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WP1 - Policy, Stakeholder and Service Analysis

D1.3 Links between missions-services-applications

Project Identification

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3-3-2022	V2	Revised by Water-ForCE project internal reviewers
7-3-2022	V3	Final version

List of Acronyms

AGRI	Directorate-General Agriculture and Rural Development
AMSR	Advanced Microwave Scanning Radiometer
AoI	Area of Interest
BAT	Best Available Technique
BWD	Bathing Water Directive
C3S	Copernicus Climate Change Service
CAMS	Copernicus Atmosphere Monitoring Service
CDS	Climate Data Store
CAP	Common Agricultural Policy
CTH	Copernicus Thematic Hub
ESA-CCI	ESA-Climate Change Initiative
CCTH	Coastal Copernicus Thematic Hub

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CDOM	Chromophoric (or colored) dissolved organic matter
CEMS	Copernicus Emergency Management Service
CEOS	Committee on Earth Observation Satellites
CHIME	Copernicus Hyperspectral Imaging Mission
CIMR	Copernicus Imaging Microwave Radiometer
CLMS	Copernicus Land Monitoring Service
CMEMS	Copernicus Marine Environment Monitoring Service
CRISTAL	Copernicus polaR Ice and Snow Topography Altimeter
DEFIS	Directorate-General Defence Industry and Space
DIAS	Copernicus Data and Information Access Services
DOC	Dissolved Oragnic Carbon
EARSC	European Association of Remote Sensing Companies
ECV	Essential Climate Variable
EDO	European Drought Observatory
EEA	European Environment Agency
EFAS	European Flood Awareness System
EIONET	European Environment Information and Observation Network
EMO-5	European Observational Grids (5km resolution)
EMODnet	European Marine Observation and Data Network
EMSA	European Maritime Safety Agency
ENVI	Directorate-General Environment
EO	Earth Observation
EQSD	Environmental Quality Standards Directive
ESA	European Space Agency
EU	European Union

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EE39	39 countries in Europe
EUGMS	European Ground Motion Service
FAO	Food and Agriculture Organization of the United Nations
GCOS	Global Climate Observing System
GDO	Global Drought Observatory
GEO	Group on Earth Observations
GFM	Global automatic satellite-based flood monitoring system
GLEON	Global Lake Ecological Observatory Network
GloFAS	Global Flood Awareness System
GMES	Global Monitoring for Environment and Security (now Copernicus)
GRACE	Gravity Recovery and Climate Experiment
GRDC	Global Runoff Data Centre
GSWE	Global Surface Water Explorer
GWD	Groundwater Directive
HAB	harmful algal blooms
HSI	Hyperspectral Imager
HTE	High-Temperature Events
IPPC-IED	Industrial Emissions Directive
IWF-SEM	International Working Group on Satellite Emergency Mapping
JRC	Joint Research Centre
LIMNADES	Lake Bio-optical Measurements and Matchup Data for RS
LST	Land Surface Temperature
MARE	Directorate-General Maritime Affairs and Fisheries
MRD	Mission Requirements Document
MSI	Multi Spectral Imager

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ND	Nitrates Directive
NRT	Near Real Time
OECD	Organisation for Economic Co-operation and Development
OLCI	Ocean and Land Color Imager
LSTM	Land Surface Temperature Monitoring
PwC	PricewaterhouseCooper
R&D	Research and development
RS	Remote Sensing
ROSE-L	Radar Observing System for Europe - L-Band
RTD	Directorate-General Research and Innovation
SAR	Synthetic Aperture Radar
SCEM	Sentinel Copernicus Expansion Missions
SDG	Sustainable Development Goal
SIC	Sea Ice Concentration
SIE	Sea Ice Extent
SIST	Sea Ice Surface Temperature
SLSTR	Sea and Land Surface Temperature Radiometer
SMAP	Soil Moisture Active Passive
SMOS	Soil Moisture and Ocean Salinity
SPIM	Suspended particulate inorganic matter (turbidity)
SPOM	Sediment Particulate Organic Matter
SRAL	SAR Radar Altimeter
SSH	Sea Surface Topography
SSS	Sea Surface Salinity

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SST	Sea Surface Temperature
SWE	Snow Water Equivalent
TEU	Treaty on the European Union
TFEU	Treaty on the Functioning of the European Union
TIR	Thermal Infrared
UN	United Nations
UNEP	UN Environment Programme
UWWTD	Urban Waste Water Treatment Directive
Water-ForCE	Water scenarios for Copernicus Exploitation
WCTH	Water Copernicus Thematic Hub
WFP	World Food Programme
WP	Work Package

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1. Introduction

1.1 Project & work package introduction

The **Horizon 2020** project **Water-ForCE** (Water scenarios for Copernicus Exploitation) is developing a Roadmap to better integrate the entire water cycle within the **Copernicus services**, thereby addressing needs and requirements from the user community, the current disconnection between remote sensing / in-situ observations and upgrade of the modelling algorithms. The clarity in terms of the needs and expectations of both public and private sectors from the core Copernicus Program and the wider research and business innovation opportunities will be delivered. The Roadmap will then also 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 organizations from all over Europe. It will bring together experts on water quality and quantity, in policy, research, engineering, and service sectors. Through close collaborations with these communities, Water-ForCE will among others:

- **Analyze EU and international 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 EU legislations.
- **Specify the technical requirements** for future Copernicus missions in order to make them more suitable for inland and coastal water remote sensing (e.g. adding new spectral bands on Sentinel-2E and onward, improved spatial resolution, hyperspectral sensors).
- **Optimize future exploitation** of Copernicus Services for inland water monitoring, management, legislation implementation, service provision and research & development through enlarged service portfolio and optimized delivery of water related products and services.

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The project is divided into eight work packages (WP), each of them focusing on a specific problem and/or target of the Copernicus service (see Figure 1). The project started 1 January 2021 with a duration of three years.

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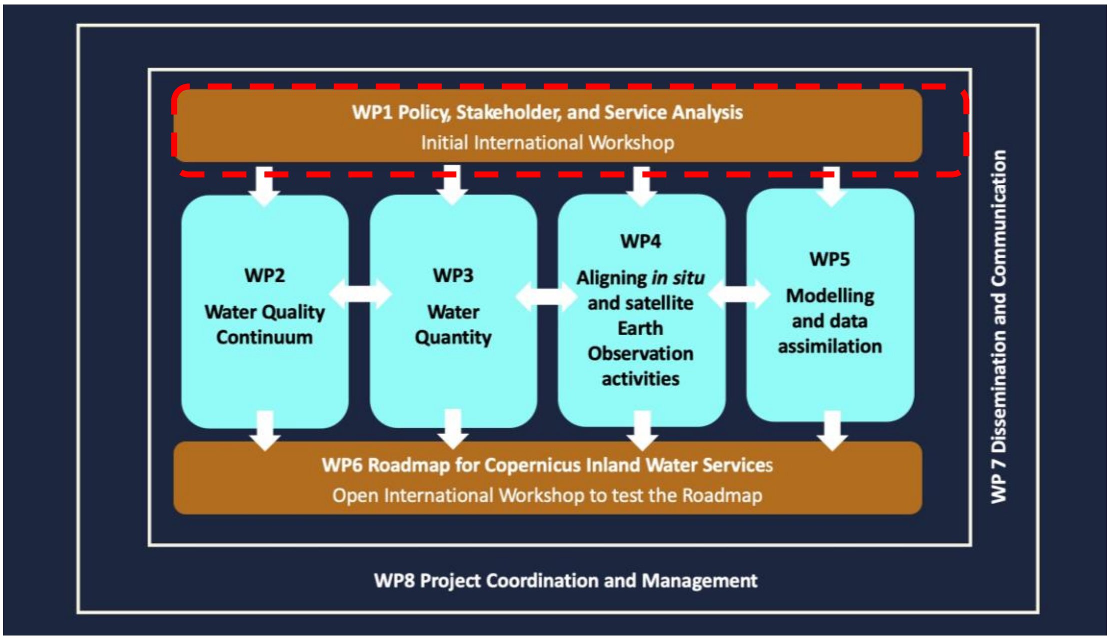

Figure 1 : Organisational structure of the different work packages in the Water-ForCE project.

This report delivers the result of Task 1.3 (T1.3): Links between mission-service applications (Deliverable 1.3 - **D1.3**).

1.2 WP1 overall aim and expected impact

The overall aim of WP1 is to identify key users within the different public domains and business sectors and evaluate whether operational services can meet policy goals. The expected impact is increased coverage of EU policies clearly identifying which and how the project would like to address them.

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WP1 has six tasks and two milestones, as shown in the table below. The tasks and milestones are closely linked and together provide input to WPs 2-6.

Table 1: overview of WP1 tasks and deliverables

Task	Deliverable
T1.1 Value chain and stakeholder identification	D1.1 List of stakeholders (M7)
T1.2 Public domain and business sector identification	D1.2 Report with assessment of domain-specific and sectoral policies and legislation (M10)
T1.3 Links between mission-service-application	**D1.3 Report with analysis of links within Copernicus programme and between Copernicus programme and domain / sector policies (M14)**
T1.4 End-user needs and requirements identification	D1.4 Report with end-user needs and requirements (M14)
T1.5 Innovation need and opportunities	D1.5 Report with analysis of business opportunities, validated by industry (M14)
T1.6 Contribution towards societal challenges, missions and SDGs	D1.6 Report on links and gaps between satellite EO and water related SDGs and climate indicators (M14)
MS1	WP1 Participants workshop (M4)
MS2	Input to the Roadmap (WP6)

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This report is the deliverable for Task 1.3.

1.3 Objectives T1.3

The objective of Task 1.3 "Links between mission-service-application from *current* Copernicus Services and *future* Copernicus missions" is to determine the links between satellite missions, services and policy driven applications. Using the inputs from T1.2, we want to identify if there are traceable links between the upstream missions and the downstream EU and international policies and resulting legislation. The Copernicus programme was developed to fill in spatial and temporal gaps in availability of environmental data and decision making. Although in some fields, such as agriculture[1], progress has been made, there remains plenty of scope where remote sensing can help in improving or developing improved monitoring and new applications. The European Commission identified the need[2] to develop improved inland water services, and for that we need to facilitate the different Copernicus Services as well as Horizon 2020 and ESA research projects.

The aim is to identify which (if any) links exist between the Copernicus programme and policy and legislative cycle: the extent to which international treaties and global agreements benefit from information provided by Copernicus EO water related services and, in turn, which of these influence the development of the Copernicus mission..

1.4 Approach

[1] See for example http://www.eo4geo.eu/training-actions/common-agriculture-policy-copernicus-webinar/

[2] *From Horizon 2020 call LC-SPACE-24-EO-2020: Copernicus evolution: Mission exploitation concept for WATER: "... to reinforce the existing portfolio offered under Copernicus and to propose an integrated approach for a coherent and consistent inland water monitoring system."*

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In D1.2 we developed the value chain with relationships and questions to address, which for ease of reference we repeat here (Figure 2)..

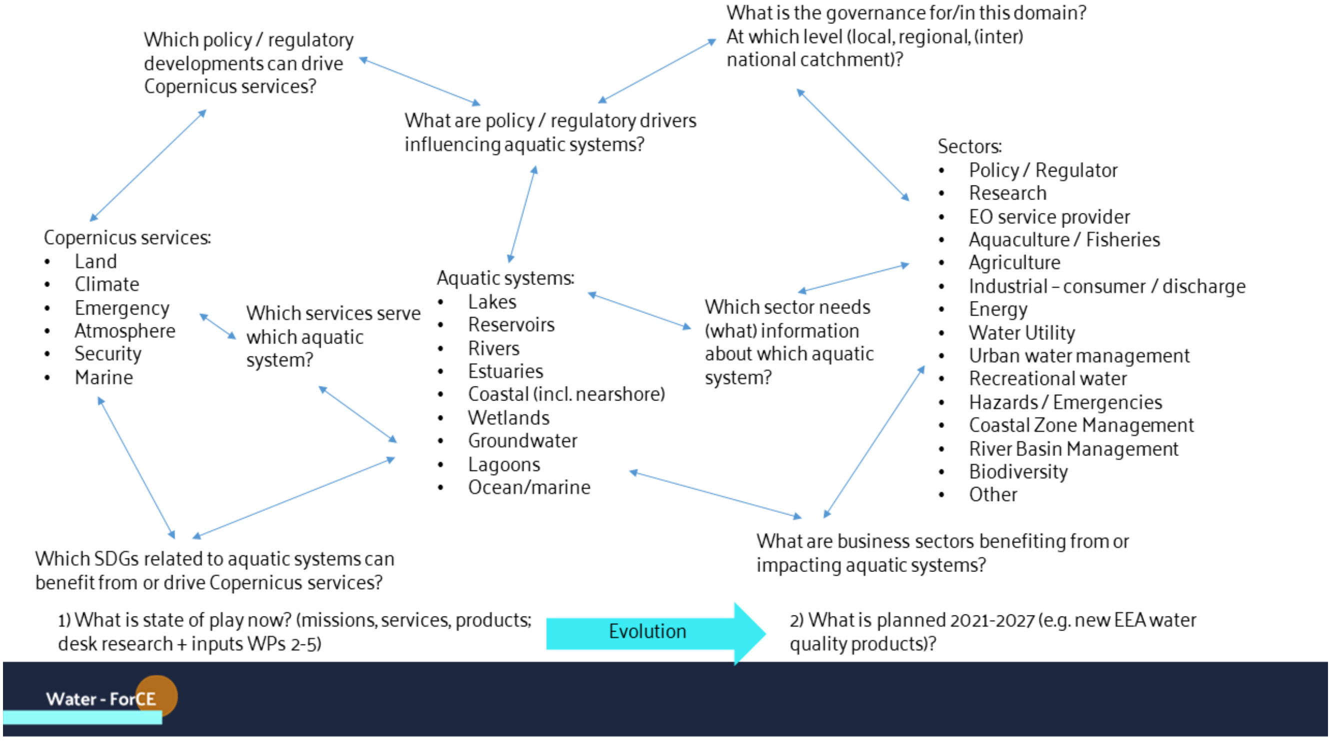

Figure 2 : Water value chain and questions to address

These questions form the basis for Deliverables 1.3-D1.6. Relevant for this deliverable are:

- which policy / regulatory developments can drive Copernicus development (i.e. where and in what way are legislative norms and standards more stringent, driving the spatiotemporal monitoring needs of public authorities and businesses to which Copernicus can respond with new products)?
- what is the state of play of current Copernicus missions and services and what is planned in the current 2021-2027 programme period in relation to inland water (aquatic systems). This analysis will attest to the extent to which Copernicus already serves the needs of public policy domains.

Copernicus is a user-driven programme, i.e. user consultation results in the requirements used to design the future missions. There is a time lag between the user requirements

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definition, the mission design and development and the subsequent launch and operations phase. This means that the current Copernicus missions (the satellite constellations and instruments) were developed a decade or so ago (building on earlier scientific/demonstration missions) and enable the current product development within the already agreed budget envelope 2021-2027. Our aim is to determine if the user needs of the water domain were considered when designing the missions and services, in order to make recommendations (beyond 2027), and from that the extent to which they can be expected to support the policy cycle (applications). We start by identifying whether or not policy has driven / drives the development of new applications through legislative and other instruments (section 2). Then we look at *current* and *planned* core missions (section 3). Next step is to describe the current Copernicus Services in relation to the (inland) water domain. Following desk literature review, we will determine if relevant words have been used in preambles, staff working documents or the actual policy and legislative documents e.g. ”Copernicus”, ”Earth observation”, ”remote sensing”.

During the literature review we used the following set of keywords, identified in D1.2.

i. Stakeholder analysis list

1. Aquatic systems: “(inland)+[3]water”, ”aquatic”, ”lake”, ”reservoir”, ”river”, ”coastal”, ”wetland”, ”groundwater”, ”lagoon”, ”ocean”, ”marine”
2. Active sectors: “policy+regulator”, ”aquaculture+fishery”, ”industrial+consumer+discharge”, ”energy”, ”water+utility”, ”(urban)+water+management”, ”recreational+water”, ”hazard+emergency”, river+basin+management”, ”coastal+zone+management”, ”biodiversity”, ”research”, ”(earth+observation/EO)[4]+service+provider”

[3] where the symbol “+” is present it indicates that the search should be performed using both words together as a single “keyword” (e.g., “inland” AND “water”)

[4] where keywords are between parentheses “()” using an additional keyword for setting further the thematic/sectoral context is suggested

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3. Copernicus Services: “Copernicus+Service”, “Atmosphere”, ”Marine”, ”Land”, ”Climate Change”, ”Security”, ”Emergency”

ii. Space community list

1. Remote Sensing terminology: ”analyse”, ”assessment”, “Copernicus”, ”detection”, ”earth+observation”, ”evaluation”, ”extent”, ”ground+based”, ”hazard”, “in+situ”, ”indicator”, ”map”, ”measure”, ”monitoring”, ”parameter”, ”pollution”, ”remote+sensing”, ”resolution”, ”satellite”, ‘spatial”, ”temporal”, ”time+series”, ”track”

iii. EARSC taxonomy list

1. EARSC thematic taxonomy: “drought”, ”turbidity”, ”run-off”, ”irrigation”, ”soil+water+index”, ”surface+soil+moisture”, ”map+vegetation+index”
2. EARSC market taxonomy: “water+use”, “map+water+depth”, “bathymetry”, “dredging”, “groundwater”, “water+plant”

iv. PwC Copernicus list

1. Market oriented terminology: “climate+modelling”, ”crop+monitoring”, ”water+resource+management”, ”water+cycle”, ”soil”, ”moisture”, ”water+stress”, ”rainfall”, ”wetland+monitoring”, ”common+agricultural+policy”, ”coastal+area+monitoring”, ”integrated+coastal+zone+management”, ”land+planning”, ”water+quality+monitoring”, ”bloom”, ”carbon+cycle”, ”plastic+waste”, ”flood+monitoring”, ”flood+forecasting”.

Since Copernicus is a user-driven programme, we start our analysis by investigating the policy and legislative domain.

2. Policy and Legislation

As we described in D1.2, we look at policies and legislation from two perspectives: i. from the perspective of space policy and how Copernicus development can (and does) drive the policy cycle and improve legislation in public sector domains such as water management, water pollution etc.. (2.1) and. ii. from the perspective of domain-specific public sector policies and legislation and how these can (and do) drive Copernicus evolution such as increased

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emission requirements (nitrogen, sulphur), the need for a more efficient use of water in agriculture etc. (section 2.2) .

2.1 Space policy and legislation: EU Space Programme and Copernicus

The Copernicus Programme was established under Regulation (EU) No 377/2014 of the European Parliament and of the Council of 3 April 2014[5]. Copernicus is the successor to Global Monitoring for Environment and Security (GMES), an Earth monitoring initiative dating back to 1998. The mission is clear from the name: the aim was to set up an operational, continuous system of monitoring in support of environment and security. Although water is a priority issue in both environmental (pollution, drinking water) and security (flooding, infrastructure) domains, it is not a given that this has been made explicit or addressed coherently and comprehensively. Indeed, the main goal of the call setting up this Water-ForCE project was: "to analyse current and planned EO space capacities together with innovative processing, modelling and computing techniques to *reinforce* the existing portfolio offered under Copernicus and to propose an *integrated approach* for a coherent and consistent inland water monitoring system".

Regulation 377/2014 was superseded by the Regulation (EU) 2021/696 of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme (EUSPA) for the period 2021-2027. This is the core space policy document for the EU. To find out if the Space Programme Regulation is explicit about meeting the needs

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014R0377 For the period 2014-2020

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of the water domain, we carried out an analysis, using the key words defined in D1.2 as guidance.

We found that the Space Programme Regulation in large part focuses on Copernicus. It specifies that one of the targets of Copernicus is to respond to requirements of public policies and support their formulation and implementation. It is noted that this is a feature of autonomous access to environmental knowledge (free, full, open data policy) that allows independent decision-making. Though inland water is not explicitly mentioned, this provision shows the importance of Copernicus for, inter alia, environment, agriculture, and land monitoring, which generally include management of inland waters. The Regulation further states that activities under Copernicus should expand their global monitoring coverage to support applications in water management. Hence, we found that the facilitation of open-source platforms available and understandable for end-users is key for ensuring successful policy implementation through more precise decision-making (by the usage of up-to-date monitoring data) in the area of the current research. Regulation supports this application: per Articles 50-51, eligible actions for Copernicus and its services shall cover innovative applications for water management and inland water quality and quantity monitoring. Being permitted by Regulation, a separate service related to inland water currently does not exist, which is considered as a significant gap in Copernicus policy.

Furthermore, Regulation provides for several levels of cooperation to facilitate Copernicus uptake. For the Commission, it is advised to work together with Member States and the European Environment Agency (EEA). Member States and Commission should establish links between Copernicus and national policies to drive commercial Copernicus applications in enterprises and start-ups. Thus, this specifically concerns suitable industry and SME policies. This can be seen as another example of policies that can be impacted by

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the Copernicus exploitation. Business opportunities and stakeholders' views on SME policies in this regard are analysed in D.1.5.

