Copernicus Academy Hub for Knowledge, Innovation and Outreach

Assessment of Copernicus Uptake (Update of the user-oriented taxonomy)

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Rationale

EARSC's extensive engagement with Earth observation user communities has highlighted the need for a common language to help service providers and users arrive at a mutual understanding of the types of services that can be offered and the benefits that can be delivered. We have developed an Earth observation taxonomy that is not only a process of naming and classifying the EO services but additionally a tool to improve the understanding between these communities.

Under this context, this document presents a reduced version of the Del 4.3. from the CopHub.AC H2020 project, which outlines the third update of the EARSC taxonomy. The EARSC taxonomy has been carefully reviewed and includes for the first time a generic definition of available products and how those form the basis for the delivery of the EO services (the combination of e.g. EO products, in-situ data, modelling etc. to deliver contextualized knowledge to a service user). This taxonomy update, from both the market and thematic perspectives, has been conducted in close collaboration with the research community through the CopHub.Ac project.

Inside this taxonomy, each catalogue of services contains specific services offered to citizens, business, government and other organisations. The taxonomy should be continuously updated to ensure its continued relevance in a fast-changing sector. We have made every effort to ensure that the structure is sufficiently robust to accommodate future market segments and thematic topics; as the market changes and grows, these changes will need to be incorporated in future taxonomy updates.

We look forward to receiving stakeholders' feedback and working with stakeholders in continuing this exciting evolution of the description and structuring of EO services.

Key words

Copernicus, Earth Observation (EO) EARSC taxonomy, Body of Knowledge (BoK), thematic, market, service, application, product, parameter

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List of Acronyms

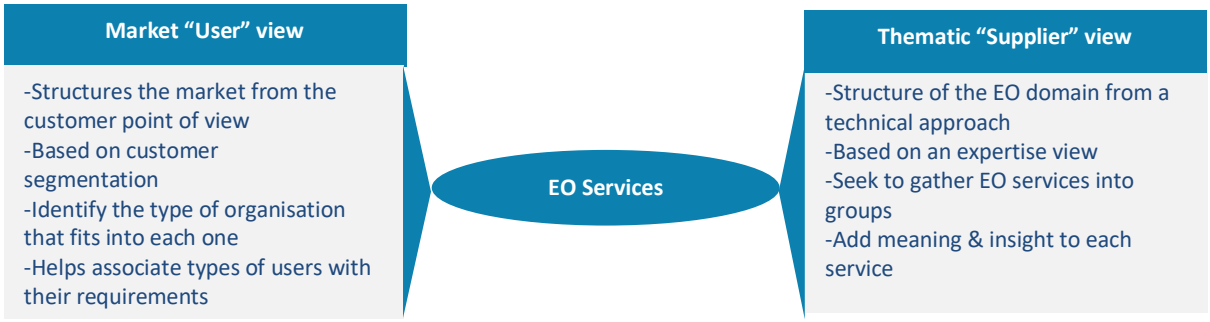
Acronym	Description
BoK	Body of Knowledge
CAMS	Copernicus Atmosphere Monitoring Services
C3S	Copernicus Climate Change Service
CLMS	Copernicus Land Monitoring Service
CEMS	Copernicus Emergency Management Service
CMEMS	Copernicus Marine Environment Monitoring Service
Chl-a	Chlorophila-a
CH4	Methane
CopHub.AC	Copernicus Academy Hub for Knowledge, Innovation and Outreach
CO2	Carbon Dioxide
DIAS	Data Infrastructure Access Services
DEM	Digital Elevation Models
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
DSM	Digital Surface Models
DTM	Digital Terrain Model
EC	European Commission
EDO	European Drought Observatory
EARSC	European Association of Remote Sensing Companies
EFAS	European Flood Awareness System
EFFIS	European Forest Fire Information System
ENVRI +	Environmental Research Infrastructures
EO	Earth Observation
EO4GEO	EO4Geoinformation sector
EO/GI	Earth Observation and Geoinformation Systems sectors
EU	European Union
Eurostat	Euro/Statistics
ESA	European Space Agency
E-SHAPE	EuroGEO Showcases: Applications Powered by Europe
GDO	Global Drought Observatory
GEOSS	Global Earth Observation System of Systems
GI	Geoinformation Systems
GICS	Global industry classification Standard
GHI	Global Horizontal Irradiance
GHG	Greenhouse Gases
GloFAS	Global Flood Awareness System
GNSS / GSA	European Global Navigation Satellite Systems (GNSS) Agency, or GSA
GWIS	Global Wildfire Information System
HBAs	Harmful Blooms
HNS	Hazardous and Noxious Substances

ICB	Industrial Classification Benchmark
IFIs	International Financial Institutions
IR	Brightness temperature
LAI	Leaf Area Index
LBS	Location Based Services (LBS)
LCCS	Land Cover Classification System
LULUCF	Land Use Change and Forestry
LU/LC	Land Use / Land Cover
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NIS	Marine Non-Indigenous Species
NO2	Nitrogen Dioxide
NRT	Near Real Time
OECD	Organisation for Economic Co-operation and Development
O3	Ozone
PaaS	Platform-as-a-Service
PM	Particulate Matter
PP	Primary Production
RBC	Reuters Business classification
REDD+	Reducing Emissions from Deforestation and Forest Degradation
R&I	Research & Innovation
S. Provider	Service Provider
SBA's	GEO Societal Benefit Areas
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
SO2	Sulphur Dioxide
SST	Sea Surface Temperature
UXO	Unexploded Objects
VCI	Vegetation Condition Index
VIS	Reflectance factor
VMS	Vessel Monitoring System
WB	World Bank
WMO	World Meteorological Organization
WP	Work Package

Executive summary

For any sector providing services, reaching a community consensus on terminology is a prerequisite for ensuring a common understanding of the information exchanged among different stakeholders. Knowledge exchange among users of geo-information services presents many challenges and the development of a "knowledge-driven" approach is considered by the Earth Observation (EO) sector to be one of the milestones for embracing its diverse group of stakeholders. This update of a user-oriented taxonomy focuses on the translation between the world of the providers of EO services and the world(s) of their users. It provides a structured view of the uptake for EO services; it brings together the products and services which are offered by suppliers and maps those to the market sectors and needs to which those products apply.

Taxonomies[2], ontologies[3], inventories[4], different types of body of knowledges (BoK)[5] or controlled vocabularies[6] are the preferred means to achieve such a "common understanding" by identifying the terms of the domain and structuring the sector through semantic relationships, preferably with a focus on the end "user". Under this foundation, the European Association of Remote Sensing Companies (EARSC) recognised a need to structure the "offer" of the sector, its products and services for the actual use of the communities from whom these offers are intended, the "uptake". EARSC prepared and issued a first version of the Taxonomy for the EO Services Market in February 2012 and revisited the document in August 2015[7]. This taxonomy provided guidelines of clear and common descriptions of products and services helping suppliers and users arrive at a common understanding of what can be offered.



EARSC representation of "User" and "Supplier" view

This report presents and explains the rationale for the proposed EO taxonomy update and to address the common products and services from two perspectives: the market view and the supplier view.

The **market view** provides a tool to help classify and understand the markets for EO services as well as to define the type of customer. The representation of market stakeholders in the use of value-added services and applications is the core of this section. It focuses on user needs and the use of Earth observation from the users' point of view.

[2] Taxonomy formalizes the hierarchical relationships among concepts and specifies the terms to be used to refer to each; prescribes structure and terminology (ref Medium article by S. Garfield, 2019)
[3] Ontology identifies & distinguishes concepts and their relationships; (ref Medium article by S. Garfield, 2019)
[4] Inventory is the listing of items; it requires some form of classification unit or individual entities to count (https://bit.ly/2HA4lGq)
[5] Body of Knowledge (BoK) is the complete set of concepts, terms and activities that make up a professional domain, as defined by the relevant learned society or professional association. Type of knowledge representation by any knowledge organization (ref link Wikipedia).
[6] Controlled vocabulary is an organized arrangement of words and phrases used to index content and/or to retrieve content through browsing or searching (ref link). More info on the Glossary section
[7] EARSC taxonomy for EO services market V1 and V2 (http://earsc.org/file_download/489/A+Taxonomy+for+the+EO+Services+Market+issue+2+%282%29.pdf)

The "market taxonomy" has been upgraded reflecting the evolution of the sector and how the user groups are structured. One of the developments is the split of the market "public and international bodies" into other sectors. Within these organizations, their employees provide or make use of the EO services for sector-specific applications such as public administration activities assisting "environmental, climate change or health security" policy making decisions or actions in the "defence & security" sector, especially under emergency and social protection. Our latest findings on the "survey into the state & health of the sector"[8] revealed a significant increase in the activities specific for different groups of users. Such was the growth in the "defence and security" segment, that even if we consider it explained by the weight of big contracts from big players in this sector, we decided to consider it in this revision as an independent sector. Other new independent market segments recently incorporated include "urban planning", supporting the activities of many service providers in the public sector, and "citizens & society" with so many people now carrying a mobile application in their pockets able to visualise applications based on EO data. The latter has not been reflected in the previous taxonomy but gained relevance being a direct "user" of special EO services available through Apps. The Figure below represents the upgraded taxonomy with the Market (User) perspective.

EARSC Taxonomy (Market /User) perspective (2020)

[8] EARSC EO Industry Survey Report (2019) (http://earsc.org/file_download/568/Industry+survey+2019+final+version+07_11_2019.pdf)

The **thematic view** provides a tool to help describe and classify the services and products that are offered by the service providers. The "thematic perspective" deals unambiguously with a thematic application area[9] (i.e. agriculture), which is not linked *per se* to the processing or acquisition of EO (or indeed, other kinds of) data or, quite naturally, to activities further upstream (i.e. satellite and sensor design or manufacture), instead the source focuses on concepts, challenges and applications in a specific domain (e.g. agriculture) or thematic segment (agriculture monitoring).

During the upgrade of the taxonomy, the structure of the thematic perspective was reviewed. The updated structure of the taxonomy thematic viewpoint allows for 4 levels/tiers in the description of EO services from the supplier side point of view. The Table below presents the EO services structure.

EO services structure

Level 1	**Thematic classes (DOMAIN)**	Single block of knowledge (big category of objects)	Largest conceptual category (typically nouns) covering all known areas of EO services from the supplier's point of view. The EARSC taxonomy contains 6 classes.
Level 2	**Thematic segment (AREA)**	Set of EO services (greater detail of objects)	Classifies concepts in greater detail, i.e. different segments. The upgrade proposes 31 areas compared with the 25 in the previous taxonomy. Description is tackled in the thematic section.
Level 3	**EO Service (SERVICE)**	Purpose of the information	EO services (sometimes considered applications by service providers) propose an action or a sequence of actions (specific events appropriate in a given situation, e.g., "assess the environmental impact of farming". For example, it unifies major entities such as environment, agriculture or deeper in granularity such as crops. The range today covers more than 80 services (see the section "Structuring the EO services" and the thematic taxonomy at the EARSC portal[10])
Level 4	EO Application	Specific for a geographical area, timeline, etc.	This level presents set **keywords** which in effect define the **products** which make up a service (key words are also considered in our taxonomy to represent **products, parameters** or **essential variables**).
	Products	Describe tangible satellite-based data products	
	Parameters & Essential Variables for the land, atmosphere and ocean	Information elements derived from EO data key *parameters* of the *Earth* and the environment	

While the major classes of the thematic taxonomy have not been adapted (**Level 1**: Six major thematic classes: atmosphere & climate, built environment, disasters & geohazards, land, marine & ocean, security & safety), the thematic areas in the **Level 2** have been slightly adapted through the addition of "climate change" under atmospheric a climate section, the specification of "biodiversity and ecosystems" for both marine and land segments, "food production" under defence and security, and adding, under the built environment thematic classes, dedicated segments on "networks" and "waste". **Level 3** includes a revision in the thematic areas adding a description of EO Services, based on the feedback from thematic experts who have been consulted. For example, under "climate change" we have integrated elements related to "climate change monitoring, mitigation and adaptation". In "built environment" domain we added a dedicated item on "urban settlements assessment". The area dedicated to "multi-hazard assessment" was included as an EO service at the request of experts in the "disasters & geohazards" domain. Better descriptions and additions complement the **Level 4** descriptions; provision of keywords such as "monitoring risk factors, fire weather index, flood map exposure" and inclusion of "early warning", in the "disaster & geohazards" domain. Concerning the land domain, we have incorporated a shift in the meaning of the concepts such as "measure land use statistics" in the sector, replacing "land accounting" or minor details such

[9] Exploring sectoral uptake of Sentinel data within academic publications (http://earsc.org/Sebs/wp-content/uploads/2020/03/SEBS-A-Task-1.1_2020_v01_submission.pdf)
[10] EARSC portal (https://earsc-portal.eu/pages/viewpage.action?pageId=15794378)

as replacement of "water level" with "surface water dynamics". The Figure below provides the main structure of the taxonomy from the thematic perspective.

EARSC Taxonomy (Thematic / Provider) Perspective (2020)

The taxonomy update includes for the first time a generic reflection on the products and how those form the basis for the elaboration of the EO services. Overall, this exercise on the taxonomy, from the market and thematic perspectives, brought the attention of experts; the research community to better align their services with the orientation of the user uptake and a first approach with the 2030 Sustainable Agenda and the matrix (SDGs and EO services) with a target language. The taxonomy should be continuously updated to ensure its continued relevance in a fast-changing sector. Whilst we hope that the structure is sufficiently robust to accommodate future market segments and thematic topics, those new segments and topics will change and should be added. Inside this taxonomy, each catalogue of services contains specific services offered to citizens, business and other organisations. There are also many generic services common to other structure levels. The taxonomy helps the process for improving understanding between communities. We will compare the taxonomy with other structures used to try and communicate the complex variety of EO services through provision of a series of matrices comparing their approaches. We look forward to receiving stakeholders' feedback and working with stakeholders in continuing this exciting evolution of the description and structuring of EO services.

1. Introduction

"If you don't know the name of the things, the knowledge of them is lost"
Carl Linnaeus

1.1. Background

The Earth Observation (EO) sector is rapidly evolving. The increase in a number of satellite constellations, platforms and the impact of a range of relevant emerging technologies creates a vibrant space for the development of new services and capabilities. Bringing these new services to their relevant markets requires a common understanding of the problems addressed and the solutions proposed between the solution provider and the market user. Mutually acknowledged taxonomies or other types of controlled vocabularies, specifying the terms of the domain and structuring it via relationships, can achieve such a common understanding. Table 1 summarises the importance of a sector taxonomy.

