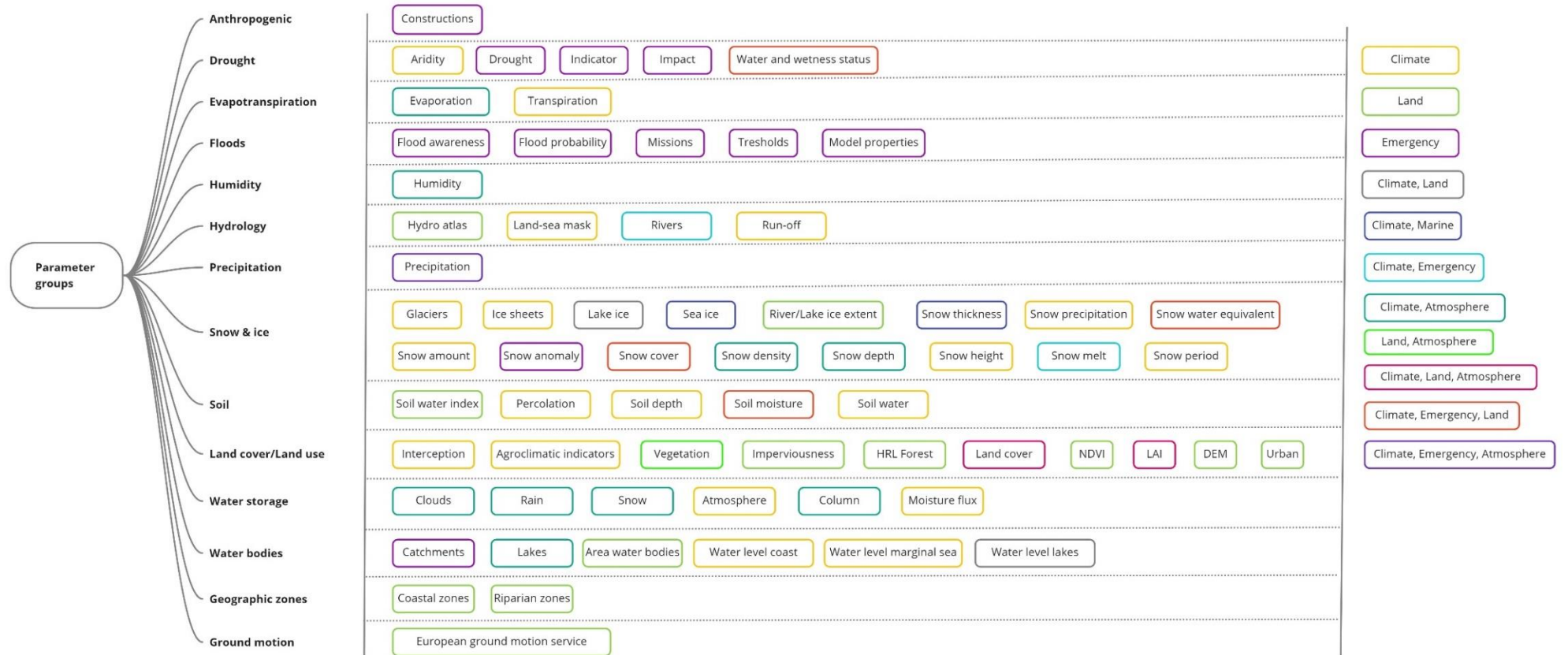


Figure 7 : Overview on parameter groups and their designated parameters.

An overview on available Copernicus data products is available in the inventory and can be accessed by going to the Excel file "D3.2\_Inventory" and using the tabs indicated in the table below:

*Table 7 : Instruction table to access data products in the Copernicus inventory.*

<b>Tab</b>	<b>Description</b>
Copernicus_inventory	Gives an overview on all data products (water quantity) currently provided by Copernicus.
Copernicus_upcoming	Gives an overview on upcoming Copernicus data products (water quantity).
Cop_PT_parameters	Pivot table providing information on the available parameters/parameter groups for each Service.

#### 4.3.2.1 C3S

The majority of the data products listed in the inventory are provided by C3S (Table 6). A brief overview on their access methods, available regions and file formats is given in Table 10. As pointed out by Table 10 all data products can be downloaded on the Climate Data Store, creating an easy access data flow. The CDS also comprises data products provided by CEMS creating a more extensive and complete data offer. More detailed information on available specific output parameters, spatial and temporal resolution, available timeframes... and direct data product links is provided in the inventory itself.