Last but not the least, we note that Regulation considers Copernicus as a contributor to international instruments related to the environment, such as the 1992 United Nations Framework Convention on Climate Change, the UN Sustainable Development Goals (see D.1.6), and the Sendai Framework for Disaster Risk Reduction. These and other international regulations will be analysed further in this chapter.

2.2 Thematic policies and legislation

As outlined above, a major goal of Copernicus is to develop or contribute to operational applications in support of EU and global policies. Indeed, the Regulation defines Copernicus core users as European Union institutions and bodies, European, national, regional or local authorities entrusted with the definition, implementation, enforcement or monitoring of a public service or policy in the areas of atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security. Having established a long list of policies (D1.2) in this section we analyse the priority documents for water using the identified keywords.

2.2.1 EU Water Policies

In D1.2 we identified a long list of water policies. This analysis will start from the key water documents that, according to the Commission, include the Water Framework Directive

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(WFD), the Environmental Quality Standards Directive (EQSD), the Groundwater Directive (GWD), and the Floods Directive (FD).[6] Other policies, including sectoral, will follow below.

Water Framework Directive (WFD)

The core instrument which commits European Union Member States to achieve the good qualitative and quantitative status of all water bodies is the Water Framework Directive (WFD) 2000/60/EC, with the text consolidated in 2014.. The WFD comprises multiple elements of the aquatic cycle as defined by the Water-forCE team[7].. Namely, the scope of WFD related to inland waters covers inland waters themselves in general, separately defining surface water, groundwater, river, lake, transitional waters, coastal water and artificial water bodies. Even though it was decided by the EC in 2020 not to revise WFD, it is still in force and its norms continue to be of huge importance for adequate governance of water management.[8]

Through the analysis of the WFD using the 'Space' key words as listed above we found that there is no specific or explicit mention of monitoring using EO data (perhaps unsurprising considering that both the WFD and the establishment of Copernicus were in 2014). Indeed, there are certain barriers to the uptake of Copernicus due to techniques explicitly mentioned in WFD, for instance, microscopy, samples, hydroacoustics, multimesh gillnets as some of the methods related to water quality monitoring.

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6 https://ec.europa.eu/environment/water/fitness_check_of_the_eu_water_legislation/index_en.htm

7 Groundwater, Lakes, Reservoirs, Rivers, Estuaries, Wetlands, Lagoons, Coastal, Ocean

8 https://watereurope.eu/the-water-framework-directive-will-not-be-revised/

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At the same time, we identified certain opportunities for Copernicus uptake, which are not explicitly mentioned but can be inferred from the text:

- Regarding water quality monitoring, it is identified that there is no indication on measures for the investigations of marine phytoplankton, surveying of macrophytes in lakes, biological surveys, assessing the hydromorphological features of rivers and lakes. These examinations can be based on EO data.
- It is mentioned that for the chlorophyll-a concentration, in the absence or replacing in-situ data, the monitoring can be done with remote sensing if sufficient accuracy is attained.
- There is a general remark on water quality monitoring methods that they should not exclusively comply with the standards listed in WFD, but also with other standards ensuring the provision of data of an equivalent scientific quality and comparability. Thus, it is concluded that methods involving Copernicus EO can also be used.
- Unlike the description of water quality measures and standards, there is no elaboration on water quantity monitoring mechanisms. However, it is stated in the WFD that 'control of quantity is an ancillary element in securing good water quality', and measures on quantity should be established. Further, for groundwater quantity status monitoring it is required by WFD to provide maps of groundwater monitoring networks in the river basin management plan. Such actions can be implemented through the use of Copernicus.
- In general, there are no mentions of 'in situ' monitoring or measurement; there are therefore no barriers to the use of EO, which potentially opens ways for Copernicus uptake.
- Among implementation actions, it is required to provide cartographic data for technical adaptations to the Directive.

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Even though some barriers to using Copernicus for WFD implementation exist, these are outweighed by the opportunities. According to the report from the European Environment Agency, the Directive now reports on 111,062 surface water bodies, 46% of which are regularly monitored for the ecological state. 80% of these bodies of water are rivers, 16% are lakes, and 4% are coastal and transitional waters. In the most recent evaluation, 4% (4,442) of water bodies still had unclear ecological state, and 23% of monitoring did not involve in situ water samples to enable ecological status assessment. Individual (mostly biological) evaluation criteria have a substantially higher proportion of water bodies with no observation data; hence, the full extent of monitoring under the WFD is still far from being fulfilled.[9]

Further opportunities for using EO data for WFD implementation were examined in the EOMORES's White Paper.[10] They conclude that water quality indicators obtained from EO data significantly complement the standard sampling, while significantly increasing the spatial and temporal coverage, especially in larger water bodies. Thus, it can improve the classification, the representativeness of the state of water bodies, the standardisation of the assessment, which ultimately leads to a simplification of water management. The White Paper recommends recognising satellite observation data as the assessment method for the purposes of WFD, create an expert group to harmonise metrics, refer to EO data in Reporting Guidance of WFD, and discuss common practice on using such data at the Member States conference.

Environmental Quality Standards Directive (EQSD)

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[9] https://www.eea.europa.eu/publications/state-of-water

[10] https://zenodo.org/record/3556478#.Ye-Lnf4zZPZ

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Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy establishes environmental quality standards for the presence of specific substances or combinations of substances in surface water that have been recognized as priority pollutants due to the severe harm they pose to or via the aquatic ecosystem. The consolidated text of 2013 modified the EQSs for 7 of the initial 33 priority substances to reflect the most recent scientific and technological understanding about the characteristics of those substances.

Our keywords investigation does not find any 'space' words, which can be explained from the Directive predating the operational Copernicus programme. Even though EQSD refers to *sampling* regarding specific substances such as cadmium, lead, mercury and nickel, reading its text we found that it is open for the uptake of Copernicus. This is possible as EQSD frequently asks for monitoring measures. The identified opportunities for Copernicus in EQSD include the following:

- Sediment and biota monitoring should be of adequate frequency and provide sufficient data for reliable long-term analysis.
- Member States were required to establish and submit to the Commission a supplementary monitoring programme and a preliminary programme by 2018[11].
- Member States need to establish maps of emissions, discharges and losses of all priority substances and pollutants, and may provide additional maps that present the chemical status information for one or more substances listed.

[11] This was a 10-year goal under this Directive. The database on monitoring substances under this directive is regularly updated https://echa.europa.eu/environmental-quality-standards

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- It is noted that monitoring should take place every three years, unless technical knowledge and expert judgement justify another interval.
- At the same time, Member States are allowed to be flexible in their monitoring measures but they shall ensure that it is carried out using best available techniques. In this case, (Copernicus) EO providers need to establish themselves as providing the best available technique.
- The Commission itself shall develop guidelines, including technical specifications, with a view to facilitating the monitoring and is invited to promote coordination of such monitoring.

Thus, the EQSD provides an opening for using EO data, giving flexibility in choosing monitoring methods, and emphasising that the best of them shall be used. Based on this we see the possibility of Copernicus implementation for providing data on specific substances in surface waters.

Groundwater Directive (GWD)

Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration establishes a framework that sets groundwater quality standards and implements steps to avoid or restrict pollution inputs into groundwater. GWD defines quality requirements that take into consideration local peculiarities and allows for future enhancements based on monitoring data and new scientific understanding. Thus, it complements WFD so its objectives regarding groundwaters can be achieved more effectively.

Similar to previous directives discussed above, the GWD does not mention any of the 'space' keywords. Again this can be explained through the fact that the GWD was developed before Copernicus became operational. We did identify a potential barrier for EO data uptake,

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which is that the GWD states that when determining background levels, the principles of a simplified approach using a subset of samples should be taken into account. However, certain requirements providing opportunities for Copernicus are definitely present:

- GWD first of all states that 'reliable and comparable methods for groundwater monitoring are an important tool for assessment of groundwater quality and also for choosing the most appropriate measures'.
- there is no mention of the necessity for in situ observations.
- GWD refers to methods provided in WFD (Annex V) to provide a coherent and comprehensive overview of groundwater chemical status and to provide representative monitoring data. As observed above in this section, for groundwater quantity WFD requires mapping of the monitoring network.

Thus, GWD generally does not pose obstacles for the uptake of Copernicus for groundwater monitoring. This conclusion is also supported by the fact that GWD is largely based on WFD concerning monitoring requirements.

Floods Directive (FD)

Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks requires Member States to determine whether all water courses and coast lines are in danger of flooding, to map the flood extent and assets and people at risk in these regions, and to implement effective and coordinated flood risk reduction measures. This Directive also underlines the public's right to obtain this information and have a say in the planning process. Similar to the previous water policies, there are no 'space' words mentioned in FD. It mainly focuses on mapping and flood risk management plans, and does not elaborate on specific monitoring measures.

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This is seen as a significant gap but at the same time we imply from the FD text that Copernicus can be utilised to its full capacity without any barriers. Especially relevant is the public's right to transparent and objective information, which Copernicus can provide. The particular opportunities for Copernicus uptake following from FD are:

- Maps within preliminary flood risk assessment (chapter II FD).
- Flood hazard maps and flood risk maps (chapter III FD).
- Flood risk management plans (chapter IV FD).

Having covered the main legislative documents for inland water management, we move to **other related policies.**

We note that the EU addressed the issue of pollution in the aquatic environment even before the WFD. Such thematic directives include the Urban Waste Water Treatment 91/271/EEC (UWWTD, consolidated in 2014), Nitrates 91/676/EEC (ND, consolidated in 2008), and Industrial Emissions Directive 2010/75/EU (IPPC-IED, consolidated in 2011). As seen from the time of these documents' adoption and later modifications, all except UWWTD, cannot mention Copernicus simply because it was not operational at the time of their development. Still, UWWTD consolidated text does not mention it either. Our keywords search moreover showed that no 'space' indicators are present in these directives. Still, the requirement for monitoring is present.

In UWWTD, the provided methods of monitoring include only sample collections with laboratory examination, which can be considered as a barrier for the Copernicus uptake. However, the directive states that alternative methods may be used if the obtained results are equivalent. Hence, there is an opportunity to use Copernicus as an alternative if it is possible to obtain necessary results, or at least it can be an addition to sampling since

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UWWTD does not provide any limitations on additional measures (in fact, there is no provision mentioning them).

In the ND, the Commission notes that there is a necessity of monitoring waters and applying methods of measurement for nitrogen compounds. Regarding the barriers, ND includes surface and groundwater samplings as one of the methods for such monitoring. However, in general the ND requires Member States to implement suitable monitoring programmes to assess the effectiveness of action programmes provided in the directive. Action programmes at the same time shall take into account available scientific and technical data and environmental conditions in the relevant regions of the Member State concerned. We concluded that there is no regulatory barrier; the ND does not limit the uptake of Copernicus as it recommends the Commision to draw up guidelines for the monitoring, and for Member States, to take additional measures if the methods from ND are not sufficient, also considering their effectiveness and cost in comparison to other possible preventive measures. Hence there are opportunities for the Copernicus use in water nitrates monitoring.

IPPC-IED provides for 'environmental inspection' which includes emissions monitoring. The directive lists certain methods, such as site visits and sampling. Such specific requirements can be seen as Copernicus barriers, however further provisions ensure that opportunities are not limited. Thus, it is permitted to introduce supplementary technical measures ensuring an equivalent level of environmental protection. It also requests to provide measures on the minimisation of long-distance or transboundary pollution, which is also an option for Copernicus uptake. IPPC-IED preamble notes that in accordance with Article 193 TFEU, this Directive does not prevent the Member States from maintaining or introducing more stringent protective measures, which are compatible with the Treaties and the Commission has been notified.

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Attention to water pollution is also paid in the new 'Inland Navigation Action Plan 2021-2027' (NAIADES III), to support a gradual modal shift towards zero emission inland waterways transport (COM/2021/324). It does not contain 'space' key words, however no barriers for Copernicus are created there. In several ways, this Action Plan can open new applications for Copernicus. Thus, it states that there is a need for monitoring and reporting carbon intensity of inland waterway vessels. Furthermore, innovative sector-wide solutions, including monitoring tools, should be implemented in ports. It is also required to use innovative solutions to reduce waterway pollution emissions, which can potentially include monitoring of such pollution with EO.

Next, we take a look at the Bathing Water Directive (BWD, Directive 2006/7/EC concerning the management of bathing water quality and repealing Directive 76/160/EEC, consolidated in 2014). It establishes management measures which include monitoring of bathing water. A keyword search did not show any results for the 'space' indicators. We note BWD is pretty restrictive in formulating the measures for monitoring, mostly focusing on the sampling method. However further reading provides the measures for which Copernicus can be potentially involved. Such opportunity arises due to the provision of BWD stating that the Member States may permit the use of other methods provided the results obtained are equivalent to those provided in BWD (sampling). Analysing the BWD text we identify the following opportunities for the Copernicus uptake:

- BWD requires observation and quality assessment over an extended period, which can be achieved through the Copernicus temporal capabilities.
- All bathing waters shall be identified annually, and they shall be inspected visually for pollution. That can be done through Copernicus spatial capabilities, especially for large water bodies.

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- BWD requires 'appropriate' monitoring of waters with a potential for cyanobacterial proliferation. This is also possible with satellite data.
- Generally, the 'management measures' of bathing waters as described by the directive include, inter alia, assessing water quality, classifying, identifying and assessing causes of pollution, giving information to the public, taking action to prevent bathers' exposure to pollution, and taking action to reduce the risk of pollution. To all these measures we can contribute by increasing Copernicus uptake.

Finally, the most recent of the presented water policies related to the current analysis is Regulation (EU) 2020/741 on minimum requirements for water reuse. It lays down minimum requirements for water quality and monitoring and provisions on risk management. As for the water policies above, no 'space' keywords are present. It obliges to perform routine monitoring to ensure compliance of the reclaimed water with the minimum water quality requirements. As it is natural for water monitoring, this Regulation also requires sampling methods for certain elements. However opportunities for Copernicus can be implied too from the provisions allowing monitoring measures that are additional or stricter to those listed in the regulation, particularly (but not excluding) for heavy metals, pesticides, disinfection by-products, pharmaceuticals, other substances of emerging concern, including micro pollutants and micro plastics, antimicrobial resistance. Further, the Regulation provides for the turbidity continuous monitoring, which can be performed with EO data. There is also an obligation on development of risk management plans, which shall comprise identifying and managing risks in a proactive way. One of their elements shall be identification of the environments and populations at risk, and the exposure routes to the identified potential hazards, taking into account local hydrogeology, topology, soil type and ecology, and factors related to the type of crops and farming and irrigation practices. All these can be achieved through the Copernicus uptake.

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The responsibility for water policy and legislation at EU level rests with the European Commission DG Environment, notably the 2012 'A Water Blueprint' (the blueprint to Safeguard Europe's Water resources - Communication from the Commission (COM(2012)673). Unlike previous policies, the Blueprint does provide that reliance on satellite imagery and derived information could considerably help the Member States to identify irrigated areas. This is the only mention of 'space' key word identified, however, it considerably adds to the understanding that space data use is recognized in water management. The Blueprint confirms that monitoring of the chemical status and pollution of EU waters is not sufficient - not only that not all substances are monitored, but also that the number of monitored water bodies is very limited. It is concluded that this leads to inappropriate decisions, the cost of which is higher than implementing suitable monitoring techniques. This justifies the observations presented above.

2.2.2 EU Sectoral Policies

Agricultural and environmental policies are closely linked to inland water management.

Agriculture

As found in D.1.2, agricultural policies are directly related to inland water management. Agriculture accounts for the largest use of water: around 40 % of the total water used per year in Europe[12]. The 2017 EC Communication "Future of Food and Farming", states that climate-smart farming supported by innovation should be implemented for monitoring in the agriculture domain through developing policy with a strong commitment to delivering public goods and ecosystems services, including for water. Farmers have a dual challenge: producing food while also protecting nature and preserving biodiversity. It is critical for our

[12] EEA article - Water use in Europe – quantity and quality face big challenges (2021) (EEA 2018)

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food production to use natural resources wisely. Thus, water management in agriculture is developing as a critical problem in the context of climate change, and this is something that the new Common Agriculture Policy (CAP) takes into account. The proposal for the new CAP was presented already in 2018 (COM/2018/392), which set fostering sustainable development and efficient management of water as a specific objective to achieve. Particularly for the fruit and vegetable sector, it required actions for improving the use and management of water, including water-saving and drainage. However, 'space' keywords are not present, and water management mechanisms in the agricultural sector are not described in this proposal.

The new CAP was formally adopted on 2 December 2021. The new CAP is due to be implemented from 1 January 2023. The new CAP covers three regulations, which will generally apply from 1 January 2023: EU Regulation 2021/2116, repealing EU Regulation 1306/2013 on the financing, management and monitoring of the CAP; EU Regulation 2021/2115, establishing rules on support for national CAP strategic plans and repealing EU Regulations 1305/2013 on support for rural development and 1307/2013 on rules for direct payments to farmers; EU Regulation 2021/2117, amending EU Regulations 1308/2013 on the common organisation of the agricultural markets, 1151/2012 on quality schemes for agricultural products, 251/2014 on geographical indications for aromatised wine products, and 228/2013 laying down measures for agriculture in the outermost regions of the EU. For the years 2021-22, a transitional regulation (EU Regulation 2020/2220) is in force.

For this research, EU Regulation 2021/2116 shall be considered in the first place. It significantly amended the provisions of the previous version of 2013, explicitly requiring the use of Copernicus, thus giving space solutions in the legislation and providing more opportunities for the Copernicus uptake:

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- The Regulation encourages Member States to use data or information products provided by Copernicus to ensure that comprehensive and comparable data is available for the purposes of monitoring agri-environment-climate policy, including the CAPs.
- As a means for the CAP implementation, the Member States shall develop integrated administration and control systems which shall comprise, inter alia, a geospatial application system and an area monitoring system. 'Area monitoring system' means a procedure of regular and systematic observation, tracking and assessment of agricultural activities and practices on agricultural areas by Copernicus Sentinels satellite data or other data with at least equivalent value.
- The Member States are encouraged to use remote sensing or the area monitoring system or other relevant technologies assisting them to carry out the on-the-spot checks.
- It is further required to supply free of charge the satellite data to those exercising area monitoring. At the same time, the Commission shall remain the owner of the satellite data.
- The Commission shall finance the actions concerning the collection or purchase of data needed to implement and monitor the CAP, including satellite data and remote sensing used to assist in the monitoring of agricultural land use. It is worth noting that this service requires Very High Resolution (VHR) satellite imagery. To implement this, the EC DG JRC issues a framework contract for the purchase of VHR imagery for the CAP on the spot checks Controls with Remote Sensing (CwRS). The most recent tender was published 25 September 2020, with a contract value of EUR 20,500,000 (period of 4 years). The contract was won by a consortium led by European Space Imaging.

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Hence, this horizontal Regulation prescribes legally binding EO methods for monitoring in the agricultural sector, which inherently involves water use, thus covering inland water monitoring by listed methods as well.

The next relevant document is EU Regulation 2021/2115. It establishes guidelines for the forms of interventions that can be used, as well as standard requirements for Member States to follow in order to achieve CAP goals. It establishes regulations for CAP Strategic Plans, as well as provides coordination, governance, monitoring, reporting, and evaluation measures for the period 2023-2027. It also covers maintenance measures for rural areas and landscapes (as from the previous CAP regulations), which is one of the CAP core aims directly related to water management. Analysis of this Regulation shows that no 'space' keywords are mentioned, including Copernicus Services. This is a major gap in this policy, also providing that even though the Regulation sets an objective for the efficient management of water and further lists the necessary measures, they are not precise and do not mention any water monitoring/observation techniques, unlike EU Regulation 2021/2116. Still, the reference is made to this regulation. Furthermore, open formulations in EU Regulation 2021/2115 itself can provide an opportunity for Copernicus. Thus, water management with EO data can be integrated for the implementation of the following requirements:

- Member States are obliged to establish the legal framework for the CAP Strategic Plans in accordance with the principles and requirements set out in this Regulation and in EU Regulation 2021/2116. The latter as described above highly relies on the use of satellite data for monitoring. Furthermore, the CAP Strategic Plans will be assessed on the level of implementation of the acts pursuant to EU Regulation 2021/2116.