Table 1- Why a taxonomy?

WHY A TAXONOMY?	
©EARSC taxonomy	• tool to improve the **understanding between communities** • process of **naming, classifying, categorizing** and **structuring** EO services and products • clear and **common description** of the knowledge landscape (ontologies, taxonomies, associations of concepts/terms, classifications, keywords) • add **meaning** and **insight** to each service and helps associate various types of content • taxonomy is **evolving** based on sector developments, market needs. It is never a "finished document" • accepted, comprehensible, useful, repeatable

It is important to note that many activities have been conducted for the improvement of the EO and Geoinformation Systems (GI) semantics and data interoperability such as the work is done by DiBiase et al. (2006)[11] in developing the Body of Knowledge (BoK) hierarchical structure with concepts and methods, by Nagai et al. (2012)[12] on an ontology registry and the semantic interoperability, and by Ahearn et al. (2013)[13] who proposed an extension of DiBiase's BoK. The evolution on this type of work continued and Gruber et al. (1993)[14] suggested ontology specifications which would help the community of service providers to harmonise catalogues of services in the context of knowledge sharing or the specification of a conceptualization of ontologies. Arvor et al. (2019)[15] advised on ontologies to interpret remote sensing images so the work on ontologies made a step in the Earth Observation sector. Many pieces of work in the "taxonomy" and "ontology" domains, in addition to the ones mentioned above, have informed and guided EO ontological development. Recent work made under the context of the EO4GEO[16] project is revolutionising the BoK providing the links with business processes and innovative skills development in both the EO and GI sectors. This work is

[11] DiBiase at al (2006) https://www.ucgis.org/assets/docs/gist_body_of_knowledge.pdf
[12] M. Nagai et al. (2012) https://www.isprs-ann-photogramm-remote-sens-spatial-inf-sci.net/I-2/235/2012/isprsannals-I-2-235-2012.pdf
[13] Ahearn, S. et al. (2013) https://www.tandfonline.com/doi/abs/10.1080/13658816.2013.802324
[14] Gruber et al. (2013) https://tomgruber.org/writing/ontolingua-kaj-1993.pdf
[15] Arvor et al. (2019) https://www.tandfonline.com/doi/full/10.1080/15481603.2019.1587890
[16] EO4GEO project aims to help to bridge the skills gap between supply and demand of education and training in the EO/GI sector

reflected in the paper from Stelmaszczuk-Górska et al. (2020)[17] which is closely connecting the development of the BoK, integrating EO concepts and the EO uptake. An expansion of this work will be introduced Section 5.2 Taxonomy adoption under the EO4GEO BoK. One commonality across all approaches is that ontologies include essential vocabulary together with a specification of the meanings from the vocabulary representational form Robert et al. (2020)[18].

The EARSC taxonomy includes an identification of the fundamental EO categories considered independently of the market/user or thematic/application approaches but also the relationship between categories. The taxonomy effort is a process of naming and classifying the EO services and products as a tool to improve the understanding between communities while the specific ontology analysis is a process of defining vocabulary, representation of knowledge and making relationships. This update of the taxonomy will further improve the accessibility of the EO services, ensuring shareability and reusability among the different taxonomy approaches in the geoinformation sector and facilitating a common description of the knowledge landscape and the relevant EO products and services. To structure this information the updated taxonomy has been juxtaposed with some categories defined as “thematic areas” under CopHub.AC fulfilling the academic fundamental research needs but also including comprehensive thematic coverage for a Europe-wide boost in demand-driven uptake of space technology and geospatial information.

1.2. Knowledge and innovation in CopHub.AC

CopHub.AC’s overall mission is to establish a long-term Copernicus hub to consolidate and sustain the Copernicus Academy as a knowledge and innovation platform. To realise this mission, several nodes have been created, including interactive web elements showing the distribution and dynamics of Copernicus related expertise and capacities. Figure 1 shows the core activities focused around; (1) **Invent** – visualizing research outcome and the distributed expertise, both in thematic and methodological aspects (2) **Inform** – reaching out to administrations and the public at large (3) **Innovate** –bridging the gap between academia and industry through monitoring innovation and uptake (4) **Interact** – bringing Copernicus Academy members together with stakeholders and users.

Figure 1: Core activities around the Copernicus Academy

[17] Stelmaszczuk-Górska, et al. (2020) Body of Knowledge for the Earth observation and geoinformation sector - a basis for innovative skills development, ISPRS 2020 issue.
[18] J. Robert et al. (2020) https://bit.ly/2P4rzc2: Representational vocabulary is expressed as “essential vocabulary”

One of the main milestones of the CopHub.AC project is to **foster the enlargement of the Copernicus Academy ecosystem through a well-orchestrated set of tools and structures**. One key to success in the market uptake process is knowledge exchange among all actors from the various sectors involved, notably research and educational institutions, industry, and the public sector. To have this exchange a common language should be used. Therefore, one of the proposed tools is the taxonomy. The taxonomy is a reflection of the structure of the services and products; the knowledge that Copernicus networks provide. The taxonomy upgrade is developed within the project under **WP4: Outreach**. It helps to structure the knowledge landscape under all the CopHub.AC processes **(WP3: Innovation & Sustain R&I capacities)** but also categorise the EO thematic perspective and structure to the gateway and the inventory of services from the Copernicus networks **(WP2: Ecosystem)**, including the Copernicus Academy members and the thematic working groups. **WP5: Connectivity** contributes to capacity building measures and expert input and the connexion with other networks. Overall the taxonomy helps to categorize these network activities and as such, forms an essential part of the project (circled in red on Figure 2) and a key element to achieve the project goals stated above.

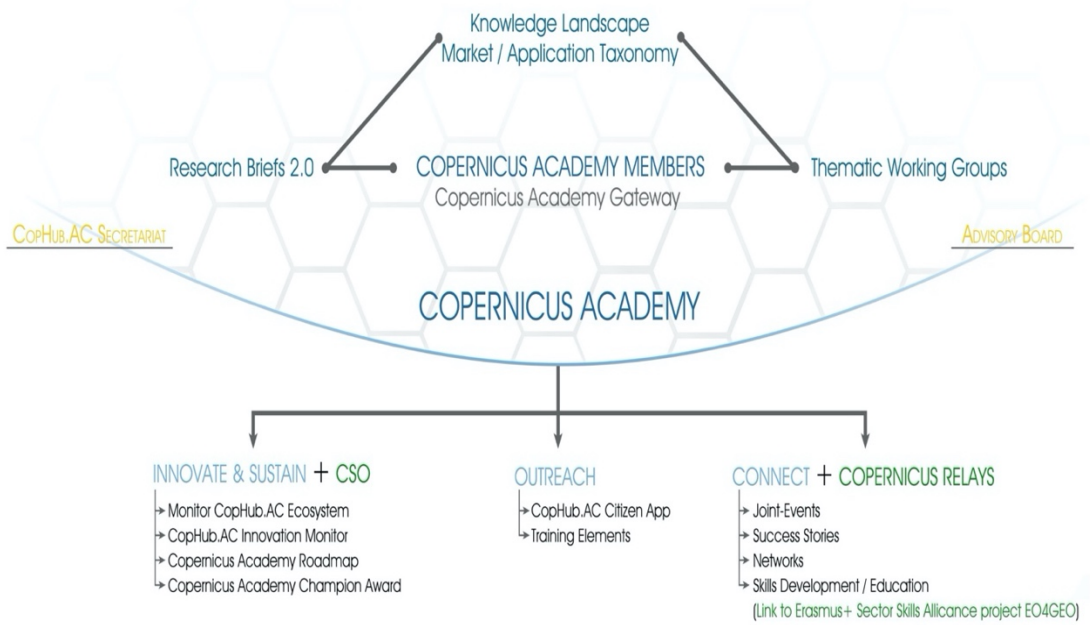


Figure 2: Taxonomy under the CopHub.AC

The CopHub.AC partnership is formed by academia, research organizations, SMEs and industry organizations. Each of these actors brings a unique perspective to the improvement of the taxonomy, i.e. the semantics and the relationships between signifiers like “word types” or “connectors” of the meaning of the geoinformation services needed to reach consensus. An ongoing dialogue with the thematic working groups created under **WP2: Ecosystem** has been established around the taxonomy structure updates through a series of dedicated webinars. The objectives of these sessions were to present the state of the EARSC taxonomy on Earth Observation services, inform the working group experts about the details of this tool, and consolidate the classification and description of EO Services based on the feedback of the thematic experts of the Copernicus Academy (See Section 6: Discussion & communication with other communities)

The presentation of the taxonomy and the exchange with experts from the Copernicus Academy and research institutions serves as a basis for the upgrade of the taxonomy including a more detailed definition of EO services. The assignment of EO services into the different thematic areas was consolidated based on the Copernicus experts' knowledge (fundamentally the experts from the Copernicus working groups). This exchange provided a good platform for discussion around the differing viewpoints on the classification of the different services and scenarios relevant to the community.

1.3. Objectives

This work forms Deliverable 4.3 of the CopHub.AC project. One of the key questions we seek to address through this work is; **how can an end user know what EO services are available that are relevant for their field/activity?**

This document compares EARSC's EO taxonomy with other taxonomies, attempting to harmonise the terminologies used on the market perspective but also the ones reflecting the EO services. For doing so we perform a range of comparisons with these terminologies (See Section **Error! Reference source not found.** Comparison to existing structures).

By providing a coherent structure to the ensemble of EO products & services, CopHub.AC provides a clear and common description of the knowledge landscape and the relationships between the constituent products and services. This will help Relays and Academy[19], and eventually potential users, to arrive at a common understanding of what types of services are on offer. A revision of the existing EARSC taxonomy and its integration has been conducted under EO4GEO project (under the body of Knowledge), providing an example of interaction with other communities, such as the research experts part of the Copernicus working groups, which illustrates the importance of open discussion between the academia & research and industry communities. The overall mission of the EARSC Taxonomy task is twofold:

1) to contribute to project objectives by structuring the EO services of the community as a basis to better understand the interplay between different products/services.

2) to make the landscape of application & market opportunities accessible to a wide range of stakeholders. This deliverable aims to categorize, analyse and assess the available EO services both from the perspective of the supplier and from the perspective of the user/customer, by linking each service to identified user requirements (See Table 17- Definition of EO users); these needs are the main target for developing EO services. Some of those examples are elaborated under the description of the EO services (Section 4.4: Structuring the EO services). A first approach on how to align the taxonomy with other user communities is also provided (See Section : Uptake).

1.4. Document structure

[19] As part of the Space Strategy for Europe, the European Commission has established a network of Copernicus ambassadors: the Copernicus Relays while the Copernicus Academy connects universities, research institutions, business schools, both private and non-profit organisations

The following text gives a brief overview of the chapters and sections that will be elaborated in the document.

- **Introduction** – provides generic taxonomy background, information about the CopHub.AC project and the role of the taxonomy within that, specific document objectives and structure.
- **Terminology and Methodology** – introduces the basic terms used in the taxonomy such as the markets, sectors, domains or thematic areas, technical language used to describe the production of EO services, specific verbs used to describe the actions of the services, and a description of how the same set of EO services form the link between the market and thematic views on the taxonomy. The Methodology sub-section describes the including the process of updating the taxonomy (Definition> Results > Uptake) including the consolidation and feedback from stakeholders. These process elements are expanded upon in subsequent chapters of the document as indicated below.
- **Definition** – provides the approach, the background and rationale of the EARSC taxonomy and the elements for comparison, and correspondences with other similar structures used by other organizations. Answers the questions 'What is the taxonomy?' and 'How do we ensure it remains up to date?'
- **Results** – presents the results of discussions with thematic experts and specifies the updated taxonomy from both Market and Thematic perspectives, providing a rationale for key changes/updates. Outlines the EO services definitions that join these two viewpoints, including the results of the iterative consultations and consolidation provided by experts. Answers the questions 'How the taxonomy was upgraded?' and ' What does the new taxonomy look like?'
- **Uptake** – providing the applicability of the taxonomy in other European projects (e.g. EO4GEO) where ontologies are discussed or international initiatives such as the Agenda for a Sustainable Development (SDGs). Answers the question ' What is the applicability to other communities?'
- **Conclusion** – consolidating the main ideas presented in the document, reiterating the highlights and main findings.
- **Annexes** – Extra information such as references, glossary, EO services structure examples, acknowledges.

The **INTRODUCTION CHAPTER** specifies the context and objectives of the taxonomy but also provides the connection with the CopHub.AC knowledge landscape. CopHub.AC's overall mission is to establish a long-term Copernicus hub to consolidate and sustain the Copernicus Academy as a knowledge and innovation platform. This platform will facilitate communication and interaction between the various communities within the EO landscape such as academic, commercial and end-users. The EO taxonomy update, presented herein, will be useful to ensure a common understanding between these different players, help structure the CopHub.AC information efficiently in the "knowledge landscape", and to help us answer the question: **how can an end-user know that one service indicated in one taxonomy is the same as another service named differently in another?**

To achieve these goals, this document presents a **taxonomy**: a process of naming and classifying the EO services and products as a tool to improve the understanding between communities; and how it is associated with the EO4GEO Body of Knowledge: a process of defining vocabulary, representation of knowledge and making relationships in the EO/GI sector. This taxonomy will contribute to the CopHub.AC project's objectives by **structuring the services provided by the Academy Members as a basis to better understand the interplay between different products/services** and **making the landscape of application & market opportunities accessible to a wide range of stakeholders.**

2. Terminology & Methodology

Service providers and potential end users can better access and use EO services when information about these services is organized into categories and subcategories within a hierarchical taxonomy. A quick review shows that there are many, different taxonomies in use and no standard exists in the EO market today. Of the various taxonomies that exist some are organised around customers and markets and some products and services. Our goal is to provide an update of the EARSC taxonomy, a single unified structure with mapping across both market and thematic perspectives (hybrid approach), to ensure the most complete representation possible. Hierarchical taxonomies require a lot of consultation, research and testing to design well. That is why we highlight the exchange, discussion, and the contribution of the experts to consolidate the outcomes presented herein. This chapter is about the importance to use the same terminology and the way to approach the users.

2.1. Using a common language

Changing something requires understanding it first. For the user uptake, it is necessary to understand why users engage (or do not engage) with the EO services. The quick review in Section 3.2: Comparison to existing structures shows that there are many exercises on taxonomies, but no standard exists today. A particularity of the EARSC taxonomy is the existence of "verbs to define the object" but also the "use of verbs to communicate the actions" that the final users need to understand in the elaboration of the services.