C3S data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

*Table 8: Instruction table to access C3S data products in the inventory.*

<b>Tab</b>	<b>Filter</b>	<b>Description</b>
Copernicus_inventory	Column B - Select "C3S"	This combination gives an overview on all data products (water quantity) currently provided by C3S.
Copernicus_upcoming	Column B - Select "C3S"	This combination gives an overview on upcoming C3S data products (water quantity).
C3S_PT_parameters		Pivot table providing information on parameters and specific output parameters for this Service.

The C3S recently (May 2021) published 2 new datasets: " Temperature and precipitation climate impact indicators from 1970 to 2100 derived from European climate projections ([link](#))" and " Hydrology related climate impact indicators from 1970 to 2100 derived from

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bias adjusted European climate projections" ([link](#)). More information on those and other upcoming products can be found in the inventory.

#### 4.3.2.2 CLMS

The Copernicus Land Monitoring Service offers important information with regards to inland water data products. As indicated by Figure 7, it provides the majority of the Land cover/Land use products. Furthermore, it is the only service providing data on river ice. Table 11 gives a brief overview on their access methods, available regions and file formats.

CLMS data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

*Table 9: Instruction table to access CLMS data products in the inventory.*

<b>Tab</b>	<b>Filter</b>	<b>Description</b>
Copernicus_inventory	Column B - Select "CLMS"	This combination gives an overview on all data products (water quantity) currently provided by CLMS.
Copernicus_upcoming	Column B - Select "CLMS"	This combination gives an overview on upcoming CLMS data products (water quantity).
CLMS_PT_parameters		Pivot table providing information on parameters and specific output parameters for this Service.

Within CLMS a second generation CORINE Land Cover (CLC), or "CLC+ "as it is called, is being developed. More information on this and other upcoming products can be found in the inventory as well.





Table 10: Overview on the provided parameter groups by C3S and their available regions, file formats and data access types.

	Drought	Evapotranspiration	Humidity	Hydrology	Precipitation	Snow & Ice	Soil	Land cover/Land use	Water storage	Waterbodies
Regions	African domain, Arctic domain, European domain, North American domain, Mediterranean domain, Mediterranean domain	x	x	x	x					
	Black sea									x
	Europe	x	x	x	x	x	x		x	x
	Global	x	x	x	x	x	x	x	x	x
	Global (94 lakes on 4 continents)									x
	Global (except for Antarctica)				x					
	Global ocean split between Northern and Southern Hemispheres						x			
	Greenland and Antarctica						x			
	Northern Hemisphere						x			
	Northern/Southern Hemispheres						x			
	Pan European	x			x		x	x		
West/East domain		x	x	x	x	x	x		x	
Data access	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)	Data download (CDS)
File format	NetCDF	GRIB, GRIB2, NetCDF, NetCDF4	GRIB, GRIB2, NetCDF, NetCDF4, NetCDF5	GRIB, GRIB2, NetCDF, NetCDF4	GRIB, GRIB2, NetCDF, NetCDF4	ESRI, CSV, GRIB, GRIB2, NetCDF, NetCDF4	GRIB, GRIB2, NetCDF, NetCDF4	GRIB, NetCDF, NetCDF4	GRIB, GRIB2	GRIB, NetCDF, NetCDF-4





Table 11: Overview on the provided parameter groups by CLMS and their available regions, file formats and data access types.

	Drought	Geographic zones	Ground motion	Hydrology	Land cover/Land use	Snow & Ice	Soil	Waterbodies
Regions	Africa							x
	Continental							x
	Continental Europe					x		
	Eastern Partnership countries (Armenia, Azerbaijan, Belarus, Georgia, Republic of Moldova and Ukraine)				x			
	EEA39	x	x	x	x	x		
	Europe						x	x
	Eu countries (28)					x		
	Global					x	x	x
	Land areas of the Copernicus participating states			x				
	Local		x					
	Northern Europe						x	
Northern hemisphere						x		
Data access	Webservices	Webservices	Not sepecified	Webservices	Webservices, Product portal, WFS, WMS, WCS	FTP, WMS, Product Portal	Product Portal	FTP, Product Portal
File format	XML, GeoTIFF, Raster	ESRI Geodatabase, SQLite database, Raster, Vector	Not sepecified	ESRI file geodatabase, Geopackage Shapefile	100 m GeoTIFF, ESRI Geodatabase, Geopackage, Shapefile, SQLite database, GeoTIFF, Global files, HDF-5, NetCDF, NetCDF4, Raster, Vector, JPEG2000	FTP, GeoTIFF, XML, NetCDF4	GeoTIFF, XML, NetCDF4	FTP, GeoJSON, XML, XSL, NetCDF, NetCDF4, GeoTIFF, ENVI, HDF5





#### 4.3.2.3 CEMS

The emergency management service aims to deliver accurate data products within a very limited response time. It is the only service providing information on e.g. flood thresholds and flood probability and -awareness. The service uses tools, such as [Rapid mapping](#), to create and provide those outputs. Furthermore, the modelsuite LISFLOOD, the heart of EFAS/GloFAS, has been released as a full open-source code. Table 13 gives a brief overview on their access methods and available regions. Information on file formats is not always available since certain products can only be accessed by a map viewer. Data products from the Rapid mapping tool can be downloaded as PDF or DOC's.