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- modernisation of agriculture and rural areas by fostering and sharing of knowledge, innovation and digitalisation in agriculture and rural areas and by encouraging their uptake by farmers, through improved access to research and innovation. Moreover, a result indicator for this objective is the protection of water quality and sustainable water use. For this objective, the Regulation calls for the establishment of the European Innovation Partnership for agricultural productivity and sustainability to stimulate innovation in this realm and encourage its wide use. As the text leaves it unspecified what type of innovation it should be, we imply that space technology is included.
- protection of water in the fruit and vegetable sector, the hops sector, the olive oil and table olives sector, where water management, water-saving, water saving, water conservation and drainage are included among intervention measures. They can be enhanced via Copernicus monitoring.
- The development of innovative products, processes and technologies in the wine sector at any stage of the supply chain

Environment

The most significant in this sector is the European Green Deal (COM/2019/640). it aims to transform the EU into a modern, resource-efficient and competitive economy. There are no 'space' key words in this act, but it does not create barriers for the EO data uptake. Opportunities for Copernicus follow from the objectives of the Green Deal, as well as general description of desired methods for achieving them. Thus, the Green Deal promotes digital technologies used for maximising the impact of policies on climate change and environment, including distance monitoring of water pollution. The given examples are artificial intelligence, 5G, cloud and edge computing and the internet of things. This reads

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as a non-exclusive list thus EO data can be added. The Green Deal mentions also the issue of food production which results in water pollution, which shall be addressed by 'new technologies and scientific discoveries'. This refers to the agricultural sector addressed earlier in this section. To stimulate Copernicus applications fostering the European Green Deal, the Horizon Europe 2021 Space programme includes an Innovation Action call for proposals "EGNSS and Copernicus applications fostering the European Green Deal"[13].

The European Commission unveiled the new Circular Economy Action Plan on March 11, 2020 (COM/2020/98), with the goal of preparing the economy for a green future, increasing competitiveness while conserving the environment. The Plan encourages the Commission to facilitate water reuse and efficiency, including in industrial processes. The core implementation instrument is the Monitoring Framework for the Circular Economy, which should be updated by the Commission. This will rely on European statistics and new indicators for the interconnection of circularity, climate neutrality and the zero pollution ambition. Space applications are not mentioned in the Plan, however this is where Copernicus data can be utilised to enhance circularity measures at multiple levels that are not yet represented in official statistics.[14]

A more specific document in this domain is Directive 92/43/EEC (consolidated in 2013) on the conservation of natural habitats and of wild fauna and flora (Habitats Directive). Water is a natural habitat for many species. The Directive aims to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory. Space technology is not listed in this Directive. At the same time, it asks for the monitoring of the incidental capture and killing of the animal species listed in Annex

[13] Source: EU Portal Funding & Tenders

[14] https://www.copernicus.eu/en/print/pdf/node/8617

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IV (a). Other monitoring requirements are not mentioned, however for the objectives of this Directive, it would be essential to monitor the habitat (water) itself to investigate factors influencing species in there. This creates an opportunity for Copernicus.

In the Biodiversity Strategy for 2030 'Bringing nature back into our lives' (COM/2020/380) no space technology is mentioned. However, it does not pose any barriers for Copernicus. Regarding inland waters and EO, the opportunities are created by requirements for forests monitoring (as they are hugely important for biodiversity, climate and water regulation); restoring free-flow of rivers; monitoring of protected areas; mapping and monitoring of ecosystem services, health or restoration efforts; creation of an EU-wide methodology to map and assess ecosystems.

In 2021, a new Zero Pollution Action Plan for Air, Water and Soil (COM/2021/400) was adopted. It sets the zero pollution vision for 2050 - 'Healthy Planet for All', stating that water pollution shall be reduced to levels no longer considered harmful to health and natural ecosystems. It also encourages taking action under WFD to realise the zero pollution ambition for all aquatic ecosystems. For this aim, the Action Plan asks the Commission to support better monitoring and reducing pollution from key substances in surface and ground waters. This policy document is one of those that explicitly mentions space methods, directly providing opportunities for Copernicus. It acknowledges the potential of innovation and digital solutions in reducing pollution, and therefore declares Copernicus as a major building block for providing monitoring data.

Regarding water pollution, the Strategic Approach to Pharmaceuticals (COM/2019/128) states that implementing innovation in this sector could support "green design", for example for facilitating the recycling of waste water. Pharmaceuticals that spread through water may pose a risk because of their toxicity or similar properties. The opportunity is

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created by the Strategic Approach in the way that it acknowledges a limited scale of monitoring in this domain, and only selected substances are monitored in surface and ground-waters under WFD. Space key words are not present. However, because the gathering and management of environmental data is mostly dependent on Union legislation and/or backed by Union finance, this might indicate a possible application of Copernicus to discover more about pharmaceutical concentrations in the environment, enabling better environmental risk assessments.

2.2.2. International Policies

As we described in D1.2, water is also an important topic for action at the international level, with a number of intergovernmental treaties in place, as well as soft law instruments and guidelines setting targets for water management. International law takes precedence over EU law.[15]

International treaties

Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) of 1992 is a one-of-a-kind international legal instrument and intergovernmental platform that strives to facilitate collaboration in order to guarantee sustainable use of transboundary water resources. It promotes joint management and conservation of freshwater ecosystems in Europe and neighbouring countries. Even though no 'space' indicators are found in the convention as it was written prior to Copernicus, it creates opportunities for the use of EO data by setting an obligation to establish

[15] CJEU Judgement of the Court (Grand Chamber) of 21 December 2011, Air Transport Association of America and Others v Secretary of State for Energy and Climate Change, Case C-366/10, paragraph 50, ECLI:EU:C:2011:864.

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programmes for monitoring the conditions of transboundary waters. Moreover, for monitoring the conditions of transboundary waters, including floods and ice drifts, as well as transboundary impact, joint monitoring programmes shall be implemented within the scope of cooperation. This approach is also in line with the EU Copernicus programme.

Convention on wetlands of international importance especially as waterfowl habitat (Ramsar Convention) of 1971 provides that wetlands are a valuable resource in terms of economic, cultural, scientific, and recreational importance, and their destruction would be irreversible. It does not mention any 'space' or 'monitoring' related keywords. However, indirect opportunities for the Copernicus uptake in wetlands can still be implied. Thus, the Ramsar Convention obliges to precisely describe and delimit on a map wetlands boundaries. Further, Parties are internationally responsible for the management and wise use of migratory stocks of waterfowl, which potentially involves monitoring efforts. Management obligations are also set regarding measures to increase waterfowl populations on appropriate wetlands. On top of this, Parties shall encourage research on wetlands and their flora and fauna. All those obligations can be performed with the use of Copernicus.

Under the Convention on Biological Diversity of 1992, 'biological diversity' means the variability among living organisms from all sources including, inter alia, aquatic ecosystems and the ecological complexes of which they are part, such as diversity within species, between species and of ecosystems. The Convention provides monitoring requirements and does not limit them to sampling methods - along with samples, Parties are also encouraged to use other techniques. Hence, there is an opportunity to implement Copernicus as a technique for monitoring aquatic ecosystems requiring urgent conservation measures and those which offer the greatest potential for sustainable use. Furthermore, it can be used for monitoring the effects of activities that have or are likely to

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have significant adverse impacts on the conservation and sustainable use of biological diversity.

All Parties committed to a worldwide stocktake every five years, beginning in 2023, as part of the Paris Agreement 2015. The goal is to review collective progress toward attaining the purpose of the Agreement and to advise Parties of additional individual activities to be done. The EU Member States, like all other nations that have accepted the Paris Agreement, have committed to making Nationally Determined Contributions to reduce greenhouse gas emissions. These contributions will be evaluated as part of the five-year global stocktake. Copernicus' planned service would provide observation-based data to make global evaluations more complete and uniform. Water monitoring concerns are also covered in the Climate Change Service inside the Copernicus framework. The Paris Agreement provides for monitoring measures, however, there is no mention of water in the treaty. As it is found in D.1.2, many inland water bodies are exposed to strong anthropogenic influences, particularly climate change, hence this might be considered as a gap.

United Nations (UN) Instruments

Unlike international treaties, UN resolutions and guidelines are non-binding. Still, they play a significant role in international order by expressing UN members' views, thus impacting not legally, but politically. Some resolutions also reaffirm norms of international treaties and promote treaty parties' commitment to compliance with their international obligations. Others may be the first step in a process that leads to the signing of a multilateral treaty. Same applies to policies developed by other international organisations. Below we present an overview of major documents regarding inland waters management from the UN, WHO, UNESCO, and the World Bank.

Adopted by the UN General Assembly, the Sendai Framework for Disaster Risk Reduction 2015-2030 sets a goal to prevent new and reduce existing water disaster risk through the

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implementation of a variety of measures, from legal to technological. It balances the use of both in situ and remote sensing information. The Framework references geospatial information technology, space data, space-based technologies and related services for water monitoring. The information from these sources should be disseminated to decision-makers and the general public. According to the framework, these measures should be promoted on both national and global levels. Moreover, through international cooperation, technology transfer should be promoted, and space data should be shared.

UN Environmental Programme (UNEP) Resolution 3/10 'Addressing water pollution to protect and restore water-related ecosystems' of 2018 stresses that monitoring water quality and quantity and sharing data are important for the effective management of water pollution. There is also a concern from the UNEP regarding limited technological capacities available to monitor water pollution. Thus, it encourages setting up water quality monitoring of significant water bodies and associated ecosystems on national levels. Governments and relevant stakeholders are invited to address this issue with tailored technologies. As a result, even if no 'space' keywords are present in the resolution, opportunities for Copernicus can follow from these statements.

The 2030 Agenda for Sustainable Development was adopted by the UN in 2015, setting up 17 global goals serving as a 'blueprint to achieve a better and more sustainable future for all'. It contains a specific goal dedicated to water, namely Goal 6 Clean Water and Sanitation. It provides that protecting and restoring water-related ecosystems is essential, but due to its framework nature leaves it up to states to decide how to reach this goal. The research in this regard shows that satellite data play a significant role in relation to most of the agenda's goals. Copernicus gives an unprecedented amount of data to support policy-makers striving to implement SDGs. Copernicus data is available on a full, free and open basis, thus simplifying monitoring efforts and reducing their costs.[16] Therefore Copernicus can serve as an instrument to take actions in accordance with the Agenda 2030. In Water-ForCE D.1.6

[16] https://www.copernicus.eu/sites/default/files/2018-10/Copernicus_SDG_Report_July2018pdf.pdf

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"Report on links and gaps between satellite EO and water related SDGs and climate indicators" the more detailed analysis on SDGs is provided. Here we note that the goals are not legally binding, however, they have a huge impact on EU strategic development policy, serving as a 'guiding principle'.

Next, the World Health Organisation (WHO), a specialised UN agency, has developed several water management guiding documents. Guidelines for safe recreational water environments 2003 note that recreational uses of inland waters are increasing in many countries worldwide. It specifically provides for the use of satellite imagery for the proactive monitoring of the areas affected by blooms of toxic algae or cyanobacteria. However, this reference is made specifically to marine environments, and there is no such indication for inland waters. This is seen as a disadvantage since the same problem is observed for inland water recreational areas. Enabling this method for monitoring would create an opportunity for Copernicus. Guidelines for the safe use of wastewater, excreta and greywater 2006 have a goal to protect public health and facilitate rational use of wastewater and identify chemicals and pathogens for risk assessment. Space-related keywords are not present, however, the guidelines describe the variety of measures, including monitoring techniques. Hence the potential opportunities for Copernicus uptake can be discovered. Guidelines for sanitation and health 2018 focus on water use and its pollution, encouraging innovation and experimentation accompanied by rigorous monitoring. No reference to space technologies was made there. However, an important remark is made regarding the development of standards and regulations: according to WHO, they should avoid prescribing specific technologies or systems for particular situations, since it can impede innovation. Instead, it is recommended to set out an expected level of performance.

Another UN specialised agency, United Nations Educational, Scientific and Cultural Organisation (UNESCO) established the Intergovernmental Hydrological Programme, which is currently in the ninth phase (IHP-IX) for the period 2022-2029. This new issue, unlike the previous one for 2014-2021 specifically addresses the use of space technologies for water resources management. It is stated that new technologies will benefit many related issues

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such as timely disaster forecasting, the use of cubesats (nanosatellites), groundwater governance, evidence-based planning, conflict resolution and trust building, real-time monitoring, and effective decision support systems. However, UNESCO affirms that there is the difficulty of gathering and comprehending raw data before applying it to a hydrological system in a decision-making context. Thus, the gap between the data and knowledge shall be bridged so it could be applicable for policy makers. As a result, it is recommended to develop techniques that are able to merge different sources of data, including from remote sensing. This provides an opportunity for Copernicus downstream applications.

World Bank

Water management concerns were also addressed by other international organisations impacting policy makers. The World Bank released in 2019 a strategic action plan on water "Working together for a water-secure world". The World Bank has water investments of over $29 billion and a staff of 300 water experts in locations worldwide. Its strategy therefore promotes water stewardship. Actions under this target should include, inter alia, measuring, planning, monitoring water use. Furthermore it encourages to to take action for coping with droughts through drought monitoring and forecasting. Notwithstanding that 'space' keywords are not present, such targets can be achieved in practice with satellite data, including from Copernicus.

2.2.3. Concluding remarks

The analysis in this section selected the most appropriate policies for the current research, and investigated the need for monitoring of specific water-related objects. We found that water is very well represented in EU policy in general, however EO data as a measure of monitoring is present in only a few, even in instruments that came after the Copernicus launch. In EU legislation, policies are interconnected with one contributing and referring to another, with the Water Framework Directive (WFD) as a central part. In other sectors, tightly linked with water use, such as agriculture, new EU policies are developed taking into account availability of satellite imagery which significantly contributes to monitoring efforts.

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The WFD directive will not be revised, leaving it to future instruments to advise on the monitoring techniques. Notably, current water instruments promoting space technology use are mostly non-binding and do not require compliance from governments. In this realm, it is recommended to lay down certain results that must be achieved but leave each Member State free to decide how to transpose directives into national laws. This also will be in line with the recommendations from WHO not to impede innovations by giving strict prescription on monitoring techniques, but set out the desired results. As seen from the analysis above, such an approach allows us to derive the potential applicability of Copernicus to a particular problem even if no 'space' references are made directly.

3. Copernicus Missions

3.1. Introduction

As said above, being able to meet the needs of the water community across the full inland aquatic system[17] requires first and foremost that their requirements are included in past, current and future system designs. In this first section we summarise the current Copernicus Sentinel missions that have a direct or indirect link with water. The second section looks at future / planned missions with a link to water. An overview of the Sentinels and their function/objectives is provided in this document's annexes.

The European Space Agency (ESA) is developing a family of missions called Sentinels specifically for the operational needs of the Copernicus programme. Each Sentinel mission is based on a constellation of two satellites to fulfill revisit and coverage requirements, providing robust datasets for Copernicus Services. These missions carry a range of technologies, such as radar and multi-spectral imaging instruments for land, ocean and

[17] Inland aquatic system in the Water-ForCE taxonomy covers lakes, aquifers and (artificial) reservoirs, rivers, estuaries, coastal (including nearshore), wetlands, groundwater, lagoons

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atmospheric monitoring. Some of them have been already launched into orbit and they are providing useful data to Copernicus programme and global users since 2014:

- Sentinel-1 is an all-weather, day-and-night radar imaging mission for land and ocean services that is supporting several services such as emergency services (floods, earthquakes, etc., marine services (identification of vessels, oil spills, etc.) and others.. Sentinel-1A was launched on 3 April 2014 and Sentinel-1B on 25 April 2016.
- Sentinel-2 is a multispectral high-resolution imaging mission for land monitoring to provide, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 can also deliver information for emergency services. Sentinel-2A was launched on 23 June 2015 and Sentinel-2B followed on 7 March 2017.
- Sentinel-3 is a multi-instrument mission to measure sea-surface topography, sea- and land-surface temperature, ocean colour and land surface reflectance in the visible and near infrared wavelengths. The mission supports ocean forecasting systems, as well as environmental and climate monitoring. Sentinel-3A was launched on 16 February 2016 and Sentinel-3B joined its twin in orbit on 25 April 2018.
- Sentinel-5 Precursor – also known as Sentinel-5P – is the forerunner of Sentinel-5 to provide timely data on a multitude of trace gases and aerosols affecting air quality and climate. It has been developed to reduce data gaps between the Envisat satellite – in particular the Sciamachy instrument – and the launch of Sentinel-5. Sentinel-5P was taken into orbit on 13 October 2017.
- Sentinel-4 is a payload devoted to atmospheric monitoring that will be embarked upon a Meteosat Third Generation-Sounder (MTG-S) satellite in geostationary orbit.
- Sentinel-5 is a payload that will monitor the atmosphere from polar orbit aboard a MetOp Second Generation satellite.
- Sentinel-6 carries a radar altimeter to measure global sea-surface height, primarily for operational oceanography and for climate studies. The first satellite was launched into orbit on 21 November 2020.

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For each Sentinel mission the Mission Requirements Document (MRD) describes all mission specific requirements in detail including also the specific scientific and policy targets for which provide products and envisaged applications. Each Sentinel mission data feeds into one or more (of the six) Copernicus program core services (formerly known as Global Monitoring for Environment and Security - GMES) established by the European Commission. The six thematic streams of Copernicus Services are the following (more details and their links with inland water in section 3 of the current report):

Fig. 3 The six existing Copernicus Core Services

3.2 Current Sentinel Missions sensors and capabilities

Current Copernicus Sentinel missions (S-1/2/3/5P), thanks to their varied and diverse technical payload capabilities and designed constellations offer a huge amount of data to users from Europe and worldwide. Presently, the Sentinel Data Access System numbers more than 380,000 registered users, it has a daily publication rate of over 38,700 products/day, and it has an average daily download volume of 405 TB. A total of 405 million products had been downloaded by users since the start of data access operations, consisting of a total data volume of 240 PB, with 82.8 PB of data being downloaded in 2020 only (cf. Copernicus Sentinel Data Access Annual Report of 2020).

From this huge volume of information and data (from Level 0 to Level 4[18]) delivered by Sentinels, a sizable and increasing number contribute with or without integration with an

[18] **Level-0** data are raw data measured by satellites; **Level -1** data are derived from Level 0 data

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in-situ or modelling component to the production of inland water products focusing on thematic mapping and geo- or biophysical variables. These products are analysed and evaluated in more detail by the other Water-ForCE project work packages., for example work packages 2 and 3 focusing respectively on water quality and water quantity.
In this document we focus on the extent to which missions have been designed with the aquatic system in mind, and for this we use the set of key words developed in D1.2, coming from the European or International inland water sectors or from remote sensing service providers. To establish this, we have conducted a text mining analysis for all the Copernicus Sentinel missions requirements (i.e. MRDs, Mission Requirement Documents) which allowed us to seek for possible references within each of the missions' primary or subsequent objectives. This desk research led us to the identification of the direct links between Copernicus missions, core services and policies focusing on inland water. The assessment started with the elaboration based on various sources of a list of Sentinel missions objectives and measurements capabilities for each mission payload user and sensor system requirements. The compiled list is presented in Annex 3.

In the sections below we present for each current Sentinel mission all the connections between mission objectives, mission requirements, user requirements level and the (inland) water sector which is based on in-depth analysis of the available MRD documentation.

Sentinel-1

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which were processed to values of sensor units, e.g. brightness temperatures, radiances or backscatter ratios; **Level -2** data are derived from Level 1 data that have been processed to geophysical quantities of interest, e.g. wave height, cloud fraction, aerosol optical depth or radiation at the top of atmosphere; **Level -3** data are derived from Level 2 data that have been spatially and/or temporally resampled, e.g. monthly averages on a global 1°x1° lat-lon grid; and **Level-4** further derived products, e.g. climate indices, obtained from analysis of multiple lower-level products.

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The Sentinel-1 imagery is provided by two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather. Main applications are for monitoring sea ice, oil spills, marine winds, waves & currents, land-use change, land deformation among others, and to respond to emergencies such as floods and earthquakes. The identical satellites orbit Earth 180° apart and at an altitude of almost 700 km, offering a global revisit time of 6-12 days depending on the area . Sentinel-1's radar can operate in four acquisition modes, single polarisation (HH or VV) and dual polarisation (HH+HV or VV+VH). The spatial resolution depends on the mode: approx. 5 m x 20 m for IW mode and approx. 20 m x 40 m for EW mode.

Sentinel-1 Mission Requirements Document (MRD) **does not contain** any direct reference to inland water policies. However, the Sentinel-1 constellation, after more than five years spent on the orbit providing global coverage measurements with a revisit period from 6 to 12 days, gives access to petabytes of raw data or imagery (see Sentinel Data Access Statistics) which feeds into Copernicus core services applications or hundreds of research or policy documents and publications focusing on inland water sector/domain. From the primary mission objectives as mentioned in the MRD we identified several objectives as having possible links with the inland water domain:

- Monitoring sea-ice zones with focus on coastal areas and extrapolating to large rivers or lakes.
- Mapping in support of humanitarian aid in crisis or emergency situations which includes flood extent or hazard, coastal areas affected by tsunami, oil spills, cyanobacteria..
- Surveillance of marine environments such as coastal areas navigation corridors, ports (sea but extrapolated to fluvial) management
- Mapping of land surfaces, either speaking about permanent or seldom water bodies, soil moisture (at surface or roots), or farmed land (agriculture).

In order to consult the full list of Sentinels mission objectives and possible measurements capabilities based on each mission payload sensor please refer to Annex 3.