2.1.1. Common language: Approaching the users

Building on a common understanding of the user needs will undoubtedly increase the uptake of EO applications in a wide range of market sectors. Two common gaps are identified that can significantly limit the exploitation of the taxonomy by external users: **the lack of awareness** and the **lack of collaboration between stakeholders**. Taking the first point, this exercise exposes the taxonomy to other communities and provides somehow the definition of the "EO service" and its structure which is commonly applied into the EO terminology and their usage within different market sectors but also with different groups such as the academia and research communities. Consequently, we could progress with the second gap solution engaging these stakeholders in the process.

Based on Bloom et al. (1956)[20] and the recent revision made by EO4GEO partners Hofer et al., (2020b)[21], the assimilation by end users follows the levels of behaviour in learning which classified six levels of cognitive performance. Thus, every process engaging another community should follow a "learning approach" and the six levels of iteration as presented in Figure 3.

[20] Bloom, B. (ed.) et.al. 1956. Taxonomy of Educational Objectives. The Classification of Educational Goals: Handbook 1 Cognitive Domain. Longmans, New York

[21] Hofer, B., Casteleyn, S., Missoni-Steinbacher, E.M., Aguilar- Moreno, E., Albrecht, F., Lemmens, R., Lang, S., Albrecht, J., Stelmaszczuk-Górska, M.A., Vancauwenberghe, G., Monfort- Muriach, A., 2020b: From Tasks to Concepts and Skills - Complementing the Body of Knowledge with a Business- oriented Perspective. Transactions in GIS. (accepted)

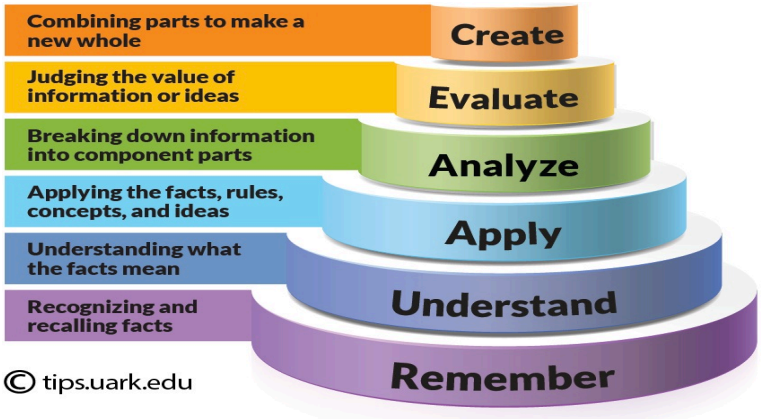


Figure 3: Bloom taxonomy and the engagement with communities.

So, the process will go from "remembering & understanding" to "evaluating & creating". The exchange with the users allows them to reflect on their particular challenges and fully understand why EO services may be a solution for their needs. In the same line of discussion, Schutzberg et al. (2012)[22] evaluates the actions and the skills as the ability to apply knowledge and use know-how to complete tasks and solve problems.

Concerning this common language, in activities where EO data is used there are three main action verbs which collaborate to deliver the "information" as a result; "understanding" the basic parts of a map, and "analysing" the relations with spatial criteria (or "creating" or "applying" EO intelligence in another domain). In this type of discussion, the focus is on the output (from Data to Information towards Knowledge to Wisdom (DIKW)). In Table 2, the example goes from the "processing of the remote sensing data" to "data products" and "information" which are related to the (Level 2)[23] of processing following the DIKW Pyramid adaptation[24] path. Table 2 reflects on the transition from "data to information" some action verbs are "collect, store, process, display" in line with the verbs used to formulate skills needed to deploy different tasks. The section "knowledge to wisdom" corresponds to other action verbs such as "analyse, evaluate, create, apply" developing a shared understating from "the needs to the solution".

Table 2- Data Information Knowledge Wisdom

DIKW	Question	Description
Data & Information	**What** data?	Refers to geospatial data content, including its quality and usability. How the data is consistently (temporally/geographically) collected and how it is "made" with a certain the level of accuracy and confidence (spatial, temporal and spectral resolution). The validation and uncertainty assessment is a crucial requirement from the end-user perspective of a satellite data product (Otto et al., 2016)[25]. For the "land" domain Justice et al., (2000)[26] defined the validation of data as "the process of evaluating (by independent means) the accuracy of satellite-derived land products and quantifying their uncertainties by analytical comparison with reference data".

[22] Schutzberg et al. (2012) http://blog.abs-cg.com/2012/06/flipping-blooms-taxonomy-in.html
[23] Classification levels L2: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/processing-levels/level-2
[24] DIKW Pyramid adaptation Commons Wikimedia.org (https://en.wikipedia.org/wiki/DIKW_pyramid)
[25] Otto et al., (2016) https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017RG000562#rog20135-bib-0090
[26] Justice et al., (2000) https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017RG000562#rog20135-bib-0055

Knowledge	**How** and what type of access?	Final or intermediate users request the information be structured in some meaningful way so as to convey facilitate decision making. The data are represented in such a way, e.g. accessing and integrating the defined data layers to produce geospatial information, developing data models as to allow a justifiable belief in the user, through which decisions can be made.
Wisdom	**Why** the user needs that information? What type of EO user?	It is related to the user of the information products derived from the data (as well as data models) across vertical markets but also amongst key user communities. The wisdom generated through the EO data service provision is the justifiable belief in the state of the world, based on the knowledge generated from the data, from which sound decisions can be made.

Ideally, verbs indicating concrete actions should be used to describe the tasks to be performed during the process of producing the EO service from the "processing" to the "distribution". Users will be capable of exploiting such verbs facilitating the identification of service steps and its structure. The section on "actionable verbs" below introduces the most commonly used verbs when defining the EO services.

2.1.2. Common language: Building EO services (data and products)

Following Hartman et al. (2016)[27], we found key definitions to improve the descriptions and manipulation of the data and its use to produce value-added products from the raw data involving the typical workflow for any EO data user (data collection, processing, analysis, distribution and use). The EO services consist of a portfolio of different products that are derivatives of the data provided by the space component, modelling, or in-situ data. Herein the EO services (defined here as delivering a specific type of analysis) and applications (defined herein as delivering that analysis applied specifically to one region/user or time) are defined as being built by products and parameters or essential variables (see Section: 2.1.4: Taxonomy definitions). To better understand the EO products, the following sub-sections will outline the (pre-)`processing stages and the language adopted in this report to describe EO services.

2.1.2.1. Data collection

Data collection and discovery of the dataset (understanding the data and the content, its downloading or working on the cloud with the corresponding imagery) is done on demand through planning with suppliers.

2.1.2.2. Data processing

To turn data into knowledge (data into EO service), first the observational data need to be acquired by satellite instruments and downloaded to ground stations in a raw format. These pre-processing levels are described in Table 3 (drawn from the ESA[28], WMO [29], NASA[30] USA data center[31] definitions.

[27] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017RG000562
[28] https://business.esa.int/newcomers-earth-observation-guide
[29] http://www.wmo.int
[30] https://science.nasa.gov/earth-science/earth-science-data/data-processing-levels-for-eosdis-data-products
[31] https://nsidc.org/the-drift/2013/08/is-it-1b-2-or-3-definitions-of-data-processing-levels/

For example, "pre-processing" strictly speaking refers to data preparation on L0-L1, while L2-L4 corresponds to "processing". Overall data processing[32] includes pre- and post-processing of imagery into usable products (creating a spectral and/or spatial subset), registering the data to a geographic projection and removing atmospheric distortions.

Table 3- Definition of processing levels (pre-processing & processing)

<table>
<tr><th colspan="3">Category</th><th>Level</th><th colspan="2">Definition</th><th>Description</th></tr>
<tr><td rowspan="2">pre-processing</td><td></td><td></td><td>0</td><td rowspan="4">Data preparation levels[33] (L0-L2)

Transforming data into a form suitable for analysis, including operations such as atmospheric correction, cloud detection and radiometric calibration</td><td>Raw telemetered data</td><td>Unprocessed instrument (raw) data (removed communication artefacts)</td></tr>
<tr><td></td><td></td><td>1</td><td>Instrument data extracted, geolocated and calibrated</td><td>1A) prepared for geolocation and radiometric calibration. Product resampled onto a cartographic grid. Reconstructed, unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters
1B) geolocation and calibration. Data processed to sensor units (e.g. brightness temperatures // data corrected for instrumental and geometrical effects)
1C) instrument specific (e.g. brightness temperature (IR) or Reflectance factor (VIS)…)</td></tr>
<tr><td rowspan="2">processing</td><td></td><td></td><td>2</td><td>Data corrected for geophysical (cartographic) effects</td><td>Derived geophysical parameters at the same resolution and location of the source data (referenced & calibrated) (e.g. sea ice concentration, land and sea surface temperature (SST), precision images and mosaics, humidity, radiative flux, ocean colour, quality index)</td></tr>
<tr><td>value added</td><td>big data analytics</td><td>3</td><td colspan="2">Composite products based on space-time grid</td><td>Ortho-rectificied data acquired during a certain period of time. Quantity retrieved from single instrument data. Variables mapped on uniform space-time grid scales, usually with some completeness and consistency. (e.g. mosaic, maps (temporal & spatial interpolation)</td></tr>
</table>

[32] data processing services include: orthorectification, atmospheric and radiometric correction, cloud free image mosaic generation, datacube productions, ancillary data formatting and fusion, multiscale, multi-source image analysis, quality validation procedures, geographic analysis, modelling procedures, automated dissemination mechanisms

[33] https://www.e-education.psu.edu/geog480/node/497

		information products	4	**Composite multi-sensor** and/or **multi-satellite product**	Model output, results or variables derived from multiple measurements or from analyses of lower-level data (e.g., variables derived from multiple measurements or model analysis) *(e.g. ocean primary productivity, or the production of a flood map which depends on land surface imaging, various wind speed measurements)*

The ESA ground segment[34] website describes "**pre and processing data information**" as the **data** that includes the imagery transmitted from the satellite to the ground receiving Earth station, plus the effort associated with conditions (cloud cover, snow, look-angle), or the products such as stereo imaging and basic corrections (radiometric, geometric). The pre-processing products result from calibration, geolocation, remapping and dynamics adjustment of Levels 0-1 data and the imagery products are used for further processing. Some processing is nowadays automated involving different processing steps, such as orthorectification, bundle block adjustment, radiometric adjustment and topographic normalisation. Those are data streams right through to the extraction of ready-to-use geo-information products.

2.1.2.3. Data analysis

Data analysis and interpretation are often considered under processing, covering the full range of activities on analytical work, aggregation where the combination with other information such as environmental data layers, model outputs or in situ data is done, the visualisation or distribution of data. In the previous Table3, the generic term of **value adding products** corresponds to the Levels (L2-L4) where processing and applications transform raw data into information. **Big data analytics** includes the processing and application-specific analysis of multiple images and a wide variety of datasets to extract information not apparent in the base data input (L3). These products often include an analysis of a given area over a period of time permitting the extraction of trends, or an indication of changes and developments and (L4) is represented by **information products** include processing and applications-specific analysis that add (typically) domain-specific value to the information. At these levels, imagery cost represents an essential, but not major, a portion of the final product and /or service (integration of datasets) (L4) price. Table 4 represents the data analysis section focus only on the analytical component.

Table 4- Data analysis categories

Category		**Description**
Processing	**Analytics - Descriptive**	Providing analytical results which describe the past and present situation by ctual measurement (what happened?) *[e.g. generic maps, derivation of NDVI, derived elevation (terrain information, topographic), deformation & displacement (near surface geology, change detection, continuous monitoring), detected features (land use, land cover), …]*

[34] Commercial Ground Segment at ESA

	Analytics - Predictive	Providing analytical (modelling, insight, what will happen?) results which estimate missing values by interpolation techniques or predict the future situation *[e.g. forecast (air quality/pollution), estimate fluxes, climate forecasting…]*
	Analytics - Prescriptive	Providing analytical results which (foresight, how can we make it happen?), it is about decision support and automation, stipulate a guide to an action *[e.g. actionable as construction sites leading to sales opportunities (impact assessment, route planning, optimization, …]*

Data providers produce accurate geometrically and radiometrically optimised data products in the required formats and specifications ready for the analysis. The actual analysis is done by service providers or experienced users with the relevant expertise and technical skills.

2.1.2.4. Data use

The resulting geo-information products may consist of a combination of reports, statistics or maps with actionably purposes, reflected in the thematic domains, consequently the thematic taxonomy is bridging the experience form the service provider for a particular need or challenge directly to the user "integrate data easily, geographically enhance information, increasing the power of information by merging data and publishing the enhanced data for its final use".

The data use under specific usage and license agreements often depends on aspects such as data aggregation, visualization and distribution showed in Table 5.

Table 5- Data use categories

Category	Description
Aggregation	Combining the satellite data with other information sources *[e.g. integrating information, GI, parameter model, thematic compilations…]*
Visualisation	Creating visual representations (online tools) that helps to see and understand what data represent. These correspond to the Platform-as-a-Service (PAAS) business model[35] and provide users with an environment (incl. tools and software providing a ready-to-use toolkit that gives the user all the necessary software for the handling, exploratory analysis and visualization of large volumes of time series data within a single framework) where they can discover, visualise and process Earth Observation data (platforms) *[e.g. models (web visualization (2D,3D), urban block models, …]*
Distribution	Providing access to data, via direct download, application programming interfaces *[e.g. API or web services, hubs, thematic platforms, DIAS…]*

[35] EO service providers business models by EARSC (see Annex): Data-as-a-Service (DAAS), Platform-as-a-Service (PAAS), Information-as-a-Service, Software-as-a-Service (SAAS), Software products, Provision of value-added geospatial information product(s) , Provision of other (non-geospatial) information product(s), Consulting.

2.1.3. EO services descriptions – standardised verbs

In a former version of the EARSC taxonomy[36], we have introduced a standard set of five verbs to describe the needs of the user (and eventually the service on offer): **assess, detect, forecast, map, and monitor**. Based on interactions with NextGEOSS project, in this revision we have added the sixth verb "analyse". Table 6 below represents the correspondence of these actionable verbs with the Bloom taxonomy providing definitions by which those were adapted to the EO domain and the market sectors. Note how value-added services are increasing in complexity from the detection and mapping to analyse and assessment.