CEMS data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

Table 12: Instruction table to access CEMS data products in the inventory.

Tab	Filter	Description
Copernicus_inventory	Column B - Select "CEMS"	This combination gives an overview on all data products (water quantity) currently provided by CEMS.
Copernicus_upcoming	Column B - Select "CEMS"	This combination gives an overview on upcoming CEMS data products (water quantity).
CEMS_PT_parameters		Pivot table providing information on parameters and specific output parameters for this Service.

Table 13: Overview on the provided parameter groups by CEMS and their available regions, file formats and data access types.

	Anthropogenic	Drought	Floods	Hydrology	Precipitation	Snow & Ice	Soil	Waterbodies
Regions	Europe	x	x	x	x	x	x	x
	Global	x	x	x	x	x	x	
Data access	(OGS) WMS	(OGS) WMS	Download CDS, FTP, MARS archive (ECMWF), WMS	Download CDS, FTP, MARS archive (ECMWF), (OGS) WMS	Download CDS, FTP, MARS archive (ECMWF), OGS WMS	Download CDS, FTP, MARS archive (ECMWF), OGS WMS	Download CDS, FTP, MARS archive (ECMWF), OGS WMS	Download CDS, FTP, MARS archive (ECMWF)
File format	NA	NA	GRIB2, NetCDF	NA	NA	NA	NA	NA

On the 26th of May 2021, the new updated [GloFAS 3.1](#) flood modelling system was released by the Emergency Management Service. Another product currently being developed is a pan-European Storm Surge Forecasting System, which will be available by the end of 2021. More information on those and other upcoming products can be found in the inventory.



#### 4.3.2.4 CMEMS

The parameters sea ice and snow thickness can play an important role in water storage estimates and water balance/modelling studies. This is why - while other aspects of the marine environment (e.g. sea surface height) were excluded - these are incorporated in the inventory. Table 15 gives a brief overview on their access methods, available regions and file formats.

CMEMS data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

Table 14: Instruction table to access CMEMS data products in the inventory.

Tab	Filter	Description
Copernicus_inventory	Column B - Select "CMEMS"	This combination gives an overview on all data products (water quantity) currently provided by CMEMS.
Copernicus_upcoming	Column B - Select "CMEMS"	This combination gives an overview on upcoming CMEMS data products (water quantity).
CMEMS_PT_parameters		Pivot table providing information on parameters and specific output parameters for this Service.

Table 15: Overview on the provided parameter group by CMEMS and their available regions, file formats and data access types.

		Snow & Ice
Regions	Arctic	x
	Baltic	x
	Global	x
Data access		WMS
File format		CSW, SUBSETTER, FTP, DGF

#### 4.3.2.5 CAMS

The majority of the Atmosphere Monitoring Service data products can be found in the parameter group "Water storage", therefore being the most important group for this Service. It contains data products such as "Specific cloud liquid water content" or "Total column water vapour". Other parameter groups are represented by lower numbers of data products. Table 17 gives a brief overview on their access methods, available regions and file formats.



CAMS data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

Table 16: Instruction table to access CAMS data products in the inventory.

Tab	Filter	Description
Copernicus_inventory	Column B - Select "CAMS"	This combination gives an overview on all data products (water quantity) currently provided by CAMS.
Copernicus_upcoming	Column B - Select "CAMS"	This combination gives an overview on upcoming CAMS data products (water quantity).
CAMS_PT_parameters		Pivot table providing information on parameters and specific output parameters for this Service.

Table 17: Overview on the provided parameter group by CAMS and their available regions, file formats and data access types.

	Evapotranspiration	Humidity	Land cover/ Land use	Precipitation	Snow & Ice	Water storage	Waterbodies
Regions Global	x	x	x	x	x	x	x
Data access	Data download	Data download	Data download	Data download	Data download	Data download	Data download
File format	GRIB, NetCDF	GRIB	GRIB	GRIB, NetCDF	GRIB, NetCDF	GRIB, NetCDF	GRIB



## 4.4 External Platforms inventory

### 4.4.1 ESA, JAXA, NOAA inventory

*The External Platforms inventory can be accessed by the tab "External\_Platforms\_inventory" in the "D3.2\_Inventory.xlsx file".*

The table below gives an overview on the data products available at the different data providers ESA, JAXA and NOAA. Parameters included in each parameter group are shown in Figure 8.