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Sentinel-2

Dedicated to supplying data for several Copernicus Services, Sentinel-2 carries a multispectral imager with a swath of 290 km. The imager provides a versatile set of 13 spectral bands spanning from the visible and near infrared to the shortwave infrared, featuring four spectral bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution.

The Sentinel-2 MRD contains several references to the Water Framework Directive underpinned by the primary objective of the mission to provide satellite data for Copernicus land services. As such, Sentinel-2 will respond to the identified need to assess simple processes and disturbances in vegetation and inland waters which further postulates the desired capability to quantitatively retrieve a set of vegetation, soil and water variables. These variables and products are estimated and compiled at a regional as well as global scale. The document identified two priority main families of products:

- Generic land cover maps (e.g. GLC 3.0 and CORINE 2018).
- Maps of geo-biophysical variables (e.g. turbidity and trophic state index) .

Since then, the Copernicus core services have evolved to cover more and more areas related to the inland water domain. During the policy workshop organised by Water-ForCE project at the end of 2021 in Copenhagen, experts from the six Copernicus Services, policy DGs and ESA presented their activities related to inland water and new derived Sentinels products (Copernicus).

Sentinel-3

Sentinel-3 is a low Earth-orbit moderate size satellite compatible with small launchers including VEGA and ROCKOT. The main objective of the mission is to measure sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. Ocean and Land Colour Instrument (OLCI) provides a set of 21 bands ranging from the visible to the near infrared light (400 nm $< \lambda <$ 1 020 nm). The Sentinel-3 provides imagery in 300 m spatial resolution. Sentinel-3 OLCI instrument ensures continuity of the ENVISAT MERIS.

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The main aim of Sentinel-3 is "*To provide continuity of ENVISAT type measurement capability in Europe to determine sea, ice and land surface topography, sea, ice and land surface temperature, ocean and land surface colour and atmospheric measurements with high availability, high accuracy, with timely delivery and in a sustained operational manner for GMES (Ed. Copernicus) users*".

Sentinel-3 has two primary mission components in support of Copernicus ocean, land, atmospheric, hydrologic and cryospheric applications: i. a topography mission providing altimeter height measurements, ii. an optical mission providing sea, land and ice surface temperature (SLST) and ocean and land colour (OLC) measurements in the visible and infrared region of the electromagnetic spectrum simultaneously and contemporaneous with the topography mission.

Besides the mission components Sentinel-3 has also several mission objectives relevant to inland water and includes measurement which requires a very high level of availability (>95%), high accuracy and reliability and in a sustained operational manner for Copernicus users:

- Primary objectives
    - Provide continuity to ocean measurements (i.e. ENVISAT) Services including: i. ocean, inland sea and coastal zone colour measurements; ii. sea surface temperature measurements; iii. sea surface topography measurements
    - Provide continuity of medium resolution land measurement (i.e. ENVISAT) capability in Europe to determine land-surface temperature and land surface colour
    - Provide, in a NRT operational and timely manner, L1b visible, shortwave and thermal infrared radiances and L2 topography products
    - Provide, in a NRT operational and timely manner, a generalised suite of high-level primary geophysical products. Products shall include as priority: Global coverage Sea Surface Topography (SSH) for ocean and coastal areas, Enhanced resolution SSH products in the Coastal Zones and sea ice regions, Global coverage Sea-Surface (SST) and sea ice surface temperature (IST), Global coverage Ocean Colour and Water Quality products, Global coverage

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Land Ice/Snow Surface Temperature products, Ice products (e.g., ice surface topography, extent, concentration).

- Secondary objectives
  - Provide continuity of medium resolution SPOT Vegetation P-like products by providing similar products over land and ocean (with lower resolution).
  - Provide secondary geophysical products including inland water (lakes and rivers) surface height data.

In line with Sentinel-3's MRD, the mission measurements and products can be used to address user community requirements for all Copernicus Core Services of which some focus on the inland water domain:

- **Maritime Safety and Security**: The European Maritime Safety Agency (EMSA) was set up in 2002 in order to provide technical and scientific assistance to the European Commission and Member States on matters relating to the proper implementation of European Union legislation on maritime safety and pollution by ships. This includes actions aimed at improving safety at sea for oil tankers and passenger ships, as well as bulk carriers, container ships and fishing vessels.

- **Global Land Monitoring Applications**: Since 2018, Sentinel-3 provides global fast daily revisit observation of the land surface. It allows monitoring a series of geo- and biophysical parameters for the continental-scale land cover use and change, from state of vegetation to water quality products, and provides support to Copernicus emergency services. Another application is the monitoring of inland rivers and lake height levels using the advanced altimetry sensor and processing which allows compiling information for hydrological services. Sentinel-3 complements other missions (e.g. SPOT Vegetation, Landsat, and Sentinel-2) which provides higher spatial resolution measurements but with longer revisit times, by having a much higher rate

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for measurements (short revisit time of less than two days for OLCI and less than one day for SLSTR) and enhanced spectral capabilities..

- **Coastal Zone Monitoring**: Sentinel-3 is able to meet the demand for new information on the status of the coastal zone water quality[19] and health. population pressure and EU legislation (e.g. Coastal Zone Management[20] or Marine Strategy Framework Directive[21]). Thus, it identified the specific requirement for environmental monitoring of water quality and phenomena such as harmful algal blooms (HAB) assessment and management. It also allows the investigation of coastal physical processes and their influence to aquaculture, sea-defences, ports and tourism. Despite the capability to monitor the coastal ecosystems due to its daily revisits Sentinel-3 does not yet have the accuracy and resolution to measure, for example, sea surface heights, surface wind and sea state which significantly affects the coastal environment (e.g. storm surge tides, coastal shipping, coastal damage). Maybe with the new generation of Sentinel-3 with the increase in resolution this would be possible.
- **Environmental Policy and Law**: Sentinel-3 mission allows to fulfil several international agreements and conventions on ocean status and regulations. For instance it will contribute to the United Nations Kyoto Protocol, the Framework Climate Convention, the European Water Framework Directive, the Biodiversity Convention, the EU Marine

[19] Sentinel-3 OLCI sensor is not usable in many coastal areas where the geomorphology is too sophisticated (e.g., archipelagos). This is due to the 300 m resolution of the Sentinel-3 data. However, the CMEMS coastal service products are based on the integration between Sentinel-2 and not only Sentinel-3.

[20] EC, 2002, (2002/413/EC) Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe

[21] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)

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Strategy, the soil thematic Strategy which stipulates or formulates the obligativity to monitor and manage the exploitation of the marine, coastal and land environments.

- **Support to European Security, Humanitarian and Emergency Services**: Sentinel-3 products are not the best fit for the rapid-task, high spatial ground resolution (<10 m) and temporal (hours) resolutions typically required for these services (e.g., floods, forest fires, earthquakes, humanitarian aid in emergencies). However, they provide a baseline wall-to-wall mapping capability at reduced resolution (0.3-1 km) prior to and following emergencies that are used in support of emergency services.

The bullet list above is a snapshot or time slice of services intended to be developed using Sentinel-3, aligned with the mission objectives as extracted from the MRD document which was reviewed and accepted during early 2011. However, since then, Sentinel-3 has entered into the operational phase and the constellation of two-satellites provides daily data to remote sensing data repositories.. In the section below focusing on services, we present for each Copernicus Core Service in particular, what are the main service products and applications that are related to inland water as presented by Copernicus Services experts during the Policy Workshop in Copenhagen at the end of 2021.

Existing R&D applications

A recent evaluation of the main activities, applications and products related to inland water by the Commission's Copernicus Services were presented during the Water-ForCE project workshop "Copernicus water component evolution – policy expert" held in Copenhagen, October 2021. These presentations are referenced in the Copernicus Services section below and as well as in other complementary projects deliverables, such as D1.6. Moreover, during the same workshop, experts from Commission policy DGs (AGRI, ENV, JRC, MARE, RTD) and EEA presented their latest activities focusing on remote sensing or in-situ components of their inland water related work with impact to current or future policies. In an extensive presentation ESA also introduced their main R&D activities on water for science and applications.

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3.3 Sentinel Copernicus Expansion Missions (SCEM) sensors and capabilities

The Sentinel Copernicus Expansion Missions represent a step forward towards a more progressive improvement of the current measurement capabilities and sensors, mostly by delivering a new generation of payload technology adding to the one that is currently deployed in orbit. The design of these new missions is backed by strong user needs and requirements linked with Europe's major policies addressing the current societal and environmental challenges. The Sentinel Expansion marks also a strategic shift in policy making using EO, migrating from research and knowledge missions to monitoring and operationalisation. This process is achieved by either leveraging the current Sentinel Missions experience and portfolio or by finding a better fit for new opportunities and innovation coming from vertical markets such as agriculture, fisheries, water resource management, etc. with the existing policies.

The Sentinel Copernicus Expansion Missions also represents the prioritisation of the European Commission Space Programme by adding new EO capabilities in order to respond to the current emerging user needs in terms of research and policy. As such, the Commission has defined the following three general priorities for the 2021-2027 policy cycle, inland water being embedded in priorities 2 and 3:

- Priority 1:
  - o Greenhouse gas monitoring, specifically on anthropogenic CO_2 emissions for which currently no European satellite observations are available
- Priority 2:
  - o Monitoring Polar regions, specifically concerning polar/Arctic observations, namely sea ice (floating ice) concentration and surface elevation.
  - o **Monitoring Agriculture, specifically on parameters which potentially could be addressed through thermal infrared and hyperspectral observations.**
- Priority 3:

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o **Mining, biodiversity, soil moisture and other parameters, requiring observations in additional bands (not available in the 2021-2027 timeframe and perhaps even not for another decade).**

Sentinel-8 Land Surface Temperature Monitoring (LSTM)

LSTM is a next generation ESA mission within the Copernicus program to complement Sentinel observation capabilities with high spatio-temporal resolution TIR (Thermal Infrared) observations over land and coastal regions in support of agriculture management services, and possibly a range of additional applications and services related to inland water. In particular, there will be direct synergies with the Sentinel-1, Sentinel-2 and Sentinel-3 missions. Sentinel-1 and -2 provides estimates of crop types and standing biomass, which together with vegetation stress information derived by the new mission can be used to predict crop yield ("crop per drop"). The biophysical parameters derived from Sentinel-2 will be important for complementing the thermal observations for monitoring of agricultural productivity and modelling water use and water stress.

LSTM will operate from a low-Earth, polar orbit, to map both land-surface temperature and rates of evapotranspiration with unprecedented field-scale detail. It will be able to identify the temperatures of individual fields and image the Earth every three days at 50 m resolution. This is about 400 times more detail than is currently acquired from space. Its observations will cover a wide temperature range, from approx. -20°C to +30°C, with very high precision (0.3°C).

The Sentinel-8 mission would deploy one or more satellites with TIR instruments optimised to support agriculture management (including irrigation, water stress, water use) services with the specific mission objectives below. The mission objectives are also directly linked with policies and downstream services (see Annex 4) and they are as follows:

- Primary objective: to enable monitoring evapotranspiration (ET) rate at European field scale by capturing the variability of Land Surface Temperature (LST) (and hence ET) allowing more robust estimates of field-scale water productivity.

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- Complementary objective: to support the mapping and monitoring of a range of additional services benefiting from TIR observations - in particular soil composition, urban heat islands, coastal zone management and High-Temperature Events (HTE),

Both the primary and complementary objective require observations of LST and emissivity (essential for derivation of LST). In the case of soil composition mapping, estimates of emissivity are the main observational requirements. The requirements of the primary mission objective are considered as mission drivers while the complementary objectives shall be supported as long as they do not constrain the primary ones.

In Annex 4 it is presented in the context of inland water sector a comprehensive assessment of EU and International policies, directives, conventions and initiatives linked with Sentinel-8 mission requirements (users, users needs, key requirements, EO products requirements) and EO downstream services classified using the European Association of Remote Sensing Companies (EARSC) thematic taxonomy of Earth observation products.

Sentinel-9 Copernicus polaR Ice and Snow Topography Altimeter (CRISTAL)

The Sentinel-9 mission has two specific primary objectives, namely, i. to measure and monitor the variability of Arctic and Southern Ocean sea-ice thickness and its snow depth, and. ii. to measure and monitor the surface elevation and changes therein of polar glaciers, ice caps and the Antarctic and Greenland ice sheets. The latter has an impact on climate change and adaptation policies since the two ice sheets of Antarctica and Greenland store a major amount of freshwater resources which are important for their contributions to the sea level rise and coastal area as well as to the evaluation of water resources.. Similarly, for Sentinel-9 there are also three secondary objectives, namely, i. to contribute to the observation of global ocean topography as a continuum up to the polar seas, ii. to support applications related to coastal and inland waters, and, iii. to support applications related to snow cover and permafrost. The secondary objective mentions as being within the scope of the mission the hydrological research which is based on the observation of water level in coastal areas as well as along rivers and lakes. The hydrological research based on Sentinel-9 products will provide important information about the freshwater supply existing in rivers

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and lakes which is intended for human use or agriculture, but also it will contribute to the knowledge about natural water cycle and ecosystems. The monitoring of global river discharge and its long-term trend contributes to the evaluation of global freshwater flux, which is critical for understanding the mechanism of global climate change. Moreover, the mission will be able to forecast the evolution and organisation of alternative modes of transport in the Arctics () but also during seasonal freeze on rivers and lakes elsewhere in the world. The third objective is focusing on another important hydrological research key parameter, which is the snowmelt timing with direct impact to the seasonal river discharge knowledge. Also, Sentinel-9 will survey the surface state change in permafrost regions with a special interest for ground thawing and its seasonal evolution which plays an important role on the human activities and infrastructures.

The European Commission has initiated the Copernicus Polar Expert Group which has the mandate to capture the EO needs for data and value-added services related to the polar regions instrumental for setting up an operational Copernicus Polar Observing System. These needs will lead to new products and services (based on satellite and in-situ components) of the existing Sentinel missions but also targeting the leverage of the six future Sentinel Copernicus Expansion Missions which are currently under development and implementation by ESA. In 2021, the Copernicus Polar Expert Group published its latest report[22] focusing on the user requirements for a Copernicus polar observing system with the expected outcome to accelerate towards operational services and products. These requirements were made available and are part of the assessment of all users requirements which defined the Copernicus Expansion Missions primary and secondary objectives. For instance the summary table from Annex 3 of the report indicates several geophysical

[22] Nordbeck O., Duchossois G., Kohlhammer G., Andersson E., Diehl T., Dinessen F., Eriksson P., Flett D., Garric G., Gros J-C., Jacq F., Molch K., Nagler T., Nicolas J, Strobl P. (2021) User Requirements for a Copernicus Polar Observing System– Phase 3 Report - Towards Operational Products and Services.

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variables needs to be taken into account for further surveying leading to new products and services with relevance to inland water domain, such as:

- for land surface and surface freshwater
    - soil moisture
    - lake ice extent
    - lake water level
    - land surface temperature
    - seasonal subsidence
- for emergency management
    - flood extent
- for security
    - vessel detection service
    - oil spill detection
    - enriched feature service (eg: fish farms, debris,..)

In the annex of the report, there are documented for each of the geophysical variables which products exist or are necessary, which space sensors are involved, possible synergies between sensors, what are the surveying gaps and the integration with in-situ observation and instruments. This specific document serves as an important example for setting up thematic sectors services based on specific user needs and transposed to space mission requirements while having in the background the link with major policies and research objectives.

Sentinel-10 Copernicus Hyperspectral Imaging Mission for the Environment (CHIME)

The Main Mission Objective of the Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) is: "To provide routine hyperspectral observations through the Copernicus Programme in support of EU- and related policies for the management of natural resources, assets and benefits. This unique visible-to-shortwave infra-red spectroscopy based observational capability will in particular support new and enhanced services for food security, agriculture and raw materials. This includes sustainable

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agricultural and biodiversity management, soil properties characterisation, sustainable mining practices and environmental preservation."

The prime objective of this mission is therefore to provide routine hyperspectral observations through the Copernicus Programme in support of EU- and related policies for the management of natural resources, assets and benefits. This unique visible-to shortwave infrared spectroscopy based observational capability will in particular support new and enhanced services for food security, agriculture and raw materials. Three core products are planned to be delivered to the user community, i.e. Level-1B Top of Atmosphere (ToA) radiances in sensor geometry, Level-1C ToA reflectances in cartographic geometry and Level-2A surface reflectances.

The CHIME's optical hyperspectral remote sensing sensor covers a broad spectral domain and has a high resolution ground sampling capabilities which leads to its potential to deliver significant enhancement in quantitative value-added products related to onshore and offshore water, ice and snow. This will support the generation of a wide variety of new products and services in the domain of agriculture, food security, raw materials, soils, biodiversity, environmental degradation and hazards, **inland and coastal waters**, and forestry. These are relevant to various EU policy needs which are not currently met or improve their implementation and operationalisation, as well as contributing to new applications and services developed by the private space downstream sector. In Annex 5 there are presented the Sentinel-10 (CHIME) links with EU and international policies and treaties relevant to the inland and coastal water sector.

Sentinel-11 Copernicus Imaging Microwave Radiometer (CIMR)

The Sentinel-11 CIMR mission is designed to observe a wide range of floating sea ice parameters, in particular sea ice concentration, and serve operational systems day and night. This mission continues with improved capabilities the previous missions monitoring floating sea ice parameters. These improvements are notably in terms of spatial resolution (~5 km), temporal resolution (sub-daily) and geophysical accuracy. Moreover, some

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additional measurements such as the Sea Surface Temperature and other parameters having global coverage with focus in the polar regions are part of the mission's primary or secondary objectives. The mission concentrates on the Polar areas with sub-daily revisit without any observational gaps while at global scale it needs to reach more than 95% coverage with daily revisit rate. The observational capability of CIMR allows it to satisfy the primary and secondary mission objectives as mentioned below and furthermore contribute to the inland water sector policy development and operationalisation.

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The primary objectives of the Sentinel-11 (CIMR) mission are the following: i. measure Sea Ice Concentration (SIC) and Sea Ice Extent (SIE), ii. measure Sea Surface Temperature (SST), iii. ensure European operational continuity of L-band (e.g. SMOS/SMAP) and enhanced AMSR type capability in synergy with other missions (e.g. MetOp-SG(B)) to enhance monitoring of the Polar Regions and Adjacent Seas.

A set of secondary objectives for the CIMR mission were identified. These objectives are not the main drivers behind the development of the mission system design, but they would allow to collect a series of observations and measurements such as:

- Sea Surface Temperature (SST) with daily coverage of the global ocean and inland seas.
- Thin Sea Ice (<0.5 m depth) with daily coverage of the marginal ice zone in the Polar Regions and Adjacent Seas.
- Sea Ice Drift with daily coverage in the Polar Regions and Adjacent Seas,
- Ice type/Stage of development in combination with other satellite data including scatterometer and SAR measurements with daily coverage in the Polar Regions and Adjacent Seas
- Snow depth on sea ice with daily coverage in the Polar Regions and Adjacent Seas
- Terrestrial Total Snow Area with daily coverage in the Polar Regions,
- Terrestrial Snow Water Equivalent (SWE) with daily coverage in the Polar Regions

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- Sea Ice Surface Temperature (SIST) in combination with other satellite data including thermal infrared imagery in the Polar Regions and Adjacent Seas
- Sea Surface Salinity (SSS) over the global ocean over monthly time-scales measure wind speed over ocean, soil moisture, land surface temperature, cloud liquid water over ocean, precipitation over ocean, terrestrial surface water extent and vegetation indices.

The sum of these objectives will allow the development of products and service applications linked with EU policy such as Water Framework Directive (e.g. water rights management, water pricing, ground water abstraction limits, protection of inland and coastal water surfaces) or International agenda related to water such as UN Sustainable Development Goals (SDG 6.4, which focuses on water use efficiency and management, or sustainable agricultural production). In Annex it is presented a complete list of policies and EU directed to which the future CIMR mission will have an impact or be linked with.

Sentinel-12 Radar Observing System for Europe - L-Band SAR (ROSE-L)

The Sentinel-12 Radar Observing System for Europe - L-Band SAR (ROSE-L) mission has the role to fill several important observation gaps in the current Copernicus missions and support key EU policy objectives by providing an enhanced continuity (to Sentinel-1's C-band) for a number of Copernicus Services and down-stream commercial and institutional uses. ROSE-L having a longer wavelength, namely the L-Band SAR sensor, allows it to penetrate clouds or thick vegetation cover and provide vital additional information to the existing services and applications or lead to the development of new ones.