[36] EARSC taxonomy work (http://earsc.org/news/a-taxonomy-for-the-eo-services-market-enhancing-the-perception-and-performance-of-the-eo-service-industry)

Table 6- EARSC taxonomy Standard verbs & comparison with Bloom & DIWK

Value added	Bloom taxonomy	DIWK	EARSC Taxonomy Verbs	Alternatives / Equivalents / Synonyms	Definition
+	**Create & Evaluate**	**Wisdom**	**Assess**	evaluate, create, understand, review, quantify, report	to watch and check a situation carefully for a period of time (not a one-time event) to discover something about it (evaluate and create is a selective exercise that attempts to systematically and objectively assess progress towards, evaluate knowledge and learning during the effort to achieve an outcome.
	Analyse & Apply	**Knowledge**	**Forecast**	predict, plan, model, estimate, project	to provide statements covering a range of different outcomes, to say what you expect to happen in the future (predict future events based on specified assumptions)
			Analyse[37]	apply, process, parse, detail	to study or examine something in detail to discover more about it (apply knowledge by detailing the elements and critically examine and relate these parts separately and/or concerning all the process)
		Information	**Monitor**	understand, track, observe, record, follow	to watch and check a situation carefully for a period of time in order to discover something about it (keeping track and understand how the natural and manmade environment change (status of) over time, it is continuing function that aims primarily to provide the management)
	Understand	**Data**	**Detect**	recognize, identify, warn, highlight, spot, measure	to notice something that is partly hidden or not clear, or to discover something, especially using a special method
–	**Remember**		**Map**	understand, locate, classify, trace	to represent an area of land in the form of a map (a feature the way it is arranged or organized)

2.1.4. Taxonomy definitions

This section provides definitions of the various terms used in the EARSC taxonomy structure. The structure is based on two main approaches: *market* and *thematic*. The **thematic approach** reflects the technician/expert view on the services, while the **market approach** reflects the customer view. This perspective bridges both communities **"Markets" (users)** & **"Thematic" (providers)** around the same complete set of EO services. These two communities naturally use different terminologies to describe the same services. In generating the taxonomy, we have tried to recognise the difference between a

[37] Analyse has been inserted in this revision of the taxonomy

client-side a description of the service and a **supplier-side** description. The terminology used to describe this approach is presented below and summarised in Table 7.

EO services sector revenues can be broken down into value-chain segments. In our exercise, the "market" oriented approach focuses on the markets the company serves instead of the products and services they make. We use the term **"markets" to describe the first level** of distinction of customer types, e.g. between public authorities and industrial users. These markets are then broken into economic industry groups with activities sufficiently similar in their economic behaviour for economic monitoring and analysis[38], e.g. the Industrial market is broken into "communications", "transportation", "marine & maritime", "utilities" and "construction". **This second tier groups in the market view are termed "Sectors"** (see a full list of all markets and sectors for the updated market view on the taxonomy in Table 16).

The semantic dimensions to be embedded in the **thematic view** include structure and representational granularity. We also had some pragmatic reasoning, identifying whether the taxonomy is descriptive[39] (providing information and responding to the question 'what?') or prescriptive[40] (affecting the structure and responding to the question 'how?'). The thematic taxonomy view also follows a hierarchical classification scheme and it will be a building block to be integrated into more advanced ontologies, such the case for the EO4GEO Body of Knowledge (BoK) discussed in Section 5.2: Taxonomy adoption under EO4GEO.

The Thematic approach focuses on the application areas in which EO service providers consider their service to reside. The differentiation between these **first order Thematic classification, termed "Domains" (or "Themes")** can be thought of in terms of how the developer sees their expertise being applied. For example, while applications to identify ships at sea and ground motion both exploit SAR technology, or climate scientists and air pollution specialists both use data on the atmosphere, the individuals doing these tasks would consider their expertise and area of applications to be very different. Within these domains too, experts' knowledge is grouped according to more precise areas of expertise. **Under the thematic view on the taxonomy, these second order groupings are described as "Areas" (or "Segments")**, e.g. within the Atmosphere & Climate Domain, expertise is classified under the Areas of climate, atmosphere and meteorology (see a full list of all Themes and Areas in the 2015-2019 version of the taxonomy, and the updated 2020 Thematic taxonomy Domains and Areas in Table 19).

These two viewpoints converge on the EO services, as shown in Table 7 below. These services form the 'bottom layer' where the Market and Thematic views on the taxonomy converge. They must therefore only be described once (See Section 4.4: Structuring the EO services). Within this work, the EO services will be presented in relation to the thematic view as major discussions have been conducted with the Academia and Research communities which are more oriented towards the expert view perspective.

EO services are described presenting a set **keywords** which define the **services** (See Section 4.4: Structuring the EO services for detail on the keywords for each service defined within the taxonomy). Services are defined here as being comprised of the following elements:

[38] OECD, Guidelines for Collecting and reporting data on research and experimental development © OECD 2015(https://bit.ly/2SYSgzU)
[39] (details/describing/classifying) an organizational scheme for classifying the structure of conditions for learning describing the approaches, methods, and goals of instruction (ref https://www.igi-global.com)
[40] (imposition /enforcement) organizational scheme for specifying the optimal and appropriate approaches and sequence of instruction to achieve corresponding specific learning objectives and desired performance outcomes (ref https://www.igi-global.com)

Parameters or **essential variables:** the information elements derived from EO data, the key parameters of the Earth and the environment, e.g. Chl_a and water temperature

Products: The output of a service, e.g. a map or a report that is of direct use to the user, e.g. a map of harmful algae distributions

Application: The application of a service to the specific needs of one (community of) user(s), e.g. a service that can detect harmful algae is trained and run on the Eastern Mediterranean, forming the Eastern Mediterranean harmful algae detection application.

These elements of the taxonomy fit together as shown in the following Tables: Table 7 shows the hierarchy of the terminology used while Table 8 shows how the EO services form the bridge between the market and thematic views on the taxonomy – both views ultimately describe this same range of services.

Table 7: Descriptive levels used in the EARSC taxonomy

Level 1	DOMAIN (Theme)	Markets	describes the first level of distinction of customer type or broad market
Level 2	AREA (Segment)	Sectors	Describes the customer type or market in more detail
Level 3	EO Service (SERVICE)		Merge of EO and model or in-situ data that provides an
Level 4	EO Application		Specific for a geographical area, timeline, etc.
	Products		Describe tangible satellite-based data products
	Parameters & Essential Variables for the land, atmosphere and ocean		Information elements derived from EO data key parameters of the Earth and the environment

Table 8- One taxonomy, two perspectives, one communality (EO services)

<table>
<tr><th colspan="6">EARSC TAXONOMY</th></tr>
<tr><th colspan="3">MARKET (User) perspective</th><th rowspan="3">EO SERVICES
(3rd level)

The special nature of EO services is their composing ability. The EO services gather the information and data for a particular object. This characteristic allows the composition of service chains that tackle the necessity of solving complex business procedures supported by technological platforms. The EO services propose an action or a sequence of actions, specific events appropriate in a given situation geographically or temporal (an application) for example, “assess the environmental impact of farming in the region of Murcia”. For example, it unifies major entities such as environment, agriculture or deeper on granularity such crops. The description of the EO services include the products which make up a service but also key words representing the parameters or essential variables.</th><th colspan="3">THEMATIC (Provider) perspective</th></tr>
<tr><th colspan="3">Customer and User (view) ⟹</th><th colspan="3">⟸ Technician and Expert (view)</th></tr>
<tr><td colspan="3">-Structures the market from the customer point of view
-Based on customer segmentation
-Identify the type of organisation that fits into each one
-Helps associate types of users with their requirements</td><td colspan="3">-Structure of the EO domain from a technical approach
-Based on an expertise view
-Seek to gather EO services into groups
-Add meaning & insight to each service</td></tr>
<tr><th colspan="2">1st level</th><th colspan="2">2nd level</th><th colspan="2">2nd level</th><th colspan="2">1st level</th></tr>
<tr><td>MARKET</td><td>Responds to the highest rank in the market perspective, describes a part of the economic activity, it is a group or groups of customers who require the products and services provided by industry. Understand the major markets in which EO services are doing business. These major markets structure prove sufficiently robust to accommodate future sector segments. We can cite as an example the market super-category “managed living resources”.</td><td>SECTOR</td><td>It provides some granularity introducing a group of business activities (industry activities) that have similar characteristics. For example (agriculture, forestry and fisheries) all in the primary sector and helping to define the type of customers.</td><td>AREA</td><td>Is the set of EO services (greater detail of objects) with similar characteristics and associated patterns. There corresponds to thematic segments in each of the domain. For example, objects to be monitored in built environment such as urban areas, infrastructure, transport, or waste. It may be also named as a segment.</td><td>DOMAIN</td><td>Responds to the highest rank in the thematic perspective, categorises by type of activity for which the observations are being made ie, risk assessment, forecasting, responding, monitoring, detecting etc. for a particular domain. We propose 6 domains (atmosphere & climate, build environment, disasters & geohazards, land, marine, security & safety). It may be also named as thematic.</td></tr>
</table>

2.2.Methodology

2.2.1. EARSC Taxonomy approach

As indicated in the Introduction, there are many types of taxonomies described in the literature, including hierarchies, classification schemas, controlled vocabularis, etc. The existing EARSC taxonomy, developed in the period 2015-2019, could be best described as a hierarchical classification approach. By structuring products and services in an agreed-upon way, potentially using a taxonomy, the CopHub.AC project will provide a common description of the knowledge landscape and its EO products and services to all stakeholders and this will help Copernicus networks to arrive at a common understanding of what can be offered. Such a list of a hierarchically ordered number of categories and provides a range of benefits such as:

- Categorisation of content
- A process of naming and classifying EO services and products
- A tool to improve the understanding between communities
- Helping to associate various types of content to influence the potential customers
- Adding meaning and insight to each service
- Assisting future content knowledge strategy

The first and second level groupings (markets/sectors and domain/areas) for the two viewpoints on the EARSC taxonomy from which we begin this study, i.e. the taxonomy developed from 2015 – 2019 are shown in Table 9 (shown again and contrasted with updated versions in Table 16 (market) and Table 19 (thematic).

Table 9- Taxonomy overview levels (2015-2019). EO services as communality

MARKET		EO SERVICES (3rd level)	THEMATIC	
MARKET (1st level)	SECTOR (2nd level)		AREA (2nd level)	DOMAIN (1st level)
Managing Living Resources	Agriculture fishing forestry	EO services from both the markets they serve and the thematic areas they represent. EO services will help suppliers and customers arrive at a common understanding of what can be offered. services defined each of which offers several products.	climate atmosphere meteorology	Atmosphere & Climate
Energy & Natural Resources	alternative energy oil& gas minerals & mining		floods landslides volcanos fires earthquakes	Disaster & Geohazards
Industrial	communications transportation marine & maritime utilities construction		agriculture inland water snow & ice topography geology land forests land use	Land
Services	real estate management insurance & finance retail & geo-marketing travel, tourism & leisure news & media		urban areas infrastructure	Built Environment
Policy Authorities	local & regional planers education, training & research security, defence & military emergency		metocean coastal marine ecosystem fisheries sea-ice ships	Marine & Maritime

International Bodies	environmental pollution & climate humanitarian operations & health		security	Security

2.2.2. EARSC Taxonomy update: Steps and sections

The goal of using a taxonomy is to improve the ability for interested parties to identify relevant content in a large collection of content, so the first levels should embrace a collection of other levels, providing the structure for more granular classifications, i.e. a hierarchical approach. Each taxonomy must, however, balance the need to be specific and also not overwhelming when choosing the number of level areas. The challenge in a taxonomy is to help users find and use the right information efficiently and effectively. So, the methodology for creating and updating a taxonomy should respond to the questions: **what this taxonomy is and how we ensure it remains relevant; how was the taxonomy upgraded and what it looks like now; how does the upgraded taxonomy align with the needs of external communities.** These questions are addressed through four specific steps in the methodology as shown in the Table below.

Table 10- Methodology steps and sections

STEPS	Methodology	Description	Questions
1	DEFINITION	Review bibliography of the existing taxonomies oriented towards user uptake (literature search, documents based on legacy of taxonomy including correlations and correspondences)	What is "the taxonomy" and how do we ensure it remains up to date?
2	RESULTS	Exchange & discussion with stakeholders to; a) Define and refine the high-level areas in the EARSC taxonomy concerning market (user) and thematic (application) perspectives and growing the level of detail and granularity with subgroups for better EO service classification. b) Reflect on the state and health of the sector to reflect changes on the levels of granularity using the market observatory. c) Provide findings on the EO services structure complemented with key information on the scope of thematic areas and the relation between them.	How was the taxonomy upgraded? and What does it look like now?
3	UPTAKE	External communication. Uptake and replication from users.	What is the applicability to other communities?

The first step in defining a successful taxonomy is ensuring that sector stakeholders understand what it is and what it is used for. The **DEFINITION** phase shows the general approach of the EARSC taxonomy and gives a rationale for the two-sided view that defines it through i) a discussion on the complexity of aligning the viewpoints of users and suppliers in one approach and ii) by comparison to a range of other, existing taxonomies (Copernicus, H2020 projects, commercial services…). This section also presents how we will ensure that the taxonomy remains continually updated and relevant (living document), through incorporation of user feedback and planning or regular review cycles. This section addresses the question "what is the taxonomy?".

The next step in upgrading the taxonomy is to discuss with relevant stakeholders, in this case the EO service providers, to ensure that we i) include all services on offer in the market, and ii) have accurate descriptions for each service. The **RESULTS** of these discussions with sector experts and the resulting relationships between the EO services are presented as **the updated taxonomy**. These results are presented for the **Market**, and **Thematic** viewpoints, with a dedicated section on the structuring of the third level, the **EO services**, as part of the Thematic viewpoint.

The third step in defining an EO taxonomy is to ensure that the results are applicable for the full range of stakeholders in the ecosystem. To this end, the **UPTAKE** section presents the applicability of the updated EARSC taxonomy to the CopHub.AC, EO4GEO and SDGs communities.

The **TERMINOLOGY & METHODOLOGY CHAPTER** presents a detailed definition of terms, concepts used in the taxonomy and provides the methodological approach for its update.

Using a common language section is integrated where the Bloom taxonomy is used for a reflection on the best way to **approach the users** providing hints for an engagement focus on user requirements as part of the communication with the user communities. This section includes the first set of verbs used describing the EO services (object to be observed). **Using a common language** section keeps the stress on the **action's "verbs"** responding to these user needs and the importance of engaging the users in the process to fulfil the requirements and provides the first link on the language to be used for the assimilation and uptake of the EO services. Understand to act!. The EO services section likewise elaborates from the data collection to the data use.