*Table 18: Overview on the number of data products (parameter) for different parameter groups for each Service.*

Parameter Group	ESA	JAXA	NOAA	Total
Drought		8	13	21
Evapotranspiration			2	2
Floods			1	1
Geographic zones	1			1
Humidity			2	2
Hydrology		2	1	3
Land cover/Land use	7	22	33	62
Precipitation		98	52	150
Snow & Ice	82	24	46	152
Soil	6	3	3	12
Water storage		24	8	32
Waterbodies	4			4
<b>Total</b>	<b>100</b>	<b>181</b>	<b>161</b>	<b>442</b>

The data products of the three providers can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

*Table 19: Instruction table to access data products in the External Platforms inventory.*

Tab	Description
External_Platforms_inventory	Gives an overview on all data products (water quantity) currently provided by the External Platforms ESA, JAXA and NOAA.
EP_PT_parameters	Pivot table providing information on the available parameters/parameter groups for the different External Platforms (ESA, JAXA, NOAA).



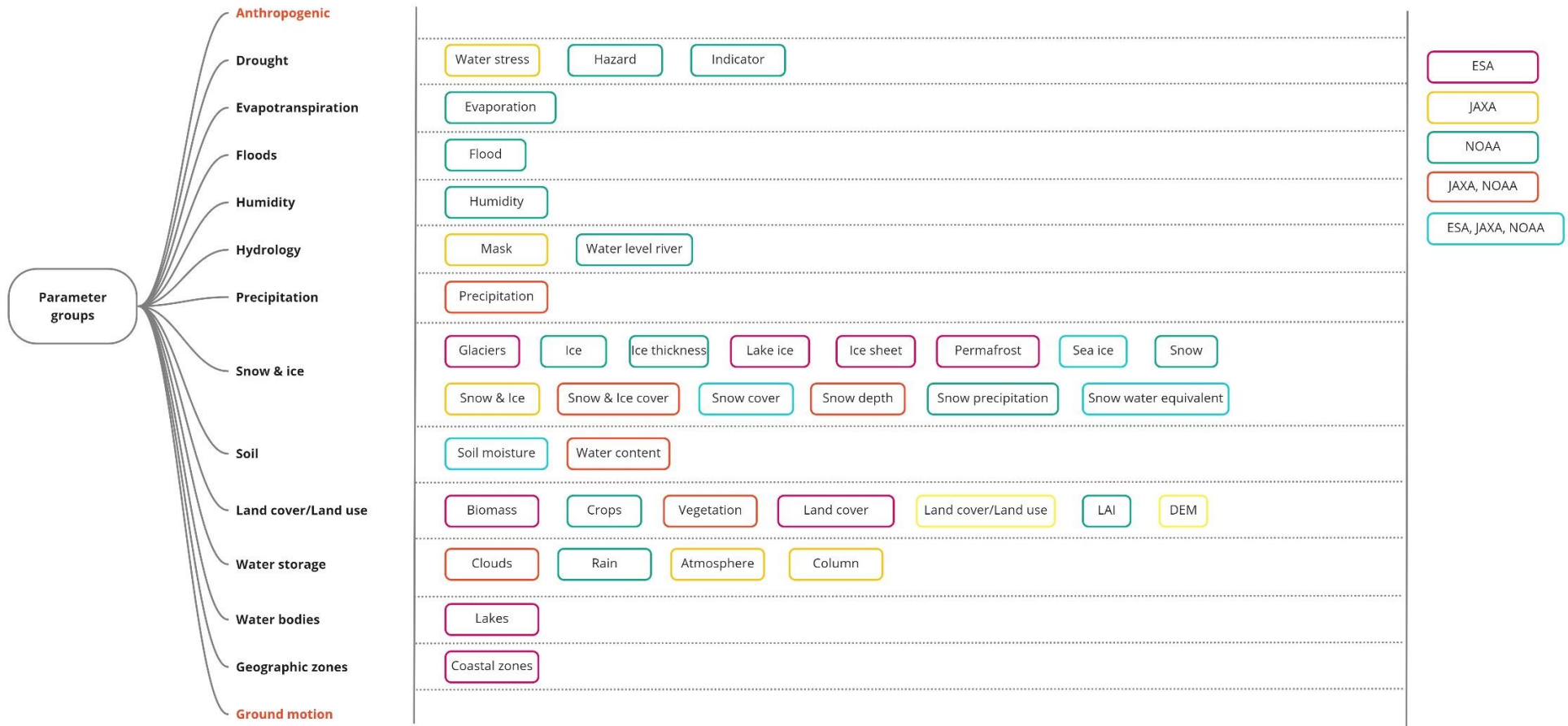


Figure 8: Overview on parameter groups and their designated parameters. Parameter group names highlighted in red indicate that the parameter group is not provided by the External Platforms compared to the Copernicus Services.