The ROSE-L mission is foreseen to have a major contribution to the following economical and societal challenges,, related or linked with water policy or which can contribute to the defining of the future Copernicus service for inland water sector:

- The safety of European citizens by greatly extending the monitoring of geohazards linked with surface motion such as landslides, subsidence and earthquake/volcanic

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phenomena into vegetated areas which are inaccessible to current Copernicus satellites and will be critical to the nascent European Ground Motion Service (EUGMS);

- The European Arctic policy and the sustainable economic development of the Arctic region by providing new information sea ice types and detection of icebergs critical to safe navigation and building of infrastructure in Arctic areas;
- Forestry and maintaining biodiversity through the continuous high-resolution monitoring of changes in global forest carbon stocks and their spatial distribution;
- Agriculture and food security by providing reliable high-resolution soil moisture information to support improved management of water use, enhances weather independent land cover and crop information, feeding meteorological and hydrological forecast models;
- EU Water Framework Directive through mapping of water availability and water use in particular for agriculture
- Climate change policy through the enhanced monitoring of glaciers and ice sheets, forest carbon stocks and changes with time and water availability;
- The European Union Integrated Maritime Policy by extending the capacity to monitor the marine and coastal ecosystem and by increasing the maritime and coastal surveillance abilities.

In the ROSE-L MRD document the following primary objectives are mentioned as summarised:

- Filling critical information gaps in the monitoring of European and Global geohazards by extending ground motion information to vegetated areas and improving flood mapping especially below vegetation;
- Enhanced monitoring of Land use, Land Use Change, Forestry and Agriculture, improving mapping leveraging on the high sensitivity of L-band SAR to vegetation characteristics and status;

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- Enabling high-resolution monitoring of soil moisture below the vegetation canopy over most vegetated land cover types and throughout the growing season;
- Enhanced monitoring of the Arctic and Cryosphere through improved sea ice mapping, iceberg detection, extending the monitoring of glaciers and ice caps and addressing the information gaps in Snow Water Content (SWE).
- Improved maritime Surveillance through complementary and more frequent information and enhanced information on sea state, surface wind and swell.

This mission design responds also to a series of requirements expressed by both the Copernicus Land Monitoring and the Emergency Management services. Some of the targets are: soil moisture, land cover mapping, crop type and status discrimination, forest type/forest cover (in support to biomass estimation), food security and precision farming, maritime surveillance and natural and anthropogenic hazards. In addition, the mission will contribute to the operational monitoring of sea ice and land ice or complement the European maritime (including coastal regions) situational awareness.

The mission also will have several key technical and operational capabilities based on the requirements derived from users needs, such as:

- support repeat-pass interferometry
- 10 minutes data latency is required to support maritime surveillance in European coastal waters..
- 200 minutes data latency between acquisition and availability of Level-1b data. (if the envisaged applications are other than maritime surveillance in coastal waters mentioned above.
- mission has the global observation capability and it will support systematic acquisitions
- repeat coverage is less than 1 x day (Arctic), 3 days (Europe) and 6 days (Global)

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- mission and payload support resolutions equal to or higher than 50 m^2 (e.g. 5 x 10m or similar) which is essential for the observation at field level for soil moisture, high resolution ice velocity mapping, or ship and iceberg detection.

Based on all the above the Sentinel-12 ROSE-L mission system design fits with the scale and objectives of the inland water sector adding to and leveraging the Sentinel-1 C-band mission.

3.4 Main Findings about Sentinel Missions

In the following paragraphs we summarise the main findings from the overall analysis of Sentinel missions. The following statements are inferred, by collecting the references to water related policies within the text, followed by the actual text analysis and summarising the findings:

- Sentinel-2 is a land sensor that was not designed for water applications. It has too low sensitivity for aquatic targets and lacks spectral bands that are needed for many water products. OLCI on Sentinel-3 has the spectral bands and sensitivity, but has far too coarse spatial resolution for most lakes and nearly all rivers. Thus, the inland and coastal water quality part of the services has to deal with sub-optimal sensors. It is envisaged that Sentinel-2E and onward will have better sensitivity and more spectral bands, but there is no expectation to launch a ESA-Sentinel satellite dedicated for inland and coastal water quality monitoring before 2035.
- The early missions relevant to the water sector (Sentinel-1/2/3) were defined to set up several EO products and services beyond the research and development stage, namely contributing to the establishment of the Copernicus Programme core Services. The main contribution of Copernicus Services enabled by the EO capabilities of the initial Sentinel mission was foreseen to have mainly an important role in the EU policy making process. Consequently, the Sentinel missions were and are contributing in supporting several inland water sector policies, most often related to assessments about water quality and water quantity, water use, water

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management, waterways transport or security, emergency and surveillance. The current technology state-of-the-art and the existing products and services focusing on the inland water sector (e.g., EARSC library of products and services, some focusing on water; e-Shape pilots focusing on water) demonstrate that Sentinel missions derived products and applications are viable for the implementation of policies as such having a bigger role beyond only providing science based policy support, for example to.the operationalisation for the current water policies.

- After the analysis of all Sentinel missions MRDs, it seems that the Sentinel missions are capable of servicing the water sector, though some gaps were identified, either arising due to spatial or temporal resolution limitation of the sensors or the underpinned Copernicus core services (i.e.. some Copernicus products are updated at large intervals of time and by the moment of release they might be already obsolete). The overall Copernicus programme capabilities will be enhanced and improved with the new generation of Sentinels (e.g. Sentinel-1C/1D, Sentinel-2c/2D) as well as with the launch of the new SCEMs which are designed to service the water sector by covering some of the existing gaps on top of providing continuity and operability to the current services. For instance, the hyperspectral, etc. mission CHIME (Copernicus Hyperspectral Imaging Mission) will provide better information (spectra) for water use or water quality, the land surface temperature mission LSTM (Land Surface Temperature Monitoring) will provide a level of information unmet before about water availability, while the SAR L-band mission ROSE-L (Radar Observing System for Europe - L-Band) will complement the existing C-band mission and provide accurate identification unobstructed by cloud or thick vegetation cover of water bodies or estimations of water levels at surface or close to surface (soil moisture).
- The SCEMs seems in general better connected (based on MRDs user requirements and mission system design, Annex 4-6) with the current European Commission water sector policies and regulations. Moreover, the new enhancements to current Sentinel capabilities and the SCEMs can contribute to other EU policies,

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international agreements and conventions, for example, climate adaptation and mitigation, biodiversity, sustainable development, or environment (see Annexes 4-6)..

- In addition to becoming the source for the service evolution and enhanced continuity by meeting instrumental and operational gaps, the SCEMs are designed to be more efficient in meeting the current policy needs and operationalisation. In general they are a better fit for the Copernicus' Services Evolution end-users requirements..
- For the early Sentinels in general the focus was on ocean and marine, with the CMEMS services focusing only recently on the coastal zone (only added a few years ago), as such their applicability in not yet fully understood for the inland water bodies (like lakes, rivers, lagoons, wetlands, etc.) or the water cycle. This, and in correlation with the complexities to survey smaller water bodies (e.g., governance, funding, methodological heterogeneity) led to slower uptake or product development of Copernicus applications focusing on smaller footprint inland water bodies, and the policy makers or public authorities relied mostly on the in-situ and ground measurements. In the past few years the focus on inland water EO services has increased, and new products and tools such as Global Surface Water Explorer[23]are developed and used in the policy and public authorities domain. The Copernicus land service incorporates several inland water products (reflectance, turbidity and trophic state index) useful for water quality and quantity which are operational for the European territory. However, the uptake is still low (the cause was mentioned above). Some of the inland water users' needs might be satisfied by the sensor capabilities of the next generation of Copernicus Sentinel Missions and the SCEMs but the sector is still missing a dedicated Sentinel mission. GALENE was proposed as a potential EarthExplorer with the launch horizon for 2032, but it was not selected. It takes at least 10 years for an EarthExplorer to prove itself and fund a

[23] https://global-surface-water.appspot.com/

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Sentinel mission based on it. Which means that Europe might not have a Sentinel mission dedicated to inland water before 2040, to say the least.

- In general there is a significant increase in spatial, spectral and temporal resolution for the Copernicus new generation of Sentinel Missions and SCEMs which seems to meet preferentially the EU and public users needs. Even so, there is still a gap for all Sentinel missions that despite the fact it prevails in providing continuous observations with fair resolution, revisit and latency, it can not compete with commercial satellite constellations. For instance Sentinel-10 CHIME is competitive in terms of spectral with any existing commercial providers but the focus and product thresholds are still concentrating for larger area size with medium coverage and observation repeat cycle.
- Low responsiveness which sometimes is so critical for emergency events and in general for (near real time) monitoring is an issue in general, as there is no tasking for Copernicus Sentinels. The Copernicus Contributing Missions are filling this gap (as well as the other gaps), but these missions are commercial and due to the high costs of acquisition the data is available only to few services (e.g., Copernicus Security, EMS or for the CAP monitoring).
- In terms of latency (i.e. period between acquisition and availability of Level 1 data) there are improvements which tend to satisfy the collected user needs, with Sentinel-12 ROSE-L having specified in the mission system requirements, a latency of 10 minutes for the marine surveillance or critical emergency service and 200 minutes elsewhere.
- In general, the Sentinel missions capability to supply long time series, the high signal to noise ratio and the broad spectral domain (e.g. presence of the SWIR bands) proves to be extremely useful for measuring geophysical variables (e.g. water turbidity) or establishing baseline assessments.
- The text mining analysis showed that some missions MRD documentation contains generic references to inland water with few keywords hits specific to the domain terminology, such as lake, rivers, reservoir, aquaculture, fisheries; others, like

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Sentinel-3 which seems to focus the most from all of them and the new generation of Sentinels MRDs, return more specific results and keywords hits focusing on inland water ecosystems and topics.. In 2018, ESA initiated an architecture design study to prepare the development of the next generation of the optical component of Sentinel 2 (i.e. Multi Spectral Imager (MSI), and Sentinel 3 with Ocean and Land Colour Imager (OLCI) and Sea and Land Surface Temperature Radiometer (SLSTR)) (Löscher et. al., 2020[24]). The study aims to take into consideration specific user needs addressing mainly the Copernicus Marine and Land services in order to design the next generation of the Copernicus Space Component optical imaging missions with a time horizon of 2032. However, despite the good fit of Sentinel-3 (and Sentinel-3C/D) or future SCEMs such as Sentinel 8 (LSTM) and Sentinel-10 (CHIME) for responding to some of the inland water sector issues, the Copernicus Program is still going to miss a Sentinel mission dedicated to inland water for the following decades (i.e., GALENE failure as Earth Explorer). In this light, it is not clear how the user needs coming from inland water are going to be addressed by the Copernicus Space Component.

4. Copernicus Services

Having looked at the space infrastructure, the next step is to look at the existing Copernicus Services, and the extent to which they provide (inland) water-related information. In this chapter we describe in what way the current Copernicus core services address water-related issues. A planned development is to set up thematic hubs that cut across different services and section 3.2 describes what is currently known about these hubs and in what way a thematic hub could be established.

[24] Armin Löscher, Philippe Martimort, Simon Jutz, Ferran Gascon, Craig Donlon, Ilias Manolis, and Umberto Del Bello. 2020. *The ESA Sentinel Next-Generation Land & Ocean Optical Imaging Architectural Study, an Overview*

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4.1 Copernicus Core Services

The EU legislation establishing the Copernicus Programme summarises the service component as follows: "delivers standardised data and information to its users, supplied on a long term and sustainable basis through a set of services, provided by companies or public entities, funded by the Commission. The information can be used by end-users for a wide range of applications in a variety of areas such as sustainable development and nature protection, regional and local planning, agriculture, forestry, fisheries, health, civil protection, infrastructure, transport and tourism". Specifically, the Regulation foresees the service component delivering "information in the following areas: atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security". These "areas" are what are now the six core services, which makes it clear that "water" is not a separate service[25]. The question to answer therefore is the extent to which "water", in this context meaning the inland aquatic system, is specifically addressed in the existing services.

Some of these questions have been answered by the "Copernicus water component evolution – policy expert" workshop organised by Water-ForCE project in Copenhagen (October 2021), where several Copernicus Services representatives provided insightful information about their main activities, services and products related to inland water. This information together with the Water-ForCE experts' views are compiled and presented in the following sections for each of the Copernicus Services individually.

Copernicus Land Monitoring Service (CLMS)

[25] The Horizon 2020 call LC-SPACE-24-EO-2020 specifies that: *"The main goal is to analyse current and planned EO space capacities together with innovative processing, modelling and computing techniques to reinforce the existing portfolio offered under Copernicus and to propose an integrated approach for a coherent and consistent inland water monitoring system."*

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The CLMS service is divided into three components, the Global component (managed by the DG Joint Research Centre - JRC), the Pan European component, and the Local component (managed by the European Environmental Agency - EEA). Its aim is to provide geographical information updated on a regular basis about land cover, land use, land use/change, state of the vegetation or water cycle. The main use of the service is for agriculture or food security, water management, and forest management.

The CLMS is the only Copernicus service that has defined an inland water theme within their services. As such, CLMS's Global component collects under a water theme a set of active operational products (gridded or non-gridded) at different ground resolutions (from coarse to high). These products are meant to monitor bio-geophysical variables at global scale and provide valuable information about the Earth's water cycle. The following products are offered under the water CLMS Global component theme:

- the water surface temperature and water quality (turbidity, trophic state) of medium and large-sized lakes.
- the surface extent covered by water on a permanent basis like lakes, with a seasonal frequency like backwater ponds, or occasional occurrence such as from severe floods.
- the water bodies.
- the water level of lakes and rivers.

Furthermore, the CLMS products are useful for hydrological modelling (which is subject to current project work package 5) as well as short- and medium-term meteorological forecasting by providing accurate estimations about the water and heat exchanges between land and atmosphere.

During the WaterForCE workshop (20-21 October 2021) held in Copenhagen the CLMS represented by both managing institutions, DG JRC and EEA, presented the view of the service about the main areas of interest, user needs and products or applications which concentrate on the inland water sector and water cycle.

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CLMS has in its product portfolio a **water bodies** product which has global coverage has a 100 m resolution and it is updated on a 10-days cycle. Another important water (bodies) application developed by CLMS is the **Global Surface Water Explorer** (GSWE) which was jointly developed by DG JRC, UN Environment and Google. The application is a virtual time machine that maps the location and temporal distribution of water surfaces at the global scale over the past 3.7 decades, and provides statistics on their extent and change. It provides better informed water-management decision-making and contributes to SDG 6.6.1 (namely "Change in the extent of water-related ecosystems over time"). The GSWE is developed for the global scale, it shows the evolution of water bodies for the past 37 years sample yearly, it combines Landsat-7/8 with Sentinel-1/2 data. In the near future the GSWE will be included in the operational portfolio of water bodies products.

CLMS is also providing a **lake surface water temperature** product with global coverage, for every 10-days and with 1 km resolution. The product currently monitors between 1000 to 2000 lakes and it is foreseen to grow to more than 4000 lakes with the help of Sentinel-3 Copernicus mission.

CLMS portfolio also accommodates several products and applications focusing on water quality. The **lake water quality** products monitor more than 4000 lakes (currently numbering 4264[26]) and they have an important contribution to SDG 6.6.1 by delivering annual information to UNEP on water quality. Currently there are two variants delivered: i. first, with global coverage with 300 m resolution and 10-day repeat cycle based on Sentinel-3 mission OLCI sensor, ii. second, with a higher resolution of 100 m and the same 10-day repeat cycle based on Sentinel-2 mission MSI data and it incorporates ***lake surface reflectance***, ***turbidity***, and ***trophic state index*** for more than 2000 lakes from Europe and Africa. Further improvements in terms of uncertainty, quality flagging or to enlarge for the

[26] *However, in order to put it in perspective: in the world there are roughly 117M lakes, or, the Caspian Sea and the next ten largest lakes contains about 60% of the total lakes volume*

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assessment of ***Chlorophyll-a***[27] or ***Cyanobacteria*** and further integration with additional in-situ data.

CLMS also developed a free and easy to use online data platform, namely the **Freshwater Ecosystem Explorer**. This application delivers accurate high-resolution geospatial data focusing on the extent of freshwater ecosystems and their change over time. The Explorer contributes to SDG 6.3.2 indicator, "Proportion of bodies of water with good ambient water quality". It contains information for roughly 4300 large lakes and it has 300 m resolution. It compares the difference between a 5-year baseline (2006-2010) with recent annual changes (2017/2018/2019) and it is updated on a yearly basis. The product allows performing advanced analysis such as water quality monitoring for turbidity or trophic states.

CLMS also delivers a **lake and river water level** product which is recognised as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS). The product is computed as a time series over lakes and rivers and besides the 11300+ stations it includes also the so called Virtual Stations (248 operational) which are measurement points upraised at the intersections of the river network with the satellite ground tracks. The water level altimetric monitoring is conducted only for rivers (basins) which are wider than 300 m (12 rivers) and lakes larger than 500 km^2 (156 lakes). It uses Sentinel-3 A&B, Jason-2 and Jason-3, and SRAL missions data; in the future Sentinel-6 data will be incorporated. The main application domains are climatological studies at basin, continental or global scales, hydrological modelling and water resource management and its main users are water management authorities and research institutions.

[27] *CLMS is not yet providing a Chlorophyll-a product directly despite the fact that Chlorophyll-a is used already in order to calculate the trophic state index which is a CLMS product.*

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CLMS intends to increase the size and quality of their portfolio by adding future products and further integration with in-situ data or between data and products (migration toward indicators). For instance CLMS will add in the near future a product concentrating on wetland monitoring in response to the accelerated rhythm of these ecosystems shrinking which is approximated to be three times faster than the rate of forest loss in the world. The land monitoring service also delivers a series of water related products such as snow water equivalent, snow cover content, lake ice extent, soil water index or surface soil moisture which contributes to other sectors beyond inland water such as agriculture or emergency.

The CLMS service evolution is concentrating on two directions, providing an enhanced continuation and continuously improving the service. The continuation of the service is conditioned by Copernicus long term commitment to maintain current products and accelerate users uptake. The enhancement is materialised by keeping state-of-the-art development level and product improvement determined by the availability of new sensors, data and algorithms. The service improvement is dependent on the introduction of new products aimed at the operationalisation of scientific research and development and as mentioned above is correlated with the development of new integrated applications and tools such as dashboards for analysis, modelling and other decision making and knowledge making purposes. GSWE and FEE explorers are very good examples where the improvement of the service should aim for.

CLMS provides support to the Water Framework Directive and Zero Pollution Strategy by delivering accurate information about water pollution, water abstraction, hydrological pressure and water bodies physical changes. As such, EEA is responsible for maintaining up to date all this information on the ecological status of waterbodies. The EU-hydro new reference water product developed by EEA (covers 39 countries in Europe - EE39) is a Copernicus enhancement of the in-situ River Network Database. It contains a photo-interpreted river network and it is already publicly available though not yet validated. CLMS delivers also pan-European surface water management products such as high-

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resolution level of wetness and water, riparian zones mapping, or the EU Digital Elevation Model and Urban Atlas Building Blocks for Height for the EU-Hydro model. Finally, the land service delivers biophysical variables contributing to high-resolution snow and ice products, including snow cover duration or aggregated river and lake ice extent, or a dashboard for the comparison between Copernicus Global Water Level product and local gauge network data.

Another area of interest is the CLMS contribution to CAP. The production of regular and seasonal agricultural maps using Sentinel missions enables the provision of independent and objective estimates of the extent of land cultivation which can be used to support efforts to ensure food security or farmers' subventions under EU's CAP (N.A. the **'checks by monitoring**' were introduced as of 2018).

Copernicus Emergency Management Service (CEMS)

The Copernicus Emergency Management Service (CEMS) provides all actors involved in the management of natural disasters, man-made emergency situations, and humanitarian crises with timely and accurate geo-spatial information derived from satellite remote sensing and completed by available in situ or open data sources. CEMS consists of two components, a mapping component, and an early warning component, which are operational since 2012. The main responsible of managing the emergency service is DG JRC which also ensures its further evolution (e.g. mode improvements, new products).

CEMS delivers a series of on-demand mapping products which allows authorised users to request based on their needs specific products. As such, CEMS provides within a short time from the occurring event (from hours to a few days) the service of rapid mapping which aima to support the critical decision involved in the emergency response. Also, CEMS provides risk and recovery mapping products which are delivered within a few weeks from the requesting moment and they are relevant for the risk prevention and recovery efforts.

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The on demand water related products are flood extent and impact maps, historical flood delineation and tsunami risk assessment.

In Europe, CEMS uses an extensive amount of in-situ data coming from data collection centres involved in the early warning and monitoring for the water sector. CEMS service is retrieving data from 68 hydrological and 22 meteorological data providers which are delivering information collected from 3503 hydrological and 44641 meteorological stations. Information like river discharge and water level, or precipitation, temperature, solar radiation, vapour pressure, wind speed and other variables are retrieved either in near real time or as historical data in order to produce daily grids data contributing to water products such as hydrological time series or the European Observational Grids (EMO-5, 5 km resolution).