The chapter also provides a set of **definitions** and the first introduction to the **taxonomy** and the **methodology** which introduces the steps for revision and update of the taxonomy from the identification (and creation), through the discussion with the stakeholders, completing with the results and findings and concluding with the uptake.

3. EARSC Taxonomy definition

This aspect of the taxonomy update work addresses the question '**What is the taxonomy**?' by analysing the approach taken and the key choices made in the development of the EARSC taxonomy and comparing it to other taxonomies used in this sector. This section outlines not only how the taxonomy is structured and comprehensive in its broadest sense, but how se can ensure that it remains so going forward.

3.1. The case for two viewpoints

Each of the perspectives of the EARSC Taxonomy is composed of several major divisions, called **thematic domains** and **major markets**, which are further divided into **thematic areas/segments** and **market subsector/segments**. The first level of the taxonomy in both views (market/thematic perspective) is shown in Figures 4 & 5. These figures represent the EARSC taxonomy for the period (2015-2019)

Figure 4: EARSC Market taxonomy (2015-2019)

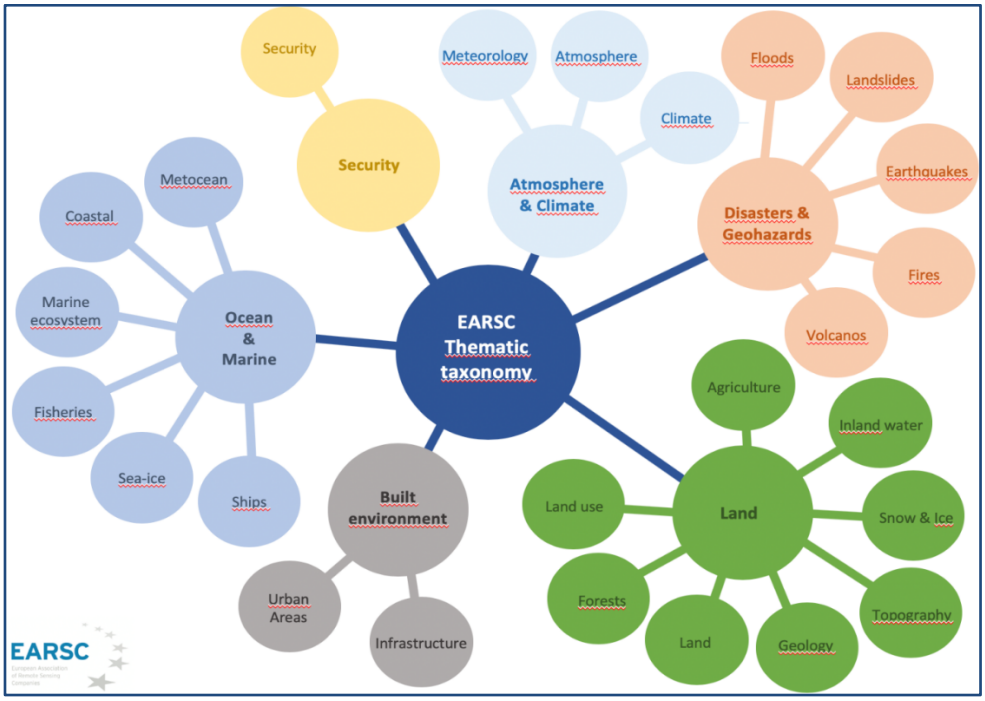


Figure 5: EARSC Thematic taxonomy (2015-2019)

These two approaches to taxonomy in the EO sector are complementary, as they provide two different ways of looking at the EO services. Trying to overpose and see any alignment, Figure 6 shows the complexity of attempting to fully describe connections between these two viewpoints. Many services,

for example, from the thematic perspective cross over the market services, especially those related to industrial, services and policy authorities. Such a level of complexity disrupts several of the key goals of a taxonomy, namely the goals of improving understanding between communities and providing clear descriptions – See Table 1). Therefore, the authors are convinced that keeping market and thematic view on the taxonomy separate, providing the richness of different perspectives from which is looking at the EO service, is for this sector the most pragmatic and smart solution.

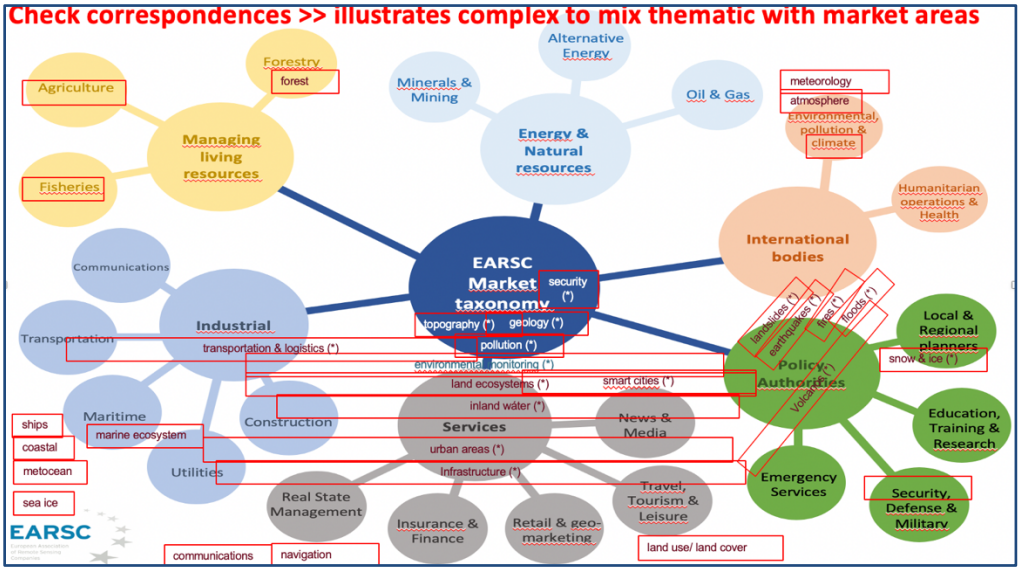


Figure 6: Correspondences market and thematic taxonomy

3.2.Comparison to existing structures

This section presents results of a comparison between the EARSC taxonomy and both perspectives (market and thematic) and other taxonomies such as the proposed by the Copernicus Entrusted Entities[41], GEO Societal Benefits Areas (SBAs)[42], a range of approaches related to International Financial Institutions grouping, commercial service provider self-descriptions and H2020 research projects descriptions. At the end of each section Pros and Cons of using the structures is included. It is to note that of the various taxonomies that exist some are organised around customers and markets and some products and services. Each is useful and our goal is to provide a single unified structure with a mapping across to switch between the two perspectives (market and thematic).

3.2.1. Copernicus Entrusted Entities taxonomy

Copernicus, through its EU Earth Observation Programme[43] offers value-adding activities streamlined through six thematic streams of Copernicus services: atmosphere, marine, land, climate change, security and emergency. The EARSC taxonomy accommodates the structure within the Copernicus Programme. Figure 7 shows the alignment of Copernicus services with the EARSC thematic taxonomy and it is in this visualization where we reflect on the first difficulty users are confronted with as those are intrinsically represented in the market taxonomy. It is the first recognition we do have that

[41] The implementation and operation of Copernicus have been delegated by the European Commission to a number "Entrusted Entities" which act as service providers. These delegated entities regularly publish Tenders through which third-party organisations can be involved in the implementation and operation of the programme (https://www.copernicus.eu/en/frequently-asked-questions)
[42] GEO Societal Benefits Areas (https://en.wikipedia.org/wiki/Societal_Benefit_Areas)
[43] Copernicus EU programme services (https://www.copernicus.eu/en/services)

Copernicus services are not focused on the "uptake" language of the users. The EARSC taxonomy provides a similarity of EO services plus the segment dedicated to "Built Environment" which is not present at the Copernicus Services and those are implicit under "Copernicus land services", so the EARSC taxonomy proposes more specialization. Nevertheless, Copernicus is dealing primarily with public sector information needs and hence a workable taxonomy must go beyond Copernicus since many other elements of the market are not addressed. The Copernicus services should influence the future market for EO services, however from the 6 services we see them more oriented to the "service provision" than the "uptake". Therefore, we propose this wide view and check the thematic perspective from each of the Copernicus services.

All of the Copernicus services are integrated at the 1st or 2nd level of the taxonomies, so we assure a good matching using, especially the thematic taxonomy to categorize the CopHub.AC knowledge landscape. In our update activity, we do anticipate a simplification on the market taxonomy suggesting different levels of detail.

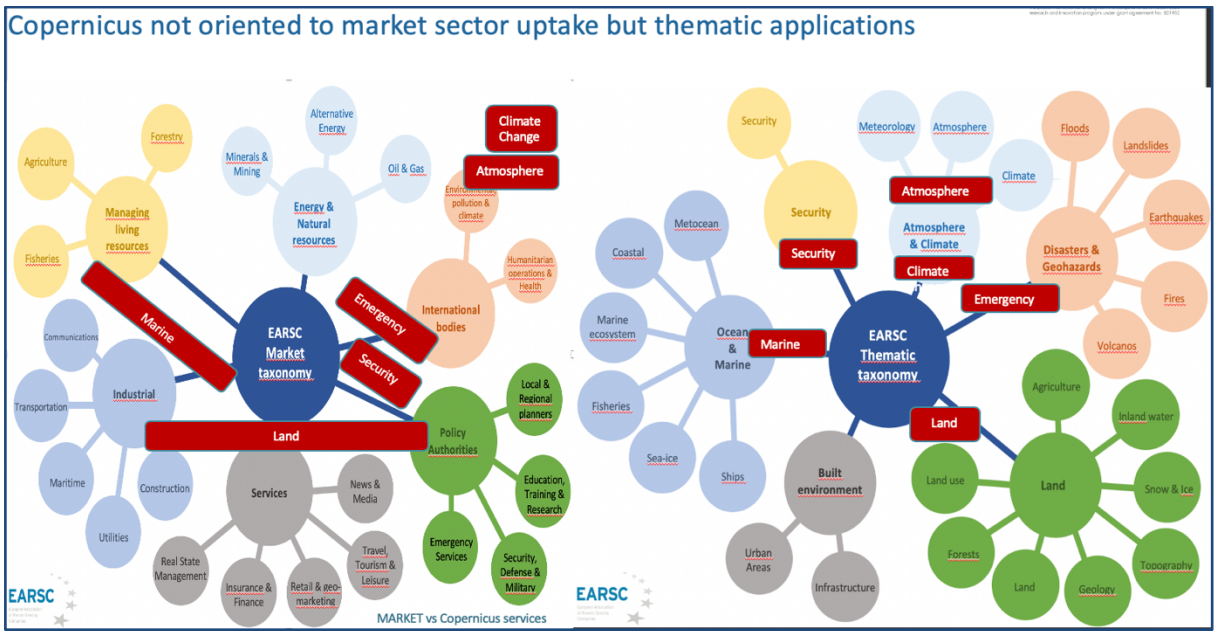


Figure 7: Correspondences market and thematic taxonomy vs Copernicus

The implementation and operation of Copernicus services have been delegated by the European Commission to dedicated service providers - the Copernicus Entrusted Entities- through a series of "Delegation Agreements" signed during the period November 2014 – October 2016. These "Entrusted Entities" are responsible for the delivery of the Copernicus Services. Note that Copernicus products[44] are not presented in Table 11 where only classifications of the Copernicus services offer are provided and presented in their respective websites[45]. Though, Copernicus services are fitting soundly with the EARSC taxonomy:

[44] Example Marine Service Products: Temperature, salinity, sea surface high, current velocity, mixed layer thickness, sea ice, wind, plankton, oxygen, nutrients, primary production, reflectance, transparency, turbidity, sea surface wave. Example of Emergency Service Products: Example of Products:
Mapping (Floods, Tsunamis, Earthquakes, Landslides, Fires, Severe Storms Volcanic eruptions Technol. disasters Humanitarian crises). Early warning: Flood Awareness System, Wildfire Information System, Drought Observatory

[45] websites checked in October 2019

- **Marine environment monitoring** incorporating services for information on the state of the oceans and regional seas and its resources. Addressing main domains such as marine resources, coastal ((e.g. water quality, pollution, coastal activities, …), metocean, marine surveillance.
- **Atmosphere monitoring** providing data records on atmospheric composition for recent years, current data for monitoring present conditions and forecasting the distribution of key constituents for a few days ahead. The offer stands to information on greenhouse gases emissions, UV radiation, ozone, overall aerosols, which affect temperature, air quality and the transmission of solar radiation, etc.
- **Climate change** services are included in the section Atmosphere and Climate due to the strong relation, as those monitor, forecast and provide data – and historical data for comparison - about greenhouse gases and aerosol concentrations.
- **Land monitoring** including a wide range of applications for use in land use / land cover change, thematic spot mapping (soil sealing, water quality and availability, spatial planning). It also covers services for ground displacement, deformation of infrastructures, etc.
- **Security** services aim at supporting the related European Union policies in the following priority areas; Border surveillance, Maritime surveillance, Support to EU External Action.
- **Emergency management** covers a wide range of emergencies resulting from natural or man-made disasters providing mappings or early warning situations.

The Copernicus services are oriented to thematic component providing the views of experts to align with the needs of the users. The EARSC thematic perspective is in full alignment with this vision but prevents this Copernicus orientation towards experts and not users needs more associated with the market (user) taxonomy. The market perspective should be more focus on the uptake and the thematic follows the request of the services providers adding a description of the services. More reflection on the Copernicus services is addressed under the section Structuring the EO services.

Table 11- Copernicus services[46]

Copernicus Marine Environment Monitoring	Copernicus Atmosphere Monitoring	Copernicus Land Monitoring	Copernicus Climate Change	Copernicus Security	Copernicus Emergency Management [47]
marine resources	air quality & atmospheric composition	systematic monitoring of biophysical parameters	assessment of climate change impacts	border surveillance	mapping component
coastal & marine environment	policy protocols	land cover and land use mapping	risk management for commodity trading	maritime surveillance	early warning component
atmosphere / ocean impact	solar energy (radiation)	thematic hot-spot mapping	sustainable water management	support to EU External Action	
marine safety	ozone layer and UV radiation	imagery and reference data			
scientific mediation /education	emissions & surface fluxes	ground displacements, inc. landslides & subsidence, deformation of infrastructure			
	climate forcing				

Copernicus Services Structure. Pros (+): downstream services tailored to the specific needs of Copernicus users generically in the public domain. Cons (-): Missing the uptake component for dedicated services in other market sectors not identified outside the major 6 domains. The EARSC taxonomy in the thematic perspective offers alignment with the full set of Copernicus services.