#### 4.4.2.1 ESA

The data products of ESA are focused on snow & ice, land cover/land use, soil and waterbodies related parameters. From the three external providers it is the only one offering information on lake parameters (aside lake ice). It also offers products on permafrost, a parameter that was not encountered at any other Service/provider.

A brief overview on the data products access methods, available regions and file formats is given in the table underneath.

Table 20: Overview on the provided parameter groups by ESA and their available regions, file formats and data access types.

	Geographic zones	Land cover/Land use	Snow & Ice	Soil	Waterbodies
Regions	Antarctica		x		
	Global	x	x	x	x
	Greenland		x		
	Northern Hemisphere		x		
	Southern hemisphere		x		
Data access	FTP, webservices (webdownload),	FTP, webservices (webdownload), OPeNDAP	FTP, web download service	FTP, web download service	FTP, web download service
File format	NetCDF, OPeNDAP	NetCDF, NetCDF-4, GeoTiff, OPeNDAP	NetCDF, NetCDF-4, .datfile, OPeNDAP, ASCII, FTP, ESRI shp, KML/WKT in CSV, .png, CF-v1.7-9	NetCDF-4	NetCDF, OPeNDAP

ESA data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

Table 21: Instruction table to access ESA data products in the inventory.

Tab	Filter	Description
External_Platforms_inventory	Column B - Select "ESA"	This combination gives an overview on all data products (water quantity) currently provided by ESA.
ESA_PT_parameters		Pivot table providing information on parameters and specific output parameters for this provider.

#### 4.4.2.2 JAXA

The listed JAXA product are very similar to the ones of NOAA. Of the three data providers it is the only one offering drought related products. The amount of water storage products is quite extensive compared to the other data providers, the Copernicus C3S not included. A brief overview on the data products access methods, available regions and file formats is given in Table 22.





Table 22: Overview on the provided parameter groups by JAXA and their available regions, file formats and data access types.

		Drought	Hydrology	Land cover/Land use	Precipitation	Snow & Ice	Soil	Water storage
Regions	Divided to 15 areas				x			
	Global	x	x	x	x	x		x
	Global (ocean)				x			x
	Global (except cold latitudes)				x			
	Global (over ocean)							x
	Hemispherical					x		
	Japan	x		x		x		x
	Land			x		x	x	x
	Land area (except forest region)					x		
	Land area (except ice sheet and dense forest)						x	
	Land over the continents of Africa and Australia			x			x	
	Polar region (over ocean)					x		
	Scene					x		
	Thai	x						x
Tile						x		
Vietnam			x					
Data access	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)	Various data portals (G-Portal = e.g. FTP, ...)
File format	*.raw, txt	Not specified	Binary image file, GEOTIFF, txt	4-byte float plain binary, little-endian, FTP, ASCII, CSV, Binary, txt	.hdf, .datfile, ASCII, Binary, txt	Not specified	Not specified	





JAXA data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

*Table 23: Instruction table to access JAXA data products in the inventory.*

<b>Tab</b>	<b>Filter</b>	<b>Description</b>
External_Platforms_inventory	Column B - Select "JAXA"	This combination gives an overview on all data products (water quantity) currently provided by JAXA.
JAXA_PT_parameters		Pivot table providing information on parameters and specific output parameters for this provider.

#### 4.4.2.3 NOAA

The third data provider NOAA provides data on evaporation and floods, important components of the hydrological cycle. These type of products were not encountered in the ESA or JAXA database. Furthermore, NOAA offers an extensive amount of land cover/ land use products, important in modelling studies.

A brief overview on the data products access methods, available regions and file formats is given in Table 25.

NOAA data can be accessed by going to the Excel file "D3.2\_Inventory" and using the filters and/or tabs indicated in the table below:

*Table 24: Instruction table to access NOAA data products in the inventory.*

<b>Tab</b>	<b>Filter</b>	<b>Description</b>
External_Platforms_inventory	Column B - Select "NOAA"	This combination gives an overview on all data products (water quantity) currently provided by NOAA.
NOAA_PT_parameters		Pivot table providing information on parameters and specific output parameters for this provider.





Table 25: Overview on the provided parameter groups by NOAA and their available regions, file formats and data access types.