CEMS has set up two early warning and monitoring floods services, namely the European and Global Flood Awareness Systems (EFAS and GloFAS). These services are contributing to: i. provide users with complementary, added value flood forecasts (probabilistic, medium range, river basin wide), ii. support the preparedness for floods at EU level (and global) by providing the ERCC and the national hydro met services with an overview of ongoing and forecasted floods, and iii. serves as a knowledge exchange platform for operational flood forecasting. EFAS and GloFAS deliver the following water related products: medium range probabilistic flood forecasts; post processed bias corrected forecasts; flash flood indicators with a lead time up to 3 days & radar based flash flood now casting; EFAS Flood & Flash Flood Notifications to all partners at river basin level; monitoring of national flood alert exceedances; soil moisture, snow maps, anomalies; hydrological seasonal outlook; and, impact forecasts and pre tasking of Copernicus EMS rapid mapping. All these products are delivered as archived outputs on the C3S (i.e. Copernicus Climate Change Service) Climate Data Store. CEMS also delivers a hydrological model, namely LISFLOOD, which is developed internally by JRC and represents a spatially distributed rainfall-runoff model. It is being used for calculating flood forecasts/hindcasts, hydrological droughts, hydrological climate projections, water resources modelling.

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For emergency management, CEMS also developed a Global automatic satellite-based flood monitoring system (GFM) which is integrated into EFAS and GloFAS websites. It is based on Sentinel-1 data which enables unobstructed all weather flood monitoring with a high spatial resolution of 20 m. The latency is very low, within less than 8 hours between sensing and product delivery and it has a high revisit frequency, for Europe between 1 to 3 days and for the rest of the world between 3 to 14 days. The service is operational from October 2021. The CEMS's GFM product has the following layers of information: observed flood event, observed water extent, reference water mask, exclusion mask, uncertainty values, affected population, affected land cover.

The following planned developments and upgrades underpinned by the Copernicus Evolution for the EFAS and GloFAS systems are foreseen:

1. Increase spatial resolution with an implementation timeline for 2022. For Europe: from 5 x 5 km to 1 arcmin (~1.8 x 1.8 km pixel size) resolution using WGS 84 projection system ---~2.8 fold increase in resolution with ~ 7.7 fold increase in pixels. For Global : from 0.1 degree to 3 arcmin 5.4 x 5.4 km pixel size) resolution
2. Continues advances of the hydrological model with the: improvement of the physical processes in the proprietary hydrological model, assimilation of satellite based data (e.g. lakes & reservoir, soil moisture) into the hydrological model, and the use of machine learning within the hydrological modelling framework.
3. Coastal flood forecast component based on the previous research done at the JRC over the past couple of years. Presently is at a proof of concept for implementation stage with the foreseen implementation timeline for 2023/2024.
4. Global Flood Monitoring Integration of Sentinel 1C data by re-processing the entire Sentinel 1 data archive for all GFM layers which may start as early as 2023.

Other emergency management services set up by CEMS are the European and Global Drought Observatories (EDO and GDO). They provide continuous monitoring, forecasting of key drought and heat indicators across Europe and the World and they are serving the EU's

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Emergency Response Coordination Centre (ERCC) as well as other international stakeholders. It is based on the integration of various methods to create one drought indicator and contains also an historic reference database of drought events. The following water related datasets are available within the two services: Standardised Precipitation Index (SPI), Low Flow Indicator (LISFLOOD derived), Soil Moisture Anomaly (LISFLOOD derived), and GRACE Total Water Storage Anomaly.

The CEMS Copernicus Evolution is foreseen to see developments and rely on several actions, such as:

I. Collection of user feedback standard/continuous and tailored)
II. CEMS components internal innovation and research (JRC and Validation) then expressed in new call for tenders
III. Close interaction between CEMS components (e.g. pretasking RM VAL EFAS, risk modelling RRM VAL EFFIS)
IV. Close interaction with Copernicus Services to maximise synergies (e.g. C3S, Land, Security, CMEMS, CAMS, In Situ)
V. International collaboration: GEO, CEOS, UN agencies and programmes (FAO, WMO, World Bank, WFP), IWG SEM and the International Charter Space and Major Disasters
VI. Establishing close links to relevant research programs at European and national level (H2020 e.g. G3P, ECFAS, WaterforCE Horizon Europe)

The CEMS component evolution is also concentrating on: i. incorporation of more data from new satellites and in situ sensors (e.g. integration of meteo /hydro observations in CEMS EW&M, exploration of social media data), ii. improving models through new algorithms or methods (e.g. model upgrades for EFAS & GloFAS, optimised AOI delineation tool), iii. deliver new products , e.g RM First Estimate product, RRM 20 Standard products), and iv. implementation of efficient data processing, visualisation and access (link to DIAS, C3S CDS, RRM Standard & Flex example: Activation map viewer, CEMS EW&M archive in Copernicus Data Services).

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Copernicus Climate Change Service (C3S)

The C3S mission is to support adaptation and mitigation policies of the European Union by providing consistent and authoritative information about climate change. The Copernicus service offers free and open access to climate data and tools based on the best available science.

C3S offers a number of essential climate variables about the ocean and land in coordination with other services and organisations, such as:

- for ocean, variables on sea surface temperature, sea level, sea ice, ocean colour in coordination with ESA-Climate Change Initiative (CCI)/Eumetsat OSI-SAF
- for land hydrology and cryosphere, variable on lakes, glaciers, ice sheets and ice shelves, soil moisture in coordination with ESA-CCI, GloboLakes, Arc-Lake, HydroWeb

C3S has the important role of providing a series of maps without gaps containing information about precipitation, surface air relative humidity, soil moisture or surface air temperature (i.e. related to evapotranspiration) which are paramount to the other services products deliveries. For instance C3S delivers products like, ERA 5 with global coverage and 31 km ground resolution which provides daily updates with 5 days latency and historical data from 1979 onwards, ERA 5-Land with global coverage and dynamic downscale of resolution to 9 km updated with 2-3 months latency and available from 1981 to now, European and Arctic re-analysis, namely the CERRA with 5.5 resolution and respectively CARRA for two AoIs with 2.5 km resolution.

C3S also delivers seasonal predictions and distributes forecast and hindcast data which are freely available for use and download from C3S servers., or new climate projection data and operating capability in the Climate Data Store (CDS), and it has made available to its users a Quality Assurance framework and a set of value adding tools and applications that transpose the climate data to actionable information and knowledge.

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One of the most important services related to water which is managed by C3S will be the **SIS: European Water Service**[28]. The Service aims to help a broad range of water managers for water allocation, flood management, ecological status and industrial water use, with information about climate change in water related variables or hydrological seasonal forecasts. SIS It offers the following products and applications: i. ensembles of hydrological impact models (data available in the CDS-Catalogue), ii. applications built with the CDS-Toolbox to explore the data, iii. practical showcases on how to use the service, iv. user guidance on the data and related activities for the **operational use in the water sector**.

C3S also made available within the CDS an interactive data applications for climate and hydrology modelling results providing hydrological-water quantity impact model ensembles, such as:

- E-HYPEcatch which has as units of assessments catchment polygons and uses a multi-model system based on perturbed calibration parameters from which one is the standard operational model and other seven are perturbed parameter models
- EHYPEgrid which relies on the EFAS drainage network and has a grid resolution of 5 km, and
- VIC-WUR is set up by Wageningen Universiteit from the Netherlands and relies on the same EFAS drainage network leading to the same 5 km resolution grid.

C3S also delivers a global hydrological prediction, the eoFlow Suite, which relies on a complex integration of the initial conditions climate data from ERA 5-Land and the forecast and hindcast climate data from SEAS5. The product is downscaled and bias corrected with 4 hydrological models and 10 output variables (e.g. temperature, precipitation, potential and total evapotranspiration, runoff, soil water, snow water equivalent and snow melt). The final

[28] *The system is currently not accessible on C3s. On C3S page it is specified that "The development of the current operational climate service for water management is based on the experience from two previous proof-of-concepts (PoCs) called SWICCA and EDgE and will also be aligned with the hydrological model system of the Copernicus Emergency Management Service (CEMS). The service is only using data from the Climate Data Store and the operational system runs entirely in the ECMWF technical environment, although developed and maintained by the contractor SMHI."*

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discharge output is uploaded to the CDS portal after quality control checks have been performed.

Copernicus Marine Environment Monitoring Service (CMEMS)

CMEMS provides regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas. The service also contributes to the protection and the sustainable management of living marine resources in particular for aquaculture, sustainable fisheries management or regional fishery organisations. It also provides important physical and marine biogeochemical components useful for water quality monitoring and pollution control.

CMEMS provides support to several important policies related to the water sector, such as WFD, MSFD, MSP, Green Deal or Bathing Directive by supplying within its catalogues a series of water quality variables and products. For instance the ocean colour information which is used to derive chlorophyll-a or phytoplankton biomass and is crucial for water quality monitoring was incorporated since 2019 into CMEMS catalogue. The ocean colour information allows monitoring and understanding of the marine food chain, the global carbon cycle, and eutrophication (run-away blooms caused by pollution and nutrient run-off that can leave zones nearly lifeless). Based on user requests, CMEMS is expanding its catalogue to include ocean colour products based on Sentinel-2 satellite data, in order to improve the resolution of water quality variables such as total suspended matter and turbidity which they already produced with the help of Sentinel-3. The high-resolution data of ocean colour from CMEMS catalogue is essential for the management and operationalisation of water policies, such as WFD or MSFD. CMEMS is also providing information which contributes directly to the implementation of the Bathing Water Directive by delivering variables and products like sea hydrodynamics, wave forecasting

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models, sea surface temperature or cyanobacteria leading to further assessment[29] of harmful algae or bacteria monitoring.

CMEMS lists on its website a series of services mapping sectoral impacts (environmental and and socio-economic impacts) to the so-called blue markets. Some of these markets are linked or related to downstream coastal zones applications and ecosystems, such as the support to policies, public health & recreation, hazards & safety, coastal services, marine food, conservation & biodiversity, etc.. CMEMS recently published a report which concentrates on Copernicus Marine coastal services use cases. For its coastal users, CMEMS is offering a series of satellite variables (waves, sea level, sea surface temperature, winds, ocean colour, sea-ice), in-situ observations (coastal buoys, tide gauges, HFR, biogeochemical data), (3D) models (tides, waves, biogeochemistry, currents), and boundary conditions for coastal models (past-present-forecast).

In December 2018 CMEMS delivered the Copernicus Coastal Roadmap which conveys a number of guidelines for the coordinated actions underpinned by the two services (land and marine) in Copernicus programme and (mainly) Copernicus evolution (2.0). The guideline recommends among others to improve the service by offering to its users important information and products on the characterisation of coastal zones, modelling and forecasting of the coastal zone, river monitoring and forecasting, climate change and coastal vulnerability. It aims also to offer solutions for the longer perspective on coastal zones via:

- coupling with coastal models by further integration of the interfaces between marine and land Copernicus Services and downstream systems through interaction and co-production with Member States

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[29] *Sentinel-3 data is used to separate cyanobacteria from "normal" phytoplankton growth. However, Sentinel-3 is not able to separate between different types of cyanobacteria blooms (some are toxic), and the bloom can be identified only after it is already strong, Sentinel- 2 does not have the proper spectral bands to identify cyanobacteria.*

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- focus on hydrology/rivers in order to monitor or forecast the major EU rivers by the production of validated river discharges for freshwater input, nutrient loading, particulate and dissolved matter; this is a horizontal action between multiple Copernicus Services, marine, land, emergency and climate.
- long term evolution of the land cover and land use monitoring system towards the Copernicus land service's EAGLE data model (EIONET Action Group on Land monitoring in Europe) and enrichment with key ecosystem variables
- long term evolution of the coastal zones: seasonal to long-term projections of the state of the coastal ocean (e.g. sea level), an interaction between marine and climate Copernicus Services
- further integration to DIAS by offering harmonised access to Sentinel and Copernicus service data and online processing capabilities for coastal applications

CMEMS objectives for Copernicus 2.0 (between 2021 and 2027) are to provide continuity and enhancements its services focusing on Blue Ocean (e.g., currents, temperature, waves, sea level), White Ocean (e.g., ice coverage, velocity, concentration, icebergs) and Green Ocean (e.g., CO2, nutrients, oxygen, primary production) but also a series of major improvements and applications for some of its vertical markets such as coastal zone, arctic, marine biology, ocean climate and digital services. One of the important evolutions is the integration of WEkEO services in the Marine services, a service desk under a common portal populated with viewers and application, and the implementation of user support. The "Evolution of Copernicus Marine for coastal zones" report published late 2018 is an intended map for improving CMEMS offer for coastal zone monitoring and forecasting focusing on the user and policy needs and as well as the synergy with other Copernicus Services and EMODnet.

The Copernicus (2.0) marine service sees a further expansion to the coastal zone and users aiming to co-design and co-produce information between the service and Member States, through the following concrete actions:

1. New satellite products (e.g. time evolving bathymetry, turbidity, waves, winds, marine debris).

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2. Full coupling between Copernicus Marine & a series of coastal models operated by MS:
3. Provision of standardised modelled river discharges (freshwater, nutrients, particulate and dissolved matter) (links with EFAS/EMS)
4. Integration in Copernicus Marine portfolio of coastal model derived information

Under Copernicus (2.0), CMEMS intends to establish the **Copernicus Coastal Thematic Hub (CCTH;** see more in the *Copernicus Thematic Hubs* section below**)** by identifying and concentrating on the implementation of the synergies and the interface harmonisation between different Copernicus Services.. The CCTH will be led by Member States ministries (MOi), together with EEA, JRC, ECMWF and coordinated within several Copernicus Services (marine, land, emergency and climate change). The CCTH will use the WEkEO/DIAS infrastructure in order to develop a one-stop coastal portal with a central service desk and an integrated catalogue including products from Copernicus Services, Sentinel data and possibly other providers such as EMODnet. Depending on the decision of the EC to start the implementation of the Copernicus Coastal Thematic Hub, a proof of concept for the Copernicus Coastal Thematic Hub can start as soon as 2022 based on the close interaction with the other Copernicus Services.

Another important step in the evolution of the CMEMS for coastal users is to initiate (depending as well on the EC decision to go forward) the implementation Coastal Marine Extensions in Copernicus 2.0, as follows:

- Discussion with member states on first priorities (national marine stakeholder forum) (2021/2022)
- Start the implementation of new “core” European coastal satellite products (from 2022)
- Start the implementation of improvements of interfaces between Copernicus Marine Service models and coastal systems operated by member states (from 2022)

Copernicus Service for Security

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The Copernicus service for Security applications aims to support European Union policies by providing information in response to Europe's security challenges. It improves crisis prevention, preparedness and response in three key areas: i. border surveillance, ii. maritime surveillance, and iii. support to EU External Action.

From the three components of the Copernicus Security Service one seems to be most relevant and linked to the inland water sector, namely the Copernicus Maritime Surveillance (CMS) Service. The CMS provides Earth Observation products (satellite images and value adding products) to support a better understanding and improved monitoring of activities at sea, within a wide range of operational functions such as maritime safety and security, fisheries control, customs, law enforcement, marine environment pollution monitoring, and others. CMS is Implemented by EMSA - European Maritime Safety Agency, under a Delegation Agreement signed with the European Commission.

In 2021 a new Contribution Agreement with the Commission (DG-DEFIS) was signed, extending the Copernicus Maritime Surveillance activities until 2027. EMSA, as the entrusted entity for this service, will continue to provide satellite images to support a better understanding and improved monitoring of human activities at sea. EMSA is responsible for implementing all related technical and operational work on behalf of the European Commission. Services cover the fields of fisheries control, law enforcement, maritime safety and security, law enforcement, customs, and marine environment, including pollution monitoring. The main value-added products currently being offered to CMS users include: vessel detection, feature detection, activity detection, oil spill detection, and wind and wave information. Also, there are made available the so-called fusion products like oil spill notifications and correlation with vessel reporting.

Another EMSA service besides CMS is also CleanSeaNet, which is the near real time European satellite based oil spill monitoring and vessel detection service, set up and operated since April 2007. It analyses satellite images, mainly from Synthetic Aperture

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Radar (SAR) but also from optical missions, to detect possible oil on the sea surface, identify potential polluters and monitor the spread of oil during maritime emergencies.

Currently EMSA is using passive (optical) and active (SAR) sensor data. EMSA has access to 14 optical satellites which enables the target or activity identification based on a wealth of data in different spectral bands, with very high ground sample resolution (VHR, from 0.3m to 10m) and in near real time (low latency, within 30 minutes after the satellite pass). EMSA also is using 6 SAR satellites which are being used for vessel detection or oil spill, day and night in quasi real time (20 minutes after satellite pass).
Due to its top capabilities, EMSA's EO services are able to identify non-reporting or non-cooperative targets (i.e., dark vessels). This done via:

- Vessel detections derived from SAR and Optical images are correlated with vessel traffic information
- Using EMSA systems, the user will have an overview of which vessels are reporting and which are not.

The most common user needs and applications for the CMS are:

- Wide area surveillance using SAR
- High resolution optical imagery to support specific operations and
- monitoring of ports and shores
- EO information combined with a range of other maritime data
- Vessel detection services for the detection of non reporting vessels
- Vessel identification

An example of successful use of CMS is the request for tasked acquisition of VHR optical image from European Fisheries Control Agency which was met within 2 ½ hrs from initiation. The service delivered very useful information, such as, the detection of the vessel of interest, the detection of features (in this case fish cage) and the monitoring of towing operations which stipulates that only one fish cage is allowed. Another success story is the

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monitoring of two vessels associated with illegal transhipment in the Suez bay, which lead to a large seizure of drugs (> 1 ton of heroin).

In terms of new satellite-based technologies EMSA will assess how optical satellite data from medium resolution sensors (e.g., Sentinel-2) can be systematically used to detect, characterise, and quantify the volume of any spilled oil. EMSA will also keep track of developments in the field of satellite-based marine litter monitoring, with specific emphasis on plastics. With the aim of increasing its existing portfolio of satellite-based capabilities, EMSA will implement proofs of concept for new Earth Observation sensors (e.g., ICEYE, Capella, etc.) and, if deemed appropriate, organise the transition of these new capabilities to operations. EMSA will also assess the maturity, relevance and reliability of new radiofrequency detection satellites in the context of maritime surveillance activities, particularly in support of maritime safety, maritime security, law enforcement and fisheries control. In addition, EMSA will assess new radar and optical satellite constellations, particularly those concerning rapid tasking and very high-resolution optical capabilities with the perspective to phase these into operational service.

Another area of improvement which is very specific and important for the operation and responsiveness of the service is the adoption of disruptive technologies such as Artificial Intelligence (AI) or Automation. Currently, EMSA has finalised the process of data preparation/annotation by compiling a large training dataset from EMSA EO archive. The next step is the procurement for the development of machine learning algorithms, starting with vessel detection and vessel classification. In the long term, EMSA is planning to centralise and automate the generation of added value products using AI, and develop predictive intelligence that will allow it to analyse data and build models to predict future patterns and outcomes.

Copernicus in-situ component (EEA)

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The Copernicus Services rely on many environmental measurements collected by data providers external to Copernicus, from ground-based, sea-borne or air-borne monitoring systems, as well as geospatial reference or ancillary data, collectively referred to as "in situ" data. The Copernicus in situ component maps the landscape of in situ data availability, identifies data access gaps or bottlenecks, supports the provision of cross-cutting data and manages partnerships with data providers to improve access and use conditions.

Copernicus in-situ is managed by EEA and has the following role:

- Determine state of play. Maintain an overview of Copernicus' in-situ data requirements, use, and challenges.
- Provide access to data. Establish, maintain, and improve operational provision of selected in-situ data in accordance with the Entrusted Entities' needs.
- Engage with data providers. Engage and create partnership and other agreements with in-situ data providers, networks, and organisations to improve in situ data access and use conditions in accordance with Copernicus' needs
- Provide support and advice. Provide support to and advise the European Commission and Copernicus Entrusted Entities regarding Copernicus in-situ data activities.

The water quality products supplied by Copernicus Services (see all the above) relies on in-situ data and the following requirement for the component were identified:

- Optical data such as lake water reflectances and Inherent Optical Properties (needed for calibrating and validating the atmospheric correction algorithm(s) and optical processes in the water (absorption and scattering). This data is needed for both algorithm development and algorithm validation
- Water constituents data relevant for calibrating the in water algorithms as well as validating the derived in water parameters (turbidity, trophic state (chlorophyll a), suspended sediment concentrations, cyanobacteria, CDOM, DOC, SPIM, SPOM and others.