[46] Website references were in November 2019 using the Entrusted Entities and Copernicus.eu website
[47] emergency management cycle: preparedness, prevention, disaster risk reduction, emergency response and recovery

3.2.2. GSA taxonomy

The GSA`s[48] GNSS market taxonomy (shown in Table 12) presents a range of segments that map well to the EARSC thematic segments, such the ones on living resources (agriculture, forestry), natural resources (energy), industrial (infrastructure, maritime), services (insurance), policy authorities (urban development) or international bodies (environment and security). It also, quite naturally, contains a range of other markets, such as aviation, rail, drones, automotive, geomatics and situational services where EO services do not provide a relevant contribution, but where positioning EO services are important. This taxonomy does include a market that is becoming more of relevance to the EO market, i.e. Consumer solutions. Table 11 reflects this correspondence matrix EARSC and GSA taxonomies, but also instigate another consideration on the policy authorities and international bodies who are not presented but embedded on the use of the market. The **GSA taxonomy Structure**: (+) oriented to users independently from the category (public/private). (-) misleading with the thematic (and experts) component while the EARSC taxonomy on the market perspective is focused only on who is using the EO services.

Table 12- Correspondence with GSA

EARSC market taxonomy		EARSC Thematic taxonomy		GSA taxonomy
managed living resources	agriculture fishing forestry	atmosphere & climate	climate atmosphere meteorology	• Agriculture & forestry • *Automotive* • *Aviation* • Consumer services: LBS, leisure, tourism, health • Emergency management & humanitarian aid • Energy & mineral resources: renewable energy, O&G, mining & raw materials • Environment & climate: env compliance, climate change monitoring & mitigation, biodiversity • *Geomatics* • Infrastructure: infrastructure monitoring, telecommunications, critical infrastructure • Insurance & finance: insurance, reinsurance, financial services • Maritime & marine environment: shipping port management, fisheries, coastal & ocean monitoring • *Rail* • Security & Defence: external action, border control, surveillance policy • *Sensors, drones & satellites* • *Space situational services* • Urban development: smart cities, urban mobility & planning, real state
energy and natural resources	alternative energy oil& gas minerals & mining	disaster & geohazards	floods landslides volcanos fires earthquakes	
industrial	communications transportation maritime utilities construction	land	agriculture inland water snow & ice topography geology land forests land use	
services	real estate management insurance & finance retail & geo-marketing travel, tourism & leisure news & media			
policy authorities	local & regional planers education, training & research security, defence & military emergency	built environment	urban areas infrastructure	
international bodies	environmental pollution & climate humanitarian operations & health	ocean & marine	metocean coastal marine ecosystem fisheries sea-ice ships	
		security	security	

[48] GSA is the European Global Navigation Satellite Systems Agency (www.gsa.europa.eu) and presents its market the report at the page https://www.gsa.europa.eu/market/market-report where the markets

3.2.3. GEO Societal Benefits Areas

GEO Societal Benefit Areas (SBA's) are domains in which Earth observations are translated into support for decision-making. Currently, the hierarchical vocabulary structuring these societal benefit categories is; Biodiversity & Ecosystem, Disaster Resilience, Energy and Mineral Resource Management, Food Security and Sustainable Agriculture, Infrastructure & Transportation management, Public Health Surveillance, Sustainable Urban Development, Water Resources Management. When comparing taxonomies, the market-oriented focus embraces most of the SBAs while for the thematic-oriented we observed some cross superposition. Figure 8 shows these correspondences and the SBAs orientation to the user perspective.

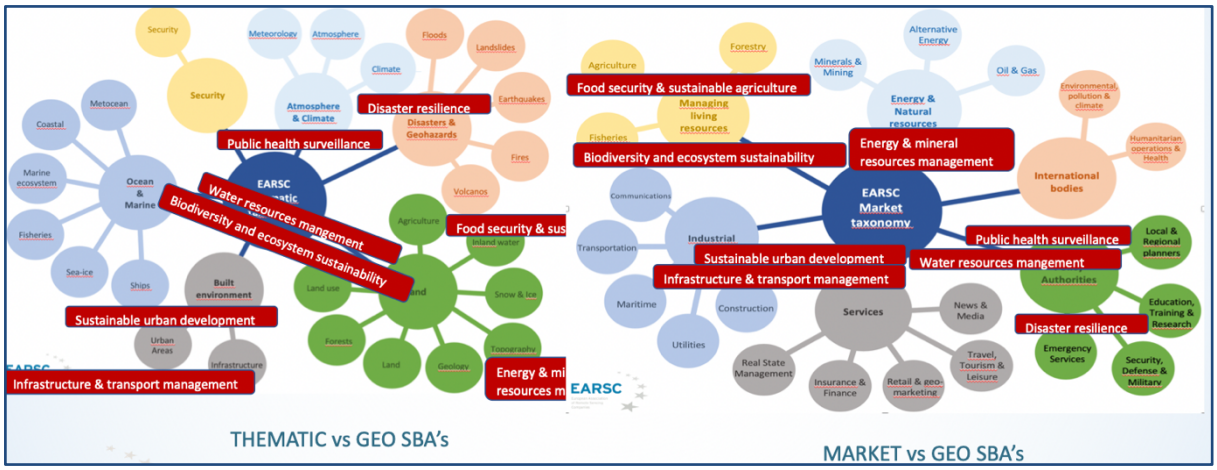


Figure 8: Correspondences market and thematic taxonomy vs SBAs

SBA's Structure. (+) Very good alignment with the users perspective and challenges. (-) this taxonomy is only focuses on societal areas but not market diversity for other user communities in sectors such as insurance, constructions, media, real state, etc, thus still a need to maintain both perspectives. The EARSC taxonomy market perspective offers alignment with the full set of SBA's.

3.2.4. International organizations' approaches

To benefit from other stakeholder's classifications oriented to address the users, markets and financial undertakings, such as the OECD[49], the Global industry classification Standard (GICS)[50], the Industrial Classification Benchmark (ICB)[51], the Reuters Business Classification (TRBC)[52], Eurostat[53], or the classification from the "International Financial Institutions" such as the World Bank[54], these groupings offer similar categories than the market-oriented taxonomy. Table 13 provides a comparison of market-oriented vs structures in relevant organizations showing in bold correspondences with the EARSC taxonomy. It is perceived that economic market sectors[55]; primary, secondary and tertiary are well presented across the taxonomies, the ones referring to quaternary and quintenary sectors provide less matching which is normally as the sector evolves and new services will be produced to fulfil the need of services and knowledge information respectively. The need to add a

[49] OECD (https://www.oecd.org/dac/stats/purposecodessectorclassification.htm)
[50] The Global Industry Classification Standard (GICS) (https://www.msci.com/gics)
[51] Industrial classification benchmark (https://www.investmentmap.org/industry_classification.aspx)
[52] Reuters Business classification (https://en.wikipedia.org/wiki/Thomson_Reuters_Business_Classification)
[53] Eurostat market themes (https://ec.europa.eu/eurostat/data/browse-statistics-by-theme)
[54] World Bank market structure (http://vocabulary.worldbank.org/taxonomy/1104)
[55] Market sectors: https://en.wikipedia.org/wiki/Economic_sector

"consumer/society" category starts to be evident as well as more diversification on the users of public authorities' services but overall the taxonomy is fulfilling quite well the generic market sectors where EO could provide a significant contribution. The comparison shows the relevance of new user communities such the consumers who gainied relevance in the last years. Another point to reflect upon is the importance to keep market and sector related ton managing living resources and energy and other resources such mining activities and oil and gas. Financial and health are recognized in all taxonomies. Market customers in the related to public administrations are also well reflected. A new consideration needs to be done when applying to ITC, communications, etc due to the development of the IoT., such consideration will reflect more granularity dedicated to that sector today not reproduced in the EARSC taxonomy. This exercise provides a very promising alignment with the World Bank reinforcement the upgrade and need of the market taxonomy for future procurement activities at International Financial Institutions.

International organizations Structure: (+) All these structures present good alignment with the market perspective. (-) Missing sectors where EO plays a significant role and adding others where EO services are not contributing at all. The EARSC taxonomy market perspective offers orientation with the full set of structures from the international organizations represented on industrial classification.

Table 13- Structured topics used by organizations referring to their users or applications

EARSC Taxonomy (Market perspective)	EARSC Market taxonomy (extended)	OECD Topics	Global Industry Classification Standard (GICS)	Industrial Classification Benchmark (ICB)	Thomson Reuters Business Classification (TRBC)	Eurostat	Worl Bank
Managing Living resources: -Agriculture -Fisheries -Forestry	Agriculture	Agriculture and fisheries				Agriculture and fisheries	Agriculture, Fishing and forestry
	Fisheries						
	Forestry						
Energy & Natural Resources: -Minerals & mining -Alternative Energy -Oil & gas	Minerals & mining		Materials	Basic materials	Basic materials	Environment and energy	Energy & Extractives
	Alternative Energy		Energy		Energy		
	Oil & gas			Oil & Gas			
International Bodies: -Environmental, pollution & climate -Humanitarian operations & health	Environmental, pollution & climate	Environment					Water, sanitation & waste management
	Humanitarian operations & health	Health	Healthcare	Healthcare	Healthcare		Health
Policy Authorities: -Local & regional planners -Education, training & research -Security, defence & military -Emergency services	Local & regional planners	Corporate governance Green growth and sustainable development				General and regional statistics Population and social conditions	Public administration
	Education, training & research	Development Education			Technology	Science, technology, digital society	Education
	Security, defence & military						
	Emergency services						Social protection
Services: -Real State management -Insurance & finance -Retail & geomarketing -Travel, tourism & leisure -News & media	Real estate management		Real estate				
	Insurance & finance	Finance	Financials	Financials	Financials	Economy and finance	Financial
	Retail & geo-marketing					Industry, trade and services	
	Travel, tourism & leisure						
	News & media						
Industrial: Communications Transportation Maritime Utilities Construction	Communications	Digital	Industrials Information Technology Telecommunications Utilities	Industrials Telecommunications Technology Utilities	Telecommunications		Information & communications
	Transportation					Transport	Transportation
	Maritime						
	Utilities				Utilities		Industry, trade and services
	Construction						
		Bribery and corruption *Chemical safety and biosafety* *Competition* *Economy* *Industry and entrepreneurship* *Employment*	Consumers Discretionary Consumers staples	*Consumer goods* Consumer services	*Cyclical consumer* *Consumer services* *Nano cyclical consumer*		

3.2.5. Commercial service providers

A comparison of the different market sector divisions reflected by services providers in the public and private domain is presented and compared with the EARSC Market taxonomy in Table 13. Overall, it shows the EARSC market taxonomy covers most of the diversity in the market organizations represented. It shows strong similarities, specifically in the primary sector about managing living resources (agriculture, fisheries, forestry) but also energy and natural resources (with string component on the mining and oil & gas). The secondary sector is well aligned predominantly with infrastructure and transport. The tertiary sector is represented with insurance and finance but addressing civil government, local authorities mainly in the urban development services. Defence and security are highlighted in most of the classifications together with environmental actors. It is also to note that companies have their own "niche", so they are not fulfilling all the market areas. We do reflect on the mix between thematic and market approach in many of the filtering by services providers but being focus on the user perspective our alienation seems quite solid representing the "market scope" from the providers. In Table 14, major market sectors which correspond with the EARSC taxonomy have been highlighted. **Commercial Service Providers Structure**: (+) Oriented to user and customers; (-) depending on the business models some companies are offering services in some market segments while other companies propose another type of services. The EARSC taxonomy market perspective offers an amplified spectrum of potential users.

Table 14- Sample of organizations referring to their user communities' structure

EARSC Market taxonomy (extended)	S. Provider A	S. Provider B	S. Provider C	S. Provider D	S. Provider E	S. Provider F	S. Provider G	S. Provider H	S. Provider I
Agriculture	**Agriculture**	**Agriculture**	**Agriculture** & food production	Natural Resources	**Agriculture** & Food production	**Agriculture** & Rural **Environment &Natural Resources**	**Civil government**	**Agriculture**	
Fisheries							**Energy**		
Forestry	**Forest** & Environment	**Forestry & Environment**	**Forestry** & climate change		**Forestry** & Climate Change			**Forestry** & REDD+ **Education & Research**	**Forestry** agricultural
Minerals & mining				Manufacturing Petroleum & pipeline	Geology & Extractives	**Energy & Infrastructure**	**Mining**	**Energy & Infrastructure**	**Energy** & utilities
Alternative Energy									
Oil & gas	**Oil, gas, Mining & Energy**	**Oil & gas**							
Environmental, pollution & climate			Land management & infrastructures	Sustainable development	**Environment** & Water management				
Humanitarian operations & health			**Maritime** surveillance	Health & Human Services					
Local & regional planners	Land administration & mapping	Land administration & mapping	Land management & infrastructures	Architecture, Engineering & **Construction** **State & local government** Public safety	Land management & urban	Urban & population		**Civil government** Mapping & GIS	Land environment & land planning Open **government**
Education, training & research				**Education**					
Security, defence & military	**Defence & Security**	**Defence & security**	**Defence** & Intelligence		**Defence & Security**		**Security**	**Defence** intelligence	**Security & defence**
Emergency services		**Emergency** & Disaster management		**Government**				Emergency management	Disaster management & prevention
Real estate management	Civil Engineering & **Infrastructures**		Risk & asset management	**Real state**					
Insurance & finance	**Insurance** & banking		**Insurance** & assets	Banking **Insurance**	**Insurance** & Asset		**Insurance** **Financial**	**Finance** & business intelligence **Insurance**	
Retail & geo-marketing				**Retail**					
Travel, tourism & leisure			Cultural heritage						**Tourism** & territorial marketing
News & media									
Communications				Telecommunications Electric & gas utilities	**Infrastructure**, mobility & communication				
Transportation				**Transportation**		ITC & **Transport**			Info mobility
Maritime	**Maritime**	**Maritime**	**Maritime** surveillance Ice monitoring				**Maritime**		Coastal areas & sea monitoring
Utilities				Water			**Utilities**		**Infrastructures** engineering
Construction									
	Aviation								

3.2.6. H2020 projects

This section presents a comparison of the EARSC taxonomy to a range of EU projects' (**NextGEOSS**[56]and e-shape[57]) taxonomies. The NextGEOSS DataHub catalogues provide pilot services developed and integrated within NextGEOSS but also other European Projects across several thematic areas. Those are similar to the ones presented in the EARSC taxonomy (represented in Figure 9). The thematic areas where NextGeoss provide pilot services are security, atmosphere, metocean, sea-ice, urban areas, landslides, agriculture, snow & ice and land, while represent the majority of these services for agriculture providers, alternative energy representatives and local and regional planners. All of these are well captured and mapped at the EARSC taxonomies (user/service). **NextGEOSS Structure**: (+) Align innovation with thematic and business with market. (-) small set of categories. NextGEOSS pilots are represented fully the EARSC taxonomy market and thematic perspectives.