		Drought	Evapotranspiration	Floods	Humidity	Hydrology	Land cover/ Land use	Precipitation	Snow & Ice	Soil	Water storage
Regions	Contiguous United States, Alaska, Hawaii, U.S. territories and at military base sites							x			
	Continental U.S., a few from Caribbean and Pacific Island stations							x	x		
	Continental United States							x			
	CONUS							x			
	Eastern two thirds of the U.S								x		
	Global				x		x	x	x	x	x
	Local						x	x	x		
	Locations across the United States, U.S. territories, commonwealths, the Compact of Free Association nations, one station in Canada							x			
	Northern hemisphere								x		
	Northern hemisphere, Southern hemisphere								x		
	Nothern hemisphere								x		
	Regional						x				
	Southern hemisphere								x		
	U.S. stations located across the 50 states, as well as U.S. territories, commonwealths, the Compact of Free Association nations, and one station in								x		
	U.S. weather stations operated or managed by the U.S. National Weather Service								x		
	United States of America, Puerto Rico, the US Virgin Islands, and various Pacific Islands								x		
US	x	x					x	x		x	
US, U.S. territories in the Caribbean and Pacific						x		x			
Western hemisphere, Eastern hemisphere, Northern hemisphere										x	
Data access		Direct download links available	Direct download links available	Direct download links available		Direct download links available	Direct download links available, WMS, WFS	Direct download links available	Direct download links available	Direct download links available	
File format	Txt, CSV, KML, Shapefile	PDF	PDF	GRIB1, GRIB2	Txt, PDF, PNG, XML	NetCDF, NetCDF-4	ASCII, CSV, *.shp, KMZ, PDF, native binary, TSV, PNG Javascript S3, MAP, NetCDF, NetCDF-4	ASCII, CSV, *.shp, KMZ, PDF, NetCDF, NetCDF-4, HTML, GRIB2	GRIB2, PNG	GRIB2, KMZ, PDF, CSV, ASCII, NetCDF, NetCDF-4	



## 5. Analysis

When preparing the Copernicus inventory, it immediately became clear that a huge amount of data and metadata is available. A lot of additional documentation is provided in the form of manuals and additional documentation or publications. The Copernicus platform also offers some tools for visualising and analysing the data. **Most data products are freely available.**

However, **users often struggle to get a clear and complete picture** of all products made available by the Copernicus Services. They fail to capture the entirety of the databases or to find the metadata information of their interest. Note how a lot of the parameters requested during [our recent workshop](#), were actually already provided by the Copernicus Services (Figure 9). We pinpointed the following bottlenecks:

1. There is a **strong lack of data-awareness within the wider community**. Additional Trainings and free online tutorials could reduce this issue. Moreover, users were unaware of the [general newsletter](#), already broadcasted by Copernicus. It could help to make these available in additional languages.
2. **A general search engine** for all Copernicus Services was widely requested. Note how [this does exist](#), but (a) there is lack of public awareness and (b) is **too limited for proper use** as the applicable filters are too basic: one can only carry out a key-word search. We advise to further elaborate this to allow for an intelligent data search by allowing to filter on area of interest, spatiotemporal resolution, latency etc. or even to really increase usability: to select your area of expertise or the objective of your research and directly get a subset of products that are most commonly used by your peers. **The CMEMS and C3S portals were considered examples of good practice.**  
It seems that users do not always find their way to their specific product of interest, partly due to the **different set-ups of the data portal from each Service**: there is no harmonization / standardization between the layout / functionalities of the webpages of the different Copernicus Services.
3. Similar products (belonging to the same parameter and/or parameter group) are sometimes scattered over different Copernicus Services. Often the detailed characteristics (e.g. coverage, temporal resolution) differ slightly, thus creating a high amount of, at a first glance, similar products. The fact that **similar products are spread over different Services** makes it very difficult to find the exact product that optimally meets your requirements.
4. In certain cases a clear **link between different Services** is visible, e.g. output products of the Emergency Management Service (CEMS) that are made available as a product in the Climate Data Store (CDS) of C3S. However, at the same time **disconnects** are noticeable as well: e.g. no linkage between land cover/land use from the CDS and the Copernicus Land Monitoring Service (CLMS). Users could benefit from a direct link between two Services: e.g. referring to the other database(s).
5. **Users did not find their way (yet) to the five DIAS ([Data and Information Access Services](#))** as they were requesting the possibility for (a) a central



repository for all data; (b) all data to be available in the cloud environment; (c) tools to process the data in the cloud and/or (d) access through GIS plugins. This indicates a lack of public awareness and a necessity to expand these platform.

Moreover, **users requested more elaborated products**: e.g. subsurface parameters (soil maps, groundwater etc.). Also information on discharge is scarce, while it was in high demand during the workshop. Note how even though some products might already be made available (Figure 9), they can still lack the **high spatiotemporal resolutions** required for certain end users.