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Recently, October 2021, EEA's in-situ component service released a report focusing on the lake water quality in-situ data requirements and availability. The report has the following components: i. key data centre for in-situ data, ii. inherent optical properties required for development of satellite EO water quality products, iii. water quality data required for calibration/validation (cal-val) of satellite EO water quality products, and iv. citizen science data that has the potential to support cal-val of satellite EO water quality products. The following key messages are coming from this report:

- Compiling detailed guidance (user manuals and standard operating procedures) on the design of in-situ sampling programmes and sampling protocols to enhance match up with satellite overpasses;
- Reviewing and cataloguing (affordable) portable sensors that can deliver high quality hyperspectral IOP data to increase in-situ data availability;
- Reviewing and cataloguing (affordable) portable sensors that can deliver high quality water quality data (especially chlorophyll a, cyanobacteria and c-DOM) for increasing in-situ data availability for these parameters;
- Document case study examples on the use of sensors on fixed monitoring buoys (e.g. GLEON) or sensors combined with targeted citizen science to demonstrate innovation in delivering matched satellite and in-situ datasets.
- Work to support initiatives such as GEO AquaWatch and the Water-ForCE Project to support further enhancement of in-situ data collection and availability for the development of the Copernicus Inland Water Services;
- Work alongside GLEON network to provide a more transparent catalogue of in situ data available on key water quality parameters (turbidity, chl a, etc.);
- Collaborate with UN GEMS/Water and LIMNADES to further promote and support the data integration and connection to additional in-situ databases;
- Organise workshop(s) with specific providers of monitoring data in order to align measurements to be better suited for purpose for EO validation (at least in terms of metadata);

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- Further support or elaborate case studies where CS data could be used to support calibration or validation of satellite EO data products.

Besides the water quality recommendations and requirement the Copernicus in-situ components identified several additional actions focusing on water quantity:

- Improving Copernicus wide access to GRDC data
- Collating information on in situ inflow data to coastal zones
- Assessment of in situ soil moisture data for suitability for satellite data validation and calibration;
- Assessment of river level monitoring networks required for satellite river level products.

4.2 Copernicus Thematic Hubs

Why a Water Hub under Copernicus? The Copernicus Regulation [377/2014] states that "the evolution of the Copernicus space component should be based on an analysis of options to meet evolving user needs". It is therefore essential to create a network and governance bringing together the needs of the water community in such a way that a roadmap can be developed as input to the Copernicus evolution programmes (of which the current project is the first step).

A relevant development for the water sector and linked to Copernicus Services is the development of the concept for the **Copernicus Thematic Hubs (CTH)**; in the section from above focusing on CMEMS we covered the establishment of the CCTH. The CTH is an initiative to regroup under one single entry point information generated by several Copernicus Services for a given high level topic. In order to reach a rich and operational level of integration it is important to implement for the CTHs the following:

- Collect and maintain in a single catalogue the relevant products and information
- Harmonise these inputs and provide to users guidance and support with the help of the contributing Copernicus Services.

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Provisions are that each Copernicus service should lead two Copernicus Thematic Hubs. Besides the CCTH presented in the section above, Copernicus Atmosphere Monitoring Service (CAMS) tentatively indicated their topics of interest and selected "health" and "CO2 & Paris Agreement" for implementation. An important aspect of the concept will be engaging with the specific user communities and increasing their uptake of Copernicus data and products and services. All thematic hubs will start with a 1-year proof-of-concept phase. A diagram of the concept has been forwarded by CAMS within a presentation from 2021 and entitled "Copernicus Thematic Hubs & Data Platforms". This diagram is presented in Annex 7.

The establishment of the CCTH by CMEMS in collaboration with several other Copernicus Services and implemented by EU institutions in close collaboration with Member States national authorities is a very good opportunity for other high level topics (or sectors) to emerge in response to their fragmentation and scattered presence within the Copernicus programme. The establishment of a **Water Copernicus Thematic Hub,** based on the CCTH analogue, could represent a viable solution for the inland water sector to crystallise under the Copernicus programme. Based on an internal communication within the Water-ForCE project, one of the experts from Sinergise provided a response which corroborates with the CCTH establishment, on the practical steps for hosting a WCTH embedded or under WEkEO.

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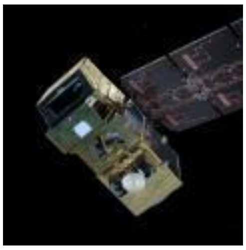
Annex 1: Sentinel Missions relevant to inland water domain

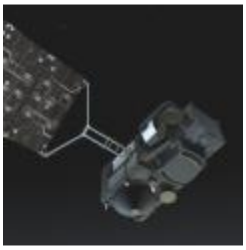
Sentinel-1

With the objectives of Land and Ocean monitoring, Sentinel-1 will be composed of two polar-orbiting satellites operating day and night, and will perform Radar imaging, enabling them to acquire imagery regardless of the weather. The first Sentinel-1 satellite was launched in April 2014. The number of Sentinel-1 user level data published since the start of operations reached ~6,000,000, and the volume of downloads made since the start of operations reached ~90 PiB.



Sentinel-2

The objective of Sentinel-2 is land monitoring, and the mission will be composed of two polar-orbiting satellites providing high-resolution optical imagery. Vegetation, soil and coastal areas are among the monitoring objectives. The first Sentinel-2 satellite was launched in June 2015.



Sentinel-3

The primary objective of Sentinel-3 is marine observation, and it will study sea-surface topography, sea and land surface temperature, ocean and land colour. Composed of three satellites, the mission's primary instrument is a radar altimeter, but the polar-orbiting satellites will carry multiple instruments, including optical imagers.

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Annex 2: Sentinel Copernicus Expansion Missions relevant to inland water domain

Mission	Description
Sentinel-8 LSTM: Copernicus Land Surface Temperature Monitoring	The mission would respond to priority requirements of the agricultural user community, for improving sustainable agricultural productivity at field-scale in a world of increasing water scarcity and variability. It would carry a high spatial-temporal resolution thermal infrared sensor to provide observations of land-surface temperature. Such measurements and derived evapotranspiration are key variables to understand and respond to climate variability, manage water resources for agricultural production, predict droughts and also to address land degradation, natural hazards such as fires and volcanoes, coastal and inland water management as well as urban heat island issues. Read: LSTM Mission Requirements Document
Sentinel-9 CRISTAL: Copernicus Polar Ice and Snow Topography Altimeter	The mission would contribute to a better understanding of climate processes, with its dual-frequency radar altimeter and microwave radiometer to measure and monitor sea-ice thickness and overlying snow depth. It would also measure and monitor changes in the height of ice sheets and glaciers worldwide, while measurements of sea-ice thickness would support maritime operations in polar oceans and, in the longer term, would help in the planning of activities in the polar regions. Read: CRISTAL Mission Requirements Document

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Sentinel-10 CHIME: Copernicus Hyperspectral Imaging Mission	Complementing Copernicus Sentinel-2 for applications such as land-cover mapping, it would carry a unique visible to shortwave infrared spectrometer, providing routine hyperspectral observations to support new and enhanced services for sustainable agricultural and biodiversity management, as well as soil property characterisation. Read: CHIME Mission Requirements Document
Sentinel-11 CIMR: Copernicus Imaging Microwave Radiometer	Responding to high-priority requirements from key Arctic user communities, the mission would carry a wide-swath conically-scanning multi-frequency microwave radiometer, to provide observations of sea-surface temperature, sea-ice concentration and sea-surface salinity, while uniquely also observing a wide range of other sea-ice parameters. Read: CIMR Mission Requirements Document
Sentinel-12 ROSE-L: L-band Synthetic Aperture Radar	The mission would provide additional information that cannot be gathered by the Copernicus Sentinel-1 C-band radar mission, since it would carry an L-band SAR, whose longer L-band signal can penetrate through many natural materials such as vegetation, dry snow and ice. It would be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security. Read: ROSE-L Mission Requirements Document

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Annex 3 Sentinel Missions & Sentinel Copernicus Expansion Missions Objectives and Possible Measurements Capabilities

Sentinel Missions

Sentinel-1	**Sentinel-2**	**Sentinel-3**
Primary mission objectives	***Primary mission objectives***	***Primary mission objectives***
Glacier cover	Biomass	Aerosol Optical Depth
Glacier motion	Fraction of Absorbed PAR (FAPAR)	Aerosol column burden
Glacier topography	Fraction of vegetated land	Biomass
Ice sheet topography	Land cover	Cloud cover
Land surface topography	Leaf Area Index (LAI)	Cloud top height
Sea-ice cover	Normalised Difference Vegetation Index (NDVI)	Colour Dissolved Organic Matter (CDOM)
Sea-ice type	Vegetation type	Earth surface albedo
		Fraction of Absorbed PAR (FAPAR)
		Leaf Area Index (LAI)
		Normalised Difference Vegetation Index (NDVI)
		Ocean Diffuse Attenuation Coefficient (DAC)
		Ocean chlorophyll concentration
		Ocean suspended sediments concentration
		Oil spill cover
		Photosynthetically Active Radiation (PAR)
Secondary mission objectives	***Secondary mission objectives***	***Secondary mission objectives***

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Dominant wave direction	Fire fractional cover	Aerosol effective radius
Dominant wave period	Glacier cover	Aerosol mass mixing ratio
Fraction of vegetated land	Photosynthetically Active Radiation (PAR)	Aerosol type
Land cover	Sea-ice cover	Aerosol volcanic ash Total Column
Oil spill cover	Snow cover	Cloud optical depth
Snow cover	Soil moisture at surface	Cloud type
Snow status (wet/dry)	Soil type	Fire fractional cover
Snow water equivalent		Sea-ice cover
Soil moisture at surface		Snow cover
Wave directional energy frequency spectrum		
Opportunity objectives	***Opportunity objectives***	***Opportunity objectives***
Biomass	Aerosol volcanic ash	Aerosol volcanic ash
Fire fractional cover	Aerosol volcanic ash Total Column	Downward short-wave irradiance at Earth surface
Sea-ice elevation	Cloud cover	Integrated Water Vapour (IWV)
Sea-ice thickness	Cloud optical depth	Short-wave cloud reflectance
Significant wave height	Earth surface albedo	Soil moisture at surface
Soil moisture (in the roots region)	Short-wave cloud reflectance	Upward short-wave irradiance at TOA
Soil type	Upward short-wave irradiance at TOA	
Vegetation type		

Sentinel Copernicus Expansion Missions

Sentinel-8 LSTM	**Sentinel -9 CRISTAL**	**Sentinel-10 CHIME**	**Sentinel-11 CIMR**	**Sentinel-12 ROSE-L**
Primary mission objectives	***Primary mission objectives***	***Primary mission objectives***	***Primary mission objectives***	***Primary mission objectives***
Fraction of vegetated land	Ice sheet topography	Biomass	Sea surface salinity	Biomass
Integrated Water Vapour (IWV)	Sea-ice elevation	Fraction of Absorbed PAR (FAPAR)	Sea surface temperature	Fraction of vegetated land

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Land cover	Sea-ice thickness	Fraction of vegetated land	Sea-ice cover	Land cover
Land surface topography	Integrated Water Vapour (IWV)	Land cover	Sea-ice type	Land surface topography
Photosynthetically Active Radiation (PAR)		Leaf Area Index (LAI)	Soil moisture (in the roots region)	Oil spill cover
Soil type		Normalised Difference Vegetation Index (NDVI)	Soil moisture at surface	Sea-ice cover
Vegetation type		Soil moisture at surface	Wind speed (near surface)	Soil moisture at surface
		Soil type	Wind vector (near surface)	
		Vegetation type		
Secondary mission objectives	***Secondary mission objectives***	***Secondary mission objectives***	***Secondary mission objectives***	***Secondary mission objectives***
Biomass	Coastal sea level (tide)	Aerosol Optical Depth	Biomass	Glacier cover
Fire fractional cover	Ocean dynamic topography	Aerosol column burden	Land surface temperature	Glacier motion
Leaf Area Index (LAI)		Aerosol volcanic ash Total Column	Snow cover	Glacier topography
Normalised Difference Vegetation Index (NDVI)		Colour Dissolved Organic Matter (CDOM)	Snow status (wet/dry)	Ice sheet topography
Sea surface temperature		Earth surface albedo	Snow water equivalent	Sea-ice elevation
Soil moisture at surface		Ocean Diffuse Attenuation Coefficient (DAC)		Sea-ice thickness
		Ocean chlorophyll concentration		Snow water equivalent
		Ocean suspended sediments concentration		Soil moisture (in the roots region)
		Oil spill cover		
		Photosynthetically Active Radiation (PAR)		
		Snow cover		
Opportunity objectives	***Opportunity objectives***	***Opportunity objectives***	***Opportunity objectives***	***Opportunity objectives***
Aerosol volcanic ash	Geoid	Aerosol effective radius	Cloud liquid water (CLW)	Dominant wave direction

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Aerosol volcanic ash Total Column	Gravity field	Aerosol mass mixing ratio	Cloud liquid water (CLW) total column	Dominant wave period
Cloud cover	Significant wave height	Aerosol type	Long-wave Earth surface emissivity	Fire fractional cover
Cloud optical depth	Wind speed (near surface)	Aerosol volcanic ash		Significant wave height
Cloud top height	Crustal motion (horizontal and vertical)	Cloud cover		Soil type
Cloud top temperature	Crustal plates positioning	Cloud optical depth		Vegetation type
Cloud type	Geoid	Cloud top height		Wave directional energy frequency spectrum
Fire radiative power	Gravity field	Cloud type		
Fire temperature		Downward short-wave irradiance at Earth surface		
Glacier cover		Fire fractional cover		
Sea-ice cover		Glacier cover		
Short-wave cloud reflectance		Integrated Water Vapour (IWV)		
Snow cover		Sea-ice cover		
Specific humidity		Short-wave cloud reflectance		
Upward short-wave irradiance at TOA		Specific humidity		
		Upward short-wave irradiance at TOA		

Source: Compiled from WMO's OSCAR database (World Meteorological Organisation Observing Systems Capability Analysis and Review Tool)

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Annex 4 Sentinel 8 (LSTM) mission service applications links with EU and international inland water domain policies

Policy/Directives/ Conventions/ Initiative	Application	Users	User needs	Key Requirements	EO product requirements	EO Services
EU Water Framework Directive	Water rights management	EEA; national and river basin management authorities	Enforcement of "unauthorized" abstractions	Monitoring of water use at irrigation system / field scale	ET at irrigation system / field scale with 1-2 day repeat, covering EU agricultural areas	Monitor water use on crops and horticulture
	Ground water abstraction limits	EEA; national and river basin management authorities	European law limits abstraction to a portion of the annual recharge. Agriculture is the main consumer of water.	Monitoring of water use at ground water reservoir and irrigation system / field scale	ET at ground water reservoir and irrigation system / field scale with monthly repeat, covering	Monitor water use on crops and horticulture Assess groundwater and run-off
	Water pricing	National authorities; farmers	Ensure that the price charged to water consumers - such as for the abstraction and distribution of fresh water and the collection and	Monitoring of water use at field scale	ET at field scale with 1-2 day repeat, covering EU agricultural areas	Monitor water use on crops and horticulture

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			treatment of waste water - reflects the true costs			
	Groundwater pollution	EEA; national and river basin management authorities	Groundwater should not be polluted at all – any pollution must be detected and stopped.	Integrated water resources management at field scale	ET at irrigation system / field scale with 1-2 day repeat, covering EU agricultural areas	Assess groundwater and run-off Assess environmental impact of farming
	Water Thermal plume monitoring	EEA; national, coastal and river basin management authorities; power plants	Definition of ecological status looks at … temperature and pollution by chemical pollutants. Energy generation uses water for cooling and other purposes. Much of it is returned to watercourses after use.	Water thermal plume monitoring	Water temperature differences at local/thermal plume scale (100 m resolution or less) and 1 K accuracy (Wan et al., 2016) with daily repeat, covering EU inland water bodies and coastal areas.	Assess and monitor water bodies
	Protection of inland and coastal water surfaces, including	EEA; national, coastal and river basin management	The purpose of this Directive is to establish a framework for the protection of inland surface waters,	Integrated water resources management and ecosystem health	ET at landscape feature scale with weekly repeat,	Monitor land ecosystems and biodiversity. Assess groundwater and run-off. Assess and monitor

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	wetlands	authorities;	transitional waters, coastal waters and groundwater which: (a) prevents further deterioration and protects and enhances the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems.	monitoring at landscape feature (water body) scale.	covering EU inland water bodies and coastal areas. Water temperature monitoring at landscape feature scale with weekly repeat, covering EU inland water bodies and coastal areas. Ancillary data for ecosystem monitoring.	water bodies. Monitor coastal ecosystem
Nitrates Directive (96/676/EEC)	Groundwater pollution	EEA; national and river basin management authorities	The prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems	Integrated water resources management at field scale	ET at irrigation system / field scale with 1-2 day repeat, covering EU agricultural areas.	Assess groundwater and run-off Assess environmental impact of farming
EU Common Agricultural Policy – Greening and	Water use/irrigation efficiency	Farmers; paying agencies; national and	The Common Agricultural Policy supports investments to conserve	Integrated water resources management	ET at field scale with 1-2 day repeat,	Monitor crops. Monitor water use on crops and horticulture.

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Rural Development		river basin management authorities; European Agricultural Fund for Rural Development (EAFRD)	water, improve irrigation infrastructures and enable farmers to improve irrigation techniques. Certain rural development measures support investments for improving the state of irrigation infrastructures or irrigation techniques that require the abstraction of lower volumes of water, as well as actions to improve water quality.	at field scale	covering EU agricultural areas	Assess the environmental impact of farming. Assess and monitor water bodies
	Water use authorizations, auditing and metering	Farmers; paying agencies; national and river basin management authorities.	Use of water for irrigation is subject to authorization, compliance with authorization procedures. All investments in irrigation are subject to requirements … setting up water metering.	Monitoring of water use at field scale	ET at field scale with 1-2 day repeat, covering EU agricultural areas	Monitor water use on crops and horticulture
	Compliance with CAP Greening Element	Paying agencies	Crop diversification – prefer crops that do not require irrigation. Ecological focus area – uncultivated buffer strips (with no irrigation).	Monitoring of water use at field/strip scale	ET at field/strip scale with 4-5 day repeat, covering EU agricultural areas.	Monitor water use on crops and horticulture.. Assess the environmental impact of farming. Monitor land

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						ecosystems and biodiversity. Detect illegal or undesired crops
	Farm advisory services	Farm advisory services; farmers	Precision agriculture/irrigation – improve sustainable management and overall performance of farm holdings and business	Integrated water resources management at intra-field scale. Crop yield optimization at intrafield scale.	ET at intra-field scale with 1-2 day repeat, covering EU agricultural areas. Ancillary information for crop yield retrieval.	Monitor crops. Monitor water use on crops and horticulture.
UN Sustainable Development Goals	Water use efficiency and management	Farmers; national and river basin management authorities, UN	SDG 6.4 - increase water-use efficiency across all sectors and ensure sustainable withdrawals. Indicators: i. Change in water-use	Integrated water resources management at catchment, ground water reservoir and	ET at catchment, ground water reservoir and irrigation system /	Monitor crops. Assess and monitor water bodies. Assess groundwater and run-off.