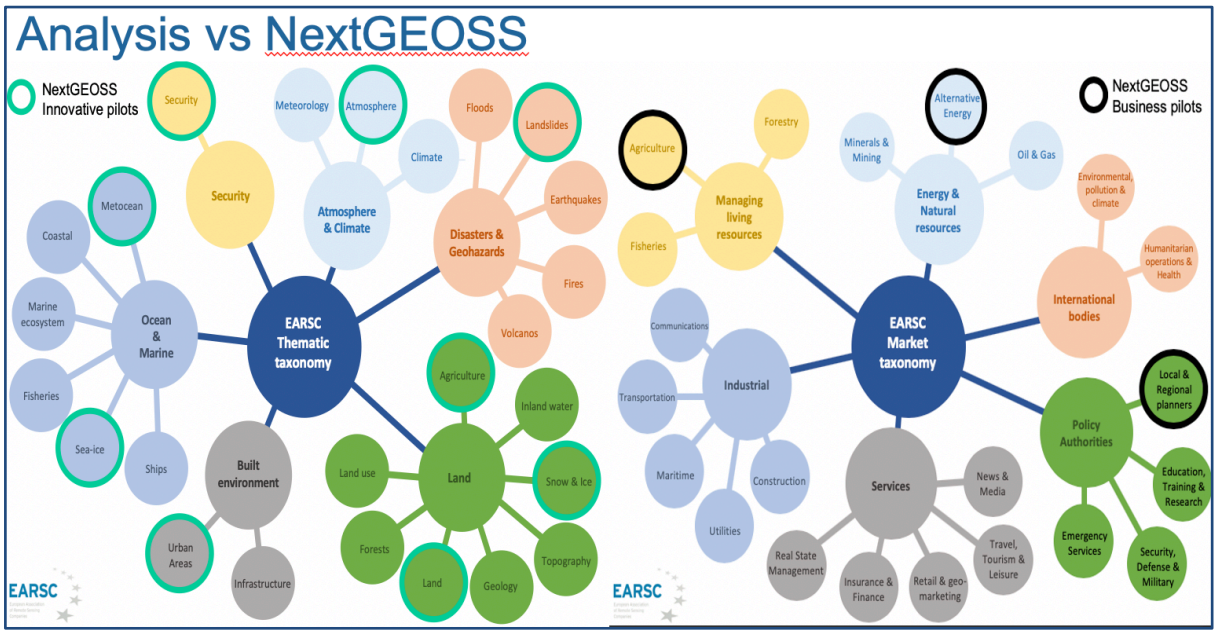


Figure 9: Correspondences market and thematic taxonomy vs EU project NextGEOSS

The e-shape project delivers a comprehensive suite of EO services to EU citizens, businesses and policy makers through the implementation of 27 pilots spanning 7 thematic areas aligned with UN Sustainable Development Goals (SDGs) and GEO Societal Benefit Areas (SBAs): food security, health, renewable energy, biodiversity, water resources, disaster resilience and climate. Each e-SHAPE Pilot is assessed according to the EARSC taxonomy, and current and potential user communities are defined along. The themes/areas that have the highest degree of alignment with Pilot user uptake can be identified as Policy authorities, International bodies, and Services (e.g. insurance/finance, real estate and travel/tourism). This accurately reflects the state of the market to date, where the public sector is the largest client sector 66% according to the EARSC EO Industry Survey Report (2019). The categories less represented are managing living resources, industrial and energy and natural resources. The thematics or greatest relevance are atmosphere and climate, land (ecosystems and inland waters) and ocean and marine. These areas and pilots are indicated in Figure 10; hence we

[56] NextGEOSS project: NextGEOSS is a centralised European Earth observation data hub and platform (https://nextgeoss.eu/ and https://catalogue.nextgeoss.eu/)
[57] e-shape represents the largest coordinated effort to showcase operational services in the field of Earth observation research in Europe.

grasp this connectivity using the EARSC thematic taxonomy. A major advantage of using EARSC Taxonomy, is to link the E-SHAPE pilots, currently presented in SDG silos, to assess crossovers in order to be able to identify possible communities of interest that can be exploited as an efficient way to expand existing user communities and/or the uptake of new products or services within them.

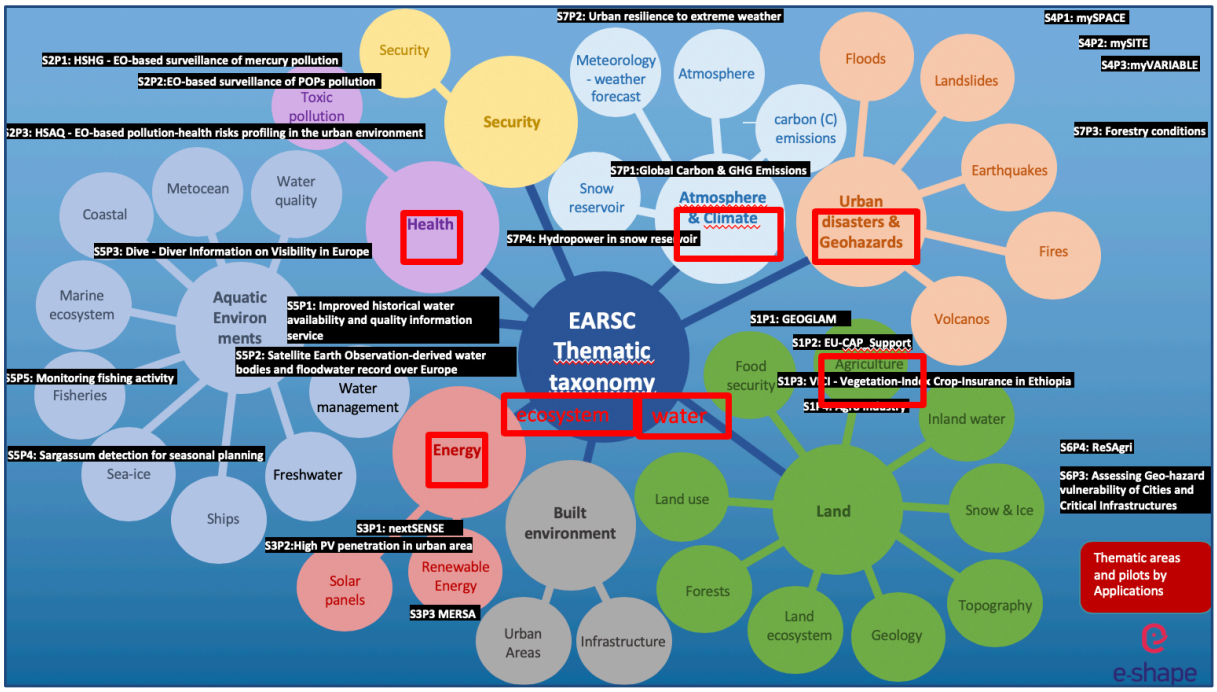


Figure 10: Correspondences market and thematic taxonomy vs EU project e-shape

e-shape Structure: (+) Align pilots and applications with innovation perspectives. (-). Pilots not in line with the uptake viewpoint. Good representation at the EARSC taxonomy thematic perspectives

Finally, we have also engaged with the ENVRI community[58]. This is the community of Environmental Research Infrastructures, projects, networks and other diverse stakeholders interested in environmental Research Infrastructure matters. The Research Infrastructures community understands the Earth as a highly complex system, formed by a large variety of interacting sub-systems, such biosphere domain, atmosphere domain, hydrosphere (marine domain) and lithosphere (solid earth). It follows a similar approach to the EARSC thematic taxonomy and the capability to categorise services which observe, analyze and model the Earth's subsystems and their interactions; e.g. atmosphere and climate change, marine and ocean and land. The services under built environment include all the human factors on the land, geohazards based on observations linked to natural risks and security and have not direct links with the Envri+ structure of the services. The ENVRI community looks forward creating a more coherent, interdisciplinary and interoperable cluster and some exchanges have been made on the taxonomy. Figure 11 shows these connexions with the thematic perspective where the main elements atmosphere, marine, biosphere and solid earth are captured in the EO services. solid Earth and biosphere are part of services dedicated to marine and land while solid earth fits with the land services.

[58] ENVRI community (https://envri.eu/)

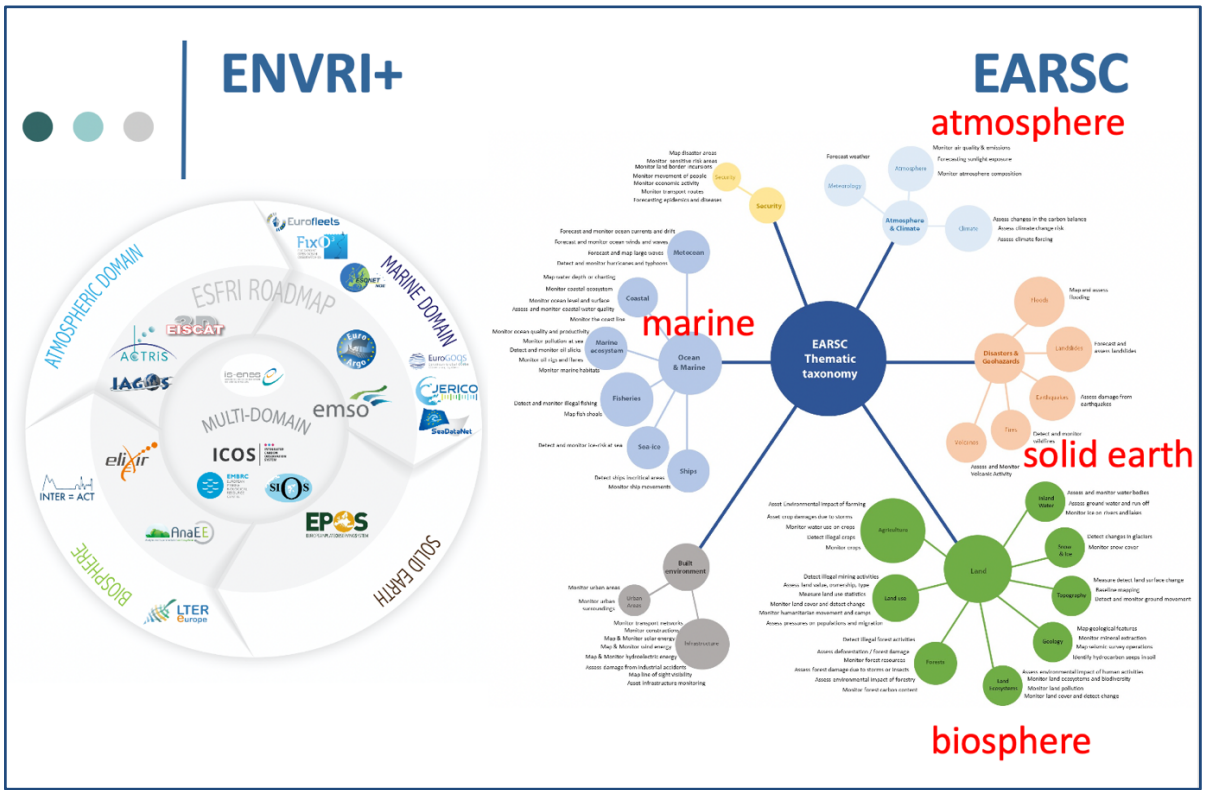


Figure 11: Correspondences thematic taxonomy vs ENVRI

ENVRI+ Structure: (+) Simplicity and very focus research community. (-) Difficult to move from the thematic viewpoint. EARSC taxonomy shows possible matching with the infrastructure community.

3.3.Incorporation of user feedback

EARSC produced its taxonomy in 2012 to apply some structure the sectors' activities to enhance accessibility to those both within and external to the sector. This structural categorization served to structure the industry surveys undertaken by EARSC and enabled comprehensible descriptions of the sector's growth, the trends and challenges thus facilitating an understanding of the state of and changes in the market. In 2015, EARSC issued an update to the taxonomy compiling a structured list of the specific needs of individual market sectors - starting with the Oil & Gas sector. Since then a few small improvements have been made around the clarification of the roles of intermediate services or describing the relationship of EO services to the SDGs. Figure 12 represents this evolution throughout the years.

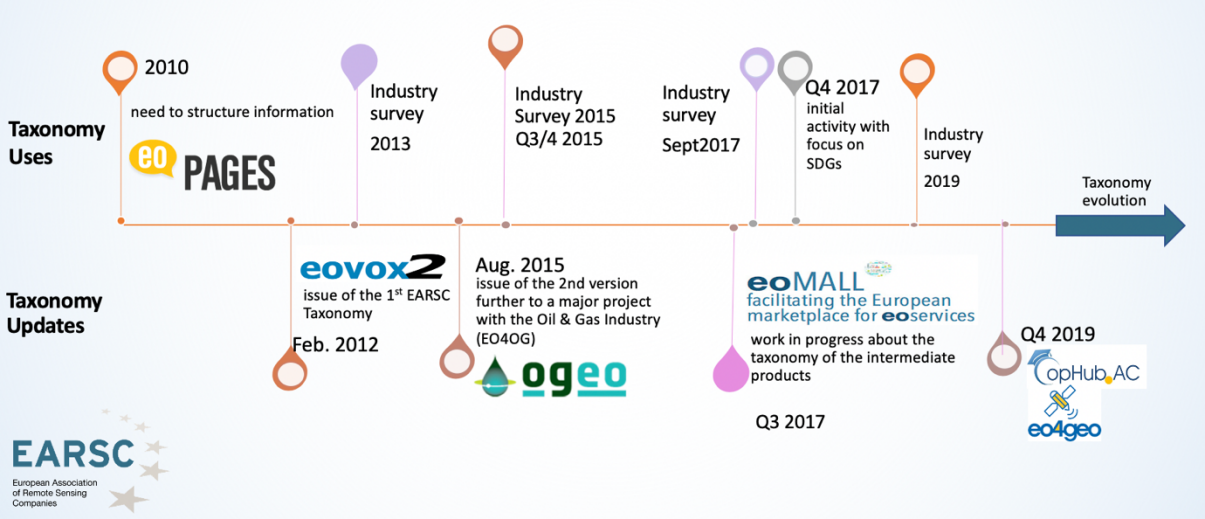


Figure 12: EARSC taxonomy evolution

This Task under CopHub.AC provides a unique opportunity to examine this evolution with people from the Academy and refine and discuss the evolving taxonomy and fill in the details.