*Important to notice*: The available Copernicus data products were **compared to a limited selection of external platforms**. Due to this selection the reader can be under the impression only a limited amount of data products with regard to e.g. hydrology or evapotranspiration is offered by the United States (US), since respectively only 1 and 2 products are mentioned in Table 18 (NOAA). However, other external platforms such as the [US Geological Survey \(USGS\)](#), [Earthdata](#) (NASA) etc. exist, all offering their own variety in datasets. Furthermore, this comparison does not exclusively focus on 1:1 data product comparison, but mainly on bottlenecks on user friendliness & data accessibility. When **comparing** the Copernicus Services **with a subset of other External Platforms** it became clear that in general:

1. The same parameter groups could be defined for both inventories, except the parameter groups "Anthropogenic" and "Ground motion", which were only applicable for the Copernicus inventory (Figure 7 & Figure 8).
2. The external data providers ESA, JAXA and NOAA all offer a vast amount of water quantity related data. At first glance, the abundance, as well as the variety of parameters belonging to one parameter group, is significantly higher for the Copernicus inventory.
3. Nomenclature of specific output parameters can be confusing and is not necessarily uniform between Services/data providers. In certain cases it is not immediately clear which specific output parameter from data source 1 coincides with a specific output parameter of source 2.
4. Data products related to precipitation and/or snow & ice parameters are highly represented, while products related to drought, evapotranspiration, floods and characteristics of water bodies (area/extent and water level) are far less accounted for.
5. Similar problems occur as with the Copernicus Services were encountered: difficult to obtain a first glance overview on where and how to access the data and its characteristics
6. The **visual representation in the [Earthdata Search \(nasa.gov\)](#)**, where one can manually select his/her area of interest on a map, is considered **an example of good practice** where some Copernicus Services and/or Copernicus general search engine can learn from.
7. NASA offers a wide variety of **trainings and free online tutorials** ([NASA Arset trainings](#)), thereby (a) increasing product awareness among the general public, (b) lower thresholds towards data accessibility and (c) they can help users find their way to related platforms from e.g. NOAA, USGS. Users asked a similar approach from the Copernicus Services.