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		statistics	efficiency over time; ii. Level of water stress: freshwater withdrawal as a proportion of available freshwater resources. SDG 6.5 - implement integrated water resources management at all levels, including through transboundary cooperation as appropriate.	irrigation system / field scale.	field scale with 1-2 day repeat, covering global agricultural areas.	
	Sustainable food production	Farmers; national and river basin management authorities, UN statistics	SDG 2.3 - double the agricultural productivity and incomes of small-scale food producers, ... through secure and equal access to land, other productive resources and inputs, knowledge SDG 2.4 - ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production; strengthen capacity for adaptation to climate change, extreme weather, drought, flooding. SDG 12.2 - achieve the sustainable	Integrated water resources management at catchment, ground water reservoir and irrigation system / field scale. Crop yield optimization at field scale.	ET at catchment, ground water reservoir and irrigation system / field scale with 1-2 day repeat, covering global agricultural areas. Ancillary information for crop yield retrieval.	Emissivity at field scale for soil state / organic carbon retrieval with monthly repeat, covering global agricultural areas. Ancillary information for crop yield retrieval. Monitor water use on crops and horticulture Monitor crops Assess environmental impact of farming Monitor land ecosystems and biodiversity. Assess climate change risk

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			management and efficient use of natural resources.			
	Improve quality of water and water-related ecosystems	National and river basin management authorities; environment ministries	SDG 6.3 - improve water quality by reducing pollution Indicator: i. Proportion of bodies of water with good ambient water quality. SDG 6.6 - protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes. SDG 15.1 - ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services. SDG 15.3 - combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	Integrated water resources management at landscape feature (water body) scale. Water body temperature monitoring.	ET at landscape feature (water body) scale with weekly repeat, covering global inland water bodies and ecosystems. Water temperature at water body scale with weekly repeat.	Monitor land ecosystems and biodiversity. Assess and monitor water bodies. Assess environmental impact of human activities Monitor land cover and detect change Assess Deforestation / Forest Degradation
UN Convention to	Drought monitoring	National and river	Drought preparedness that	Integrated water	ET at regional scale	Monitor water use on crops and

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Combat Desertification	and water security	basin management authorities; relief and development agencies	responds to human needs, while preserving environmental quality and ecosystems. Comprehensive drought early warning and monitoring systems, ..., upstream-downstream water uses, the link between water and land use. Early Warning System (EWS) would guide affected countries by providing timely information that they can use to reduce risks and to better prepare for an effective response	resources management at regional scale and catchment scale	and catchment scale with 4-5 day repeat, covering global agricultural areas.	horticulture Monitor crops. Assess and monitor water bodies. Monitor land ecosystems and biodiversity. Monitor land cover and detect change Assess pressures on populations and migration. Map disaster areas
	Land degradation – erosion and salinization	Farmers; irrigation management authorities	Limit and manage surface or flood irrigation with better ET monitoring. Development of sustainable irrigation schemes for crops and livestock	Monitoring of water use at irrigation system / field scale scales. Crop yield optimization	ET required at irrigation system / field scale with 1 – 2 day repeat, covering global agricultural areas. Ancillary information for crop yield retrieval.	Monitor water use on crops and horticulture.Monitor crops. Assess Environmental impact of farming

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	Soil carbon storage		Increasing soil carbon builds a precious reservoir and helps to offset greenhouse gas emissions. It also contributes to the fertility of the soil, the foundation for all land-based natural and agricultural ecosystems which provide a major part of the world's food supply, natural resources and biodiversity.	Soil management at field and regional scales.	Emissivity at field and regional scales for soil state / organic carbon retrieval with monthly repeat, covering global agricultural areas.	Assess changes in the carbon balance Monitor land ecosystems and biodiversity
UN Framework Convention on Climate Change	Risk management and climate change adaptation	Insurance providers; farmers; national authorities	Insurance and other kinds of disaster risk management can facilitate public-private partnerships for dealing with extreme weather related calamities. Transferring risk through insurance could play a useful role in adaptation to climate change and disaster risk management.	Crop water stress at field/farm scale	ET at field/farm scale with 4-5 day repeat, covering global agricultural areas. Ancillary information for crop stress retrieval.	Monitor water use on crops and horticulture. Monitor crops Assess climate. change risk

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	Lake surface water temperature	National regional water management authorities; environment ministries	Land surface temperature is a Global Climate Observing System (GCOS) Essential Climate Variable	Lake surface temperature at water body scale	Surface water temperature at water body scale with a weekly repeat, covering global inland water bodies.	Assess and monitor water bodies
Natura 2000 Directive	Natural habitat monitoring	Environment ministries, regional and national authorities.	The aim of this Directive shall be to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States. Natural habitats means terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural	Integrated water resources management at landscape feature scale. Monitoring of water temperature.	ET at landscape feature scale with weekly repeat, covering global inland water bodies and ecosystems. Water temperature at water body scale with weekly repeat.	Monitor land ecosystems and biodiversity. Assess and monitor water bodies. Monitor coastal ecosystem.Assess environmental impact of human activities
Integrated Coastal Zone Management (Marine	Thermal plumes monitoring	Coastal authorities; power plants	Integrated coastal management aims for the coordinated application	Water thermal plume monitoring	Water temperature differences at	Monitor coastal ecosystem. Monitor ocean quality and

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Strategy Framework Directive)			of the different policies affecting the coastal zone and related to activities such as nature protection, aquaculture, fisheries, agriculture, industry, offshore wind energy, shipping, tourism, development of infrastructure and mitigation and adaptation to climate change.		local/thermal plume scale (100 m resolution or less) and 1 K accuracy (Wan et al., 2016) with daily repeat, covering EU coastal areas.	productivity. Monitor marine habitats
	Aquaculture impact and optimization	Coastal authorities; aquaculture businesses	Integrated coastal management aims for the coordinated application of the different policies affecting the coastal zone and related to activities such as nature protection, aquaculture, fisheries, agriculture, industry, offshore wind energy, shipping, tourism, development of infrastructure and mitigation and adaptation to climate change.	Water surface temperature.	Water temperature differences at coastal features' scale with daily repeat, covering EU coastal areas.	Monitor coastal ecosystem Assess and monitor coastal water quality. Monitor ocean quality and productivity. Monitor marine habitats. Assess environmental impact of human activities
GEO Global Agricultural Monitoring initiative and	Development of harmonized global	National and regional governments; aid	Provide timely and transparent information based on EO ...	Early warning of crop water stress. Crop yield	ET required at regional and field	Monitor crops. Monitor water use on crops and horticulture.

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Agricultural Market Information System	crop outlooks	agencies; commodity traders.	through developing a transparent, timely, qualitative crop condition assessment in primary agricultural production areas highlighting potential hotspots of stress/bumper crops.	forecasting.	scales with 3 – 4 day repeat, covering global agricultural areas. Ancillary information for crop yield retrieval.	Assess pressures on populations and migration
	Coordination and enhancement of global baseline datasets	National and regional governments; UN agencies (FAO); aid agencies; agricultural commodity markets.	Compiling and enhancing baseline geo-spatial datasets that are fundamental for improving our capability to effectively monitor global agriculture such as cropland distribution and crop calendars	Irrigation system classification. Irrigation calendars. Crop water use maps. Statistics on yield in relation to water use. Soil conditions.	ET required at field and regional scales with 3 – 4 day repeat, covering global agricultural areas. Emissivity at field and regional scales for soil state / organic carbon retrieval with monthly repeat, covering global agricultural areas.	Monitor crops. Monitor water use on crops and horticulture. Assess pressures on populations and migration. Baseline mapping. Monitor economic activity
G20 Agriculture	Food and water	National authorities,	We emphasise that water is an	Integrated water	ET required at field	Monitor crops. Monitor water use

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Ministers' Declaration 2017	security monitoring	UN agencies (FAO), agricultural commodity markets	essential production resource for agriculture and is therefore critical for feeding the growing world population. Climate change and rising competition for water will further increase pressure on water resources in many regions and have a negative impact on vulnerable rural populations. Water scarcity and excess water threaten agriculture and food security and nutrition. This can contribute to political and social instability and to large-scale migration. We are committed to policy approaches that foster increased agricultural productivity while ensuring that water and water related ecosystems are protected, managed and used sustainably. We aim to foster the efficient and environmentally friendly use of all agricultural inputs	resources management at catchment, ground water reservoir and irrigation system / field scale. Early warning of crop water stress. Crop yield forecasting. Crop water use maps. Soil management at field and regional scales.	and regional scales with 3 – 4 day repeat, covering global agricultural areas. Emissivity at field and regional scales for soil state / organic carbon retrieval with monthly repeat, covering global agricultural areas. Ancillary information for crop yield retrieval.	on crops and horticulture Assess pressures on populations and migration Assess environmental impact of farming Assess climate change risk

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			and the application of sustainable agricultural production practices, including livestock husbandry, soil management and water conservation. We welcome … improving transparency of international commodity markets and its role in assessing food price volatility.			
EU Regulation for Rural development	Union priorities for rural development	EU member states	The achievement of the objectives of rural development, which contribute to the Europe 2020 strategy for smart, sustainable and inclusive growth, shall be pursued through the following six Union priorities for rural development, which reflect the relevant Thematic Objectives	Increasing efficiency in water use by agriculture	ET required at irrigation system / field scale with 1 – 2 day repeat, covering european agricultural areas.	Monitor crops Monitor water use on crops and horticulture Assess environmental impact of farming
EEA Report on Climate	Climate change	EU member states	Irrigation demand is projected to	Increasing efficiency in	ET required at	Monitor crops Monitor water use

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Change, impacts and vulnerability in Europe 2016	impacts in different sectors (agriculture, tourism, ecosystem services, human health, etc)	and national authorities	increase, in particular in southern Europe where there is already considerable competition between different water users	water use by agriculture	irrigation system / field scale with 1 – 2 day repeat, covering european agricultural areas.	on crops and horticulture Assess climate change risk

Source: From *"Copernicus High Spatio-Temporal Resolution Land Surface Temperature Mission: Mission Requirements Document"* Issue Date 14/05/2021. Ref ESA-EOPSM-HSTR-MRD-3276

Annex 5 Sentinel-10 (CHIME) mission service applications links with EU and international inland water domain policies

Policy/Directives/ Conventions/initiatives	Market Area	Stakeholders	User needs	EO Data products	Key observational Requirements

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EU Water Framework Directive. **EU Bathing Water Directive, EU Urban Waste Water Treatment Directive, EU Biodiversity Strategy, Natura 2000, United Nations Convention on Biological Diversity, United Nations Sustainable Development Goal No. 6** **Ramsar Convention on Wetlands**	Inland- and coastal waters	Water Protection Agencies, Water authorities, Aquaculture industry, Dredging industry, Recreation and tourism sectors,	Water quality assessment for e.g. inland and coastal water management, aquaculture practices, fishery; Water pollution management for e.g. harmful algae blooms; Ecosystem assessment in terms of e.g. phytoplankton typing and phenology, underwater light field; Mass transport for e.g. coastal erosion; Coral reef assessment; Understanding roles of lakes in the global carbon cycle	Spectral water leaving radiance, inherent optical properties, light penetration depth, phytoplankton pigments (chl-a, PC, PE) and size class, suspended matters (with their inorganic/organic fractions), coloured dissolved organic matter, bottom properties (substrate types, status and depth), type and properties of aquatic vegetation (submerged, floating and emergent vegetation), type and properties of floating materials (e.g. oils, cyanobacterial scum)	Spatial resolution: HIGH/MODERATE Spectral resolution: HIGH Temporal resolution: HIGH/MODERATE Data latency: MEDIUM/LONG High SNR in the VNIR (plus SWIR for extreme turbid waters, emerging vegetation and floating materials, improving atmospheric correction);
EU Common Agriculture Policy (CAP) **Nitrates European directive** **EU Thematic Strategy for Soil Protection** **Soil Framework Directive**	Agriculture & Food security - Crop phenology & productivity - Stress & disease - Smart farming - Food nutrition	Public Sector: EC-DG-Agri, EC_DG_Grow, European Environmental Agency, EC – Joint Research Centre (JRC), National Administrations, International Organisations (e.g. FAO, WFP), National Environmental Authorities, Water Protection Agencies Private Sector: Individual Farmers, Farming Organisations, Farming	Spatio-temporal monitoring of crops & harvest regional management, Agricultural statistics, Food security scenarios, nutrition and early warning. Monitoring of plant traits (biochemical/ phenological features to characterise plants	Vegetation properties: - Fraction of Photosynthetically Active Radiation - Leaf Area Index - Leaf Pigment content (Chl, Car, Anth) - Canopy water/ dry matter content - Canopy nitrogen uptake - Crop phenology, EWT (cm) - Leaf Mass Area	Spatial resolution: HIGH Spectral resolution: HIGH Temporal resolution: MODERATE Sentinel 2 compatibility: YES

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Sustainable Development Goal No.2, No. 12, No. 15		Advisors, Seeding Companies, Agrochemical Companies, Renewable Energy Industry, Food Industries, Agricultural Insurances, Financial Industries	and detect crop stresses and disease), Support of smart farming/ precision farming activities. Fertilization and plant protection management, Irrigation Management. Quantification of stabilising features such as dry matter, litter, organic and mineral crusts. Characterisation of soils with respect to fertility and degradation.	- Fraction of Non- Photosynthetic Vegetation - Light use efficiency Topsoil properties: - Soil salinity	
EU Soil Thematic Strategy, Soil Framework Directive, UN SEEA (System of Environmental-Economic Accounting), UN Convention for Combating Desertification and Land Degradation Common Agricultural Policy (CAP), Fertilizers Regulation, EU Biodiversity Strategy	Agriculture and arable lands, soils; Public, local and regional planners for conservation management	Ecologists, public services (administration, national geological surveys, land use planning, risk mitigation, environmental impact studies), NGOs	Environmental Protection; Soil conservation /Land degradation (e.g. erosion intensity); Soil Attributes (Nitrogen, Carbon, Carbonate, and Organic matter); Soil Restoration soil contamination areas prone to soil erosion	- Soil mineralogical composition (clay, carbon, iron oxides, carbonates, gypsum) - Soil variables (Corg, texture, salinity, nutrients, hydrophobicity, contamination, infiltration rate, soil sealing, top-soil moisture, soil compaction) - Soil carbon storage (inorganic and – organic carbon, hydrocarbons) - Heavy metal type and extent - Organic matter discrimination (dry matter, litter to humus)	Spatial resolution: HIGH Spectral resolution: HIGH Temporal resolution: MODERATE Data latency: MEDIUM/LONG Driving temporal sampling at local and regional scales to quantify erosive loss under varying weather conditions

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2020, **Regional Policies (INTERREG),** **EFSA strategy 2020,** **Sustainable Development Goal No. 15**				- Soil quality index	
UN Convention to combat desertification (UNCCD), **Aarhus Convention,**	Environmental degradation and hazards	Agricultural consulting, Rangeland management EU Joint Research Centre UN / FAO / UNEP and related institutions, especially in context of the UNCCD (UN Convention to combat desertification), Mining authorities and companies, Environmental protection agencies Regional, National and International authorities, Civil Protection, Copernicus EMS	Characterisation and monitoring of oil spills, Toxic waste disposals (status and extent e.g. for asbestos). Wildfire fuel and load (Species type, dry biomass abundance, canopy leaf water)	Hydrocarbon spill, Dry biomass abundance, Oil and gas spills and seeps;	Spatial resolution: HIGH/MODERATE Spectral resolution: HIGH Temporal resolution: HIGH Data latency: SHORT/MEDIUM Temporal resolution as driver Trade-off analysis to be considered wrt. high spatial resolution vs. high radiometric performance requirement.
EU Arctic Policy **Climate Change Initiative**	Snow, ice and hydrology	EU External Action National, regional and local water resource managers, hydropower	Environmental degradation and hazards, Permafrost degradation, Snow	Snow albedo Accurate snow-covered area Meltwater ponds mapping. Snow grain size, light	Spatial resolution: MODERATE

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		industry, tourism area, avalanche warning authorities.	Predicted amount and rate of release of water from snow/ice. Water availability at catchment scale. Early warning for avalanche risk. Mitigation options to increase snow/ice water resource availability (reduction of black carbon and dust sources). Environmental degradation and hazards, Permafrost degradation, Snow cover	absorbing impurities (e.g. black carbon, dust), cryoconites, cryophilic algae.	Spectral resolution: HIGH Temporal resolution: HIGH/MODERATE Data latency: SHORT

Source: From *"Copernicus Hyperspectral Imaging Mission for the Environment - Mission Requirements Document"* Issue Date 21/01/2021 Ref ESA-EOPSM-CHIM-MRD-3216

Annex 6 Sentinel-11 (CIMR) mission service applications links with EU and international inland water domain policies

Policies Directives	Applications	User Requirements	User entities
EU Integrated Policy on the Arctic	Climate Change and the Arctic Environment, sustainable development in the Arctic, International cooperation on Arctic matters	Monitoring of floating sea ice and ocean surface parameters with high spatial resolution to support sustainable development and environmental security, cooperation and long term monitoring of societal impacts in the Arctic Environment. Enhance the safety of navigation in the Arctic.	Arctic States, EC, ESIF, UN, UNCLOS, ECGFF, ACGF, TEN-T, OSPAR, GEOCRI.

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EU Water Framework Directive	Water rights management, Water pricing, Ground water abstraction limits, Protection of inland and coastal water surfaces	Monitoring of water use from field scale to irrigation system level for enforcing sustainable water abstraction for agricultural production	EEA; national and river basin management authorities
UN Sustainable Development Goals	Water use efficiency and management, Sustainable agricultural production	Reporting on the SDG 6.4 for increase water use efficiency across all sectors and ensure sustainable withdrawals.	National statistical offices, UNEP, UN Statistics
UN Framework Convention on Climate Change	Risk management and climate change adaptation	Mitigating water scarcity impacts related to climate change or extreme weather calamities	Insurance providers; farmers; national water authorities
Marine Strategy Framework Directive (MSFD)	Integrated coastal zone management, Protection of marine biodiversity http://ec.europa.eu/environment/mari ne/eu-coast-and-marinepolicy/marine-strategy-frameworkdirective/index_en.htm	Water thermal plume monitoring, aquaculture management	Coastal authorities; power plants OSPAR
Geo Cold Regions Initiative (GEOCRI)	Biodiversity and ecosystem sustainability, disaster resilience, energy and mineral resource management, food security and sustainable agriculture, infrastructure and transportation management, public health surveillance (weather extremes, water-related illness etc.) water resources management. The GEOCRI mission is to develop a user-driven approach for Cold Regions information services to complement the mainly current science-driven efforts, which will strengthen synergies between the environmental, climate, and cryosphere research efforts and foster the collaboration for improved earth observations and information on a global scale. https://www.earthobservations.org/ac tivity.php?id=115	There is the need to provide coordinated Earth observations and information services across a range of stakeholders to facilitate well-informed decisions and support the sustainable development of the cold regions globally.	Users from both the public and private sectors, including managers and policy makers in the targeted societal benefit areas, scientific researchers and engineers, governmental and nongovernmental organizations, and international bodies
Northern Dimension policy framework	Thematic partnerships related to environment (NDEP), public health and social well-being (NDPHS), transport and logistics (NDPTL), and culture (NDPC). The Northern Dimension policy aims at providing a	Arctic coastal zone monitoring, satellite hydrographic monitoring and assessment of environmental trends along the arctic coast.	Regional and subregional organizations and commissions in the Baltic and Barents area,

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	common framework for the promotion of dialogue and cooperation, strengthening stability, well being and intensified economic cooperation, promotion of economic integration and competitiveness and sustainable development in Northern Europe. https://eeas.europa.eu/diplomaticnetwork/northern-dimension_en		the sub-national and local authorities, nongovernmental organizations and other civil society organizations (including notably indigenous peoples' organizations), universities and research centres, business and trade union communities, etc.
EU-PolarNet initiative	Supports a EU-wide consortium of expertise and infrastructure for polar research to better assimilate Europe's scientific and operational capabilities in the Polar regions. http://www.eupolarnet.eu/	Improved coordination of data and infrastructure between EU member polar research institutions.	EC, EU member polar research institutions, public, private organizations, universities and research centres
European Maritime Transport Policy	Maritime Safety and Security; Digitalisation and Administrative Simplification; Environmental Sustainability and Decarbonisation; Raising the Profile and Qualifications of Seafarers and Maritime Professions and; EU Shipping: A stronger global player. https://ec.europa.eu/transport/themes/ strategies/2018_maritime_transport_s trategy_en	Floating sea ice and ocean surface parameters to be monitored with high spatial resolution.	Shipping operators, Maritime transport industry, CLIA, EBA, ECSA, EMPA, ETF, Interferry, and WSC
IMO International Code for ships operating in polar waters (Polar Code)	The Polar Code is intended to cover the full range of shipping-related matters relevant to navigation in waters surrounding the two poles – ship design, construction and equipment; operational and training concerns; search and rescue; and, equally important, the protection of the unique environment and ecosystems of the polar regions. http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx	Improved knowledge on sea ice and other hazards for polar navigation. In particular sea ice thickness and concentration forecasting.	European Community, Ship owners' Association (ECSA), ship operators

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Source: *"Copernicus Imaging Microwave Radiometer (CIMR) Mission Requirements Document."* Issue Date: 06/10/2020, Ref: ESA-EOPSM-CIMR-MRD-3236, Version 4.0

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Annex 7 Copernicus Thematic Hubs Concept

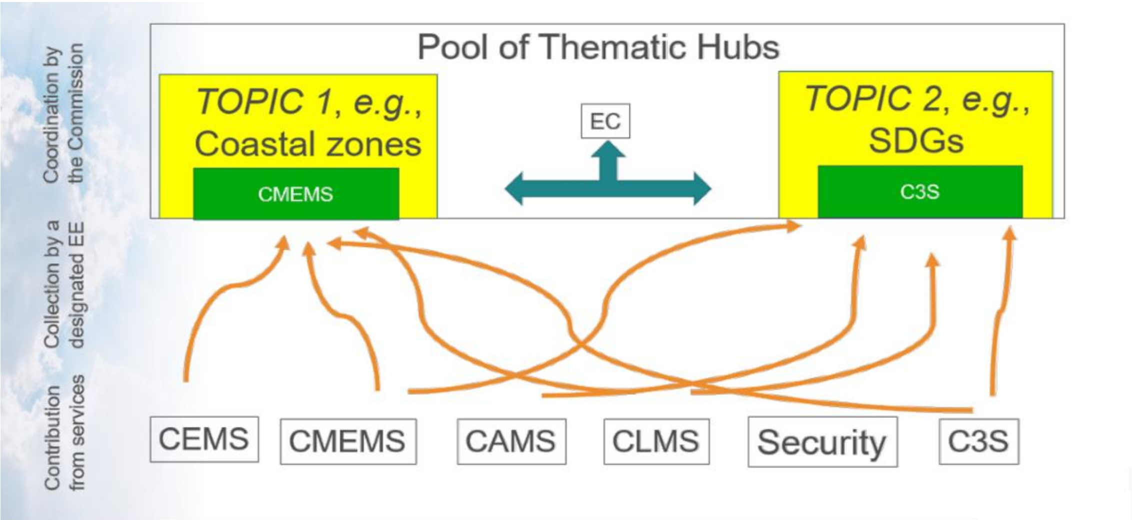

Diagram of the Copernicus Thematic Hubs concept. Source: "Copernicus Thematic Hubs & Data Platforms", CAMS, 2021

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