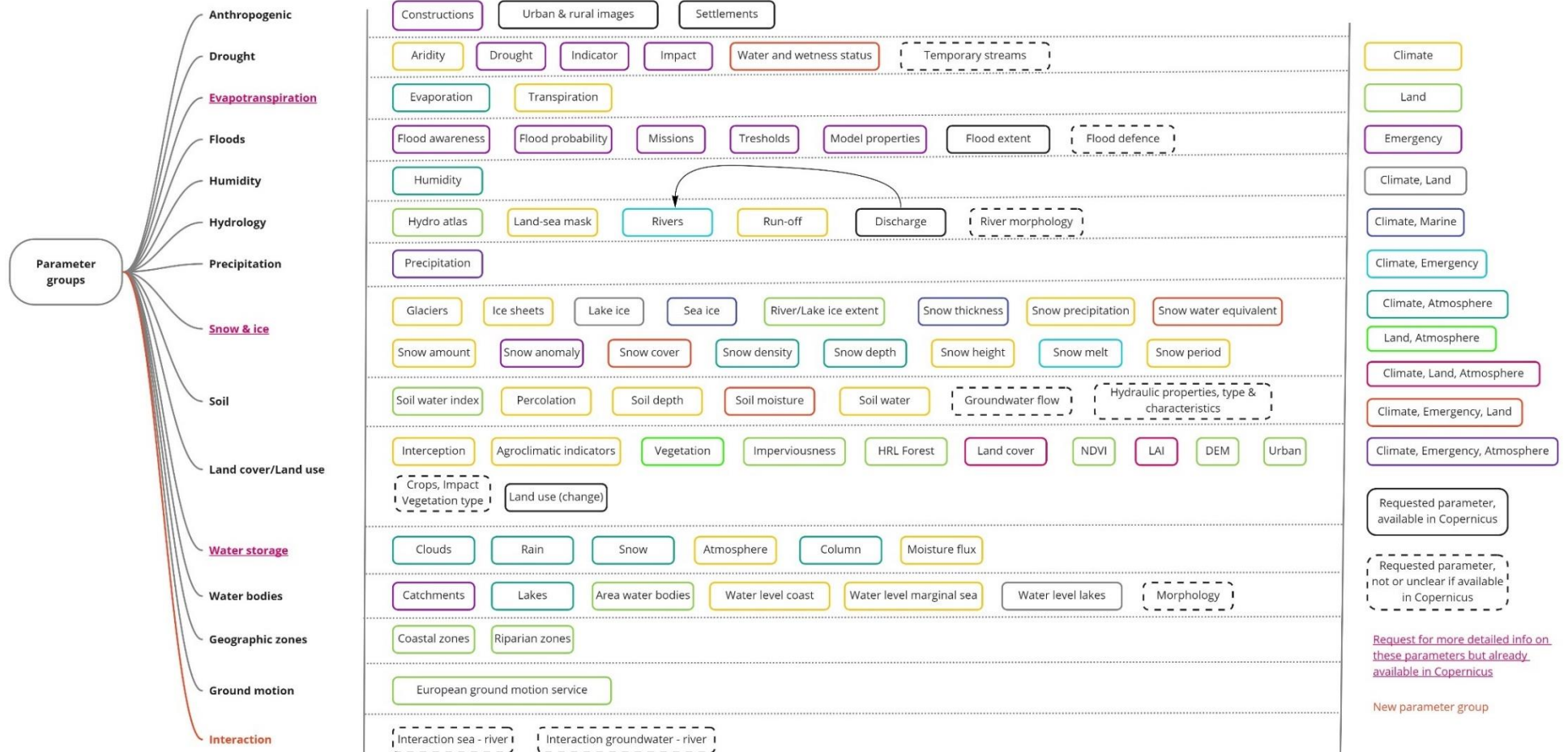


Figure 9: Overview of parameters requested in D3.1 with indication if already available (full border), not yet available or unclear (dotted border), available but more detailed products required (pink text) and a new parameter group (red text)





## 6. Conclusions

In general, the following can be concluded:

1. The Copernicus Services already offer an extensive amount and high variety of data products and tools related to water quantity and the hydrological cycle. Most of these are freely available. The relevant products are included in the [inventory](#).
2. Data products related to precipitation and/or snow & ice parameters are highly represented, while more elaborated products related to drought, evapotranspiration, floods and characteristics of water bodies are far less accounted for even though these seem to be in high demand.
3. The Copernicus Services already have a solid organizational structure and are evolving at a high pace. An extensive amount and high variety of data products is already available, but one of the key issues for the Copernicus platform seems to be the data awareness by the end user.
4. Users often struggle to get a clear and complete picture of all products made available by the Copernicus Services. Some bottlenecks were identified:
  - a. There is a lack of data-awareness with the wider community. Additional Trainings and free online tutorials could reduce this issue. The NASA Arset trainings are considered to be an example of good practice.
  - b. [The general search engine for all Copernicus Services](#) is considered to be too limited for proper use because the filters are too basic. The CMEMS and C3S data portals and especially NASA's Earthdata portal were considered examples of good practice.
  - c. Each Copernicus Service applies a different set-up for its data portal, making it more difficult for users to navigate through multiple ones.
  - d. Similar products that only differ slightly in terms of coverage or spatiotemporal resolution, are sometimes scattered amongst multiple Services. This inhibits the user to find the exact product that optimally meets his/her requirements.
  - e. Most Services apply data from other services. Users could benefit from additional cross-references. Moreover, some disconnects were identified e.g. there is no link between land cover/land use from the CDS and the Copernicus Land Monitoring Service (CLMS).
  - f. Users did not find their way (yet) to the five DIAS, even though they requested the related services.
5. Even when products were present, they can still lack the high spatiotemporal resolutions required for certain end users.
6. Users did also request more elaborated products: e.g. subsurface parameters (soil maps, groundwater etc.) and discharge.



## 7. Recommendations

Recommendations for developing the Roadmap:

1. It is advisable to link the current inventory of water quantity products with the water quantity products currently being inventoried under WP 2. Note how both inventories are merely a snapshot in time as every year, new products are being added to the Copernicus Services.
2. The inventory should form the basis of future tasks, where it will be compared with recent innovations in processing, modelling and (cloud) computing techniques to facilitate more data driven techniques, early warning systems and cloud computing. The latter being in high demand by the end user. This work will be continuously carried out throughout WP3.
3. It would be beneficiary to strengthen the collaboration with the hosts of all Copernicus Services: to share the user uptake gained during Water-ForCE and to further streamline our output with the information they require to optimise their Services. The central question is: What kind of input do they need from the participants? This will establish a 2-way communication between users as well as hosts. E.g. Cross-check between end users and Copernicus hosts how current provided data formats / data accessibility matches with end user computation platforms and / or can be aligned.
4. Even though many products are already provided by the Copernicus Services - more than many users are aware of - some users do request more elaborated products such as subsurface parameters (soil maps, groundwater dynamics, and riverine discharge). Many end users do still require information on a much higher spatial resolution (several orders of magnitude) than is currently available on any platform. One key question to solve, together with the hosts of all services: does this fall within the scope of Copernicus Services?
5. We advise to not solely focus on new innovative techniques or products, but to also tackle the main barriers that inhibit users to obtain a clear and complete picture of all products made available by the Copernicus Services.