The taxonomy is recognized by the companies when presenting their offer for any sector providing services for users. Though, it is very important to note that taxonomies allow evolution and discussion with different players as continuous revision. That was the case under the context of the forum for information exchange between the oil and gas and geoinformation professional communities (EO4OG)[59] where the taxonomy was translated into a comprehensive set of products for the O&G sector. Each of these products was considered in a comprehensive taxonomy update where the needs of the clients (the Oil & Gas industry) were expressed as "challenges" and a set of products have been identified to meet those challenges. This approach has been mirrored by EC studies on market evolution of Copernicus services done by Consultancies such as PwC or SpaceTecPartners[60] and reflected in many company websites from the EARSC membership.

Modification requests to the taxonomies should be collected and taken into consideration for regular updates. In general, successful taxonomies follow some reference principles including that:

- elements that make up the reference taxonomies should be recognised terms. For example, business domains, areas, and categories
- they should not have more than 3/4 levels. Ideally the taxonomy should be meaningful at the area level (2nd level), with the category level (3rd level) providing a detailed view where required.
- they should explicitly note the source of a term and/or definition and related terms

3.4.Consolidation and feedback

In close cooperation with the CopHub.AC WP2 under the Thematic Working Groups (TWG) of the Copernicus Academy, three special sessions about the Earth Observation taxonomy developed by EARSC were organized and background information was submitted respectively (See Annex "Background info to experts"). The objectives of the sessions were to present the EARSC taxonomy

[59] https://earsc-portal.eu/display/EO4/EO4OG+Home
[60] https://www.copernicus.eu/en/documentation/studies-and-surveys/studies-and-surveys

and its evolution, inform the experts about the details of this tool (background, rationale, structure) and consolidate the classification and description of EO Services, based on the feedback of the thematic experts of the Copernicus Academy. The webinars had a duration of more than one hour and took place "online" on Friday (8th May 2020), Wednesday (20th May 2020) and Thursday (28th May 2020). A series of follow up calls with working groups and academic and research organizations were engaged in to reach consensus on the definitions of the EO services and the developments to be included in the taxonomy update.

This exercise aimed to present the EARSC thematic taxonomy structured in main 6 domains (atmosphere & climate change, built environment, disaster & geohazards, land, marine, security & safety) to experts in the Copernicus domains covering (atmosphere, climate, emergency, land, marine and security). More than 20 experts were engaged in the review process, specifically discussing the recent taxonomy updates regarding the first 3 levels of the thematic taxonomy (i.e. the definition of EO services). An overview of the feedback from these experts is shown in Table 15. These recommendations were part of the discussion which ended up with the integration as part of the outcome from the upgrade of the taxonomy, particularly om the description of the EO services.

Table 15- Examples of modifications and exchange with experts

Domains	Comments revision
atmosphere & climate change	• climate change as a triggering factor for many geohazards and have a direct effect for many other processes; • reflection on climate change monitoring, mitigating and action included in the 2nd level;
built environment	• add dedicated item on urban settlements assessment; • given the current climate change adaptation and mitigation policies, it is justified to include a specific EO service focussing on the urban green and blue space which would look into a specific use scenario of monitoring ecological functioning and ecosystem services in an urban context; • monitoring of energy loss and heat maps are treated at "monitor urban areas";
disaster & geohazards	• added "the multi-hazard assessment"; • early warning (early/quick/rapid detection) considered in all geohazards; • added "monitoring of risk factors", and alert issuing on spots where risky combinations are recorded; • risk is prevention, extent and burnt area is rapid damage estimation; • added term "dynamic" to emphasize the possibility to frequently update (from forecast to situation monitoring) risk assessment; • added response and recovery phase on "map and assess flooding"; • added "fire weather index[61]"; • added in definition, the hazard is often PGA (peak ground acceleration) combined with vulnerability layers for risk estimation; • added terms: "flood map" (exposure) or "dynamic" to emphasize the possibility to frequently update (from forecast to situation monitoring) risk assessment;
land	• certain shift in the meaning and concept; "measure land use statistics" has been replaced by "land accounting" and the "land use statistics" have been included in the key words;

[61] Fire weather index

	• added “forest condition mapping” in ecosystem assessment activities, the basic products are forest condition mapping products (including, degree of fragmentation, leaf cover density, etc); • regrouped “assess and monitor specific crop acreage and yield harvest” and “monitor specific crop types” with other generic services such “asses and monitor crops disease and stress” and “monitor and forecast crops yields”; • “measure land statistics” placed with “land accounting”; • in ecosystem assessment activities, the basic products are forest condition mapping products (including, degree of fragmentation, leaf cover density, etc., consequently add “forest condition mapping”; • added service” assess land accounting”; • replace “water level” with “surface water dynamics”; • merge assess forest types with monitor & manage forest resources;
marine	• alignment with the 10 markets for blue economy[62] at the market taxonomy and reflect on keep in mind green (ecosystem and biodiversity), blue (water quality...etc) and white (sea ice) ocean; • added “marine litter”, “hazardous and noxious substances (HNS)”, and “plastic and microplastic” which are recognized as a big problem by the International Maritime Organization[63]; • check the integration of “detect and monitor oil slicks” and “monitor oil rigs and flares” in a single service; • “monitor ocean level and surface” moved to “meteocean”;
security and safety	• added specific services to cover “monitor critical assets”, “monitor borders”, “monitor health” and “monitor food security”; • delete “map disaster areas” and placed as generic in “emergency”; • “assess pressures on populations” and “monitor humanitarian movement” have been merged;

3.5. Future interactions

As indicated in our first release of the EARSC taxonomy, another factor in proposing a taxonomy is the use of language. We are working in English and the very words used may be recognised differently to non-native English speakers. Perhaps the easiest and most well-known example here could be “security” which means safety as well as security in French and many other languages. Similarly, cultural differences can alter the understanding. For example, the question of electricity generation and transmission could be recognised as an industry or as a service (we choose industry because we include it with other utilities – but this is also a term open to interpretation!). So, we can only apologise to those who find that they disagree with our views. We are quite ready to listen to alternative proposals and to keep this document live; but at the same time, its strength will be in its robustness and hence ability to accommodate new terms, market sectors, EO services etc without fundamental change. We shall review this periodically and invite comment and suggestions as to improvements.

[62] https://marine.copernicus.eu/markets/
[63] http://www.imo.org/en/MediaCentre/HotTopics/marinelitter/Pages/default.aspx and http://www.imo.org/en/MediaCentre/HotTopics/Pages/HNS-2010.aspx

It is also important to note that it should evolve continuously – in detail. Future interactions of the taxonomy are expected in a 2/3 years' timeframe. The establishment of mechanisms to gather user feedback and respond promptly are considered under the EARSC activities keeping alive the discussion with user communities such as, for example, raw materials, oil and gas, agro-insurance, etc but also through other project activities such the FIRE project [64] which will establish a user community across different sectors, starting with agriculture, energy, raw materials, infrastructure, marine, and urban spaces.

Providing "one" agreed EO taxonomy for services is challenging. The **DEFINITION CHAPTER** introduces the EARSC taxonomy and its perspectives and includes correlations and correspondences with other stakeholders's structures in the community. The previous figures showed differences and correspondences in categorising EO services by user communities when sorting user perspective but also addressing the applications.

The EARSC taxonomy provides a certain degree of alignment with all of these structures from the research communities towards more market orientated ones and indicating advantages and potential disadvantages. Some recommendations were taken into account for the upgrade of the taxonomy, especially the cross-check with the GSA structure and the Industrial taxonomies.

This section also addresses how and what user feedback has been incorporated during the taxonomy update process, along with the question of how we ensure that we can continue to keep it up to date in this fast-moving sector.

4. Results: Taxonomy Evolution

The Results chapter presents the structural elements and the specific updates of the taxonomy, responding to the question of 'How was the taxonomy upgraded?' and presenting what it looks like now. Section 4.1 covers the "users" and their definition while Section 4.2 will analyse the composition of the "thematic" (suppliers) perspective. Section 4.3 discusses the structure of the EO services which form the bridge between these two views.

4.1. Market (user) view on the Taxonomy

4.1.1. Market: Taxonomy classification

The updated Market view on the taxonomy is presented in Table 16 with the major markets & sectors. Evolution changes are presented in "bold". Ending December 2019, EARSC has upgraded the "Market taxonomy" reflecting on the evolution of the sector. We prefer to focus here on functions developed in the different market levels. Therefore, we have included the public sector functions in several market areas. The user groups related to "policy authorities" and "international bodies" were embedded in other market sectors fulfilling such activities as defence and security or environmental, climate & health market areas. The new group "citizens & society" has been defined to account for the citizen as a client, as serviced by EO services delivered directly to citizens through Apps.

[64] FIRE project (http://earsc.org/news/press-release-fire-sets-out-to-shape-the-future-of-earth-observation-solutions-for-europe-s-industry)

The latest EARSC "Survey into the state & health of the sector"[65] revealed a significant increase in the activities specific for different groups of users. Such was the growth in the "defence and security" segment that we decided to consider it now as an independent Market in our taxonomy. We also added a sector on "urban planning", supporting the activities of many service providers in the public sector such as "smart cities" or "local and regional planning". The customer was always a local planner but due to the increase in revenues of these type of services deserve their own independent category. Another evolution is the one regarding the "industrial" and "services" segments which were considered to be too generic, so they have been replaced by more focused activities on the "infrastructure and transport" and "financial" activities where "ICT and digital interfaces" were integrated. These modifications respond to more adjusted classification on the type of users of the EO services. Table 16 shows these evolutions in bold.

Table 16- Evolution of the market taxonomy

EARSC market taxonomy (2015-2019)		**Updated (2020) taxonomy (major Markets & sectors)**	
managed living resources	agriculture fishing forestry	managed living resources	agriculture fishing forestry
energy and natural resources	alternative energy oil& gas minerals & mining	energy and mineral resources	**renewable** energy oil& gas **raw materials**
industrial	communications transportation maritime utilities construction	**infrastructure & transport**	construction utilities & supplies communications & connectivity transport & logistics marine travel & tourism
services	real estate management insurance & finance retail & geo-marketing travel, tourism & leisure news & media	**financial & digital services**	insurance & real estate retail & geo-marketing news & media **ICT & digital interfaces**
policy authorities	local & regional planers education, training & research security, defence & military emergency	**urban development**	**smart cities** local & regional planning
international bodies	environmental pollution & climate humanitarian operations & health	**defence & security**	emergency & **social protection** security, defence & military humanitarian operations
		environmental, climate & health	environmental ecosystems & pollution health care meteo & climate
		citizens & society	**consumer solutions** leisure education, training & research

The figure 13 represents the update of taxonomy from the market/user perspective.

[65] EARSC Survey into the State & Health of the European EO Services Industry 2019 (http://earsc.org/file_download/568/Industry+survey+2019+final+version+07_11_2019.pdf)

Figure 13: EARSC Taxonomy (Market perspective)

4.1.2. Market: User terminology

Major user groups have been identified and a description is provided in Table 17, which shows a structured view of the "offer" of the sector, its services for the actual use of the communities from whom it is intended, i.e. the "uptake". The "EO services" are the common point bridging the "market" and the "thematic" taxonomy, serving the needs of the users (adding key targets and terminology) and providing the knowledge and expertise of the services providers. The EO services are largely analysed and most benefit from the understanding of the "action verbs" which categorize its description (verb + object).

The needs and challenges are closely expressed by services providers as "EO services" and in some cases as products using EO data dedicated to meeting the needs (challenges) of the Markets which are expanded in the table below.

Table 17- Definition of EO users[66]

MARKET TAXONOMY				
Market	**Description**	**Sector**	**Users**	**"Needs" relevant to "EO services"[67]**
Managed living resources	Users in managed living resources refer to human activities exploiting natural organic resources. Knowledge and information products to forge a viable strategy for the user's operations such as the assessment of the status of the resource due to natural or human activities for effective commercial exploitation and conservation. This includes **agriculture, fishing and forestry** sectors.	**Agriculture**	Agricultural commodities/trading, agricultural production / horticulture, agricultural services, agriculture machinery, agriculture and rural development policy, agri chemicals / plants & fertilizers, animal production / livestock/ Stock traders on commodity price like wheat, coffee. The EO/GI users also include agriculture and rural policy makers and insurers.	• forecast production yield and monitor variability in crop development; • support usual farm management / operations providing highly accurate customized consultation to any farmer and for any kind of crop, from the smallest to the largest scale; • calculate the correct amount (savings) of fertiliser, water or pesticides; • more informed decision-making on crop type and land use, savings on seed through optimising seed density during planting (vegetation-Index Crop-Insurance); • implement a crop production index to build an insurance product; • evaluate farm solvency & trade on commodities stock exchange; • monitor farming deforestation impact and delineate field boundaries; • assess losses based on actual damage extent in the field overall monitor several stages in the value chain to make better-informed decisions in planning, planting and growing the new crops; • …
		Fishing	Fish stock management, fishing fleets, fishery distribution logistics, aquaculture / fish farms, coastal management agencies. Besides, the users include fisheries authorities / policy makers.	• improve fisheries economic activity boosting their income, making the fishing experience easier, safer, and more sustainable, assessing fish shoals, catch optimisation & understanding the impact, overfishing, livestock monitoring/management, etc; • detect patterns of illegal behaviour at sea (illegal fishing, narco-traffic, immigration, maritime pollution, piracy); • …
		Forestry	Forest management, forest services, commodities, logging industry, wood, paper and pulp industry, forest policy, forest machinery. They also include forest policy makers.	• establish historical forest area changes and implement forest monitoring solutions; • verify the impact of and compliance with no-deforestation policies and transform the industry towards sustainable practices (sustainable management of forest);

66 Descriptions have been contrasted with the conceptual activities undergoing at the Body of Knowledge (BoK) under the EO4GEO project (www.eo4geo.eu)

67 Needs have been extracted from EARSC services providers activities at EARSC membership (www.earsc.org/members), Copernicus market report 2019 (https://www.copernicus.eu/sites/default/files/2019-02/PwC_Copernicus_Market_Report_2019_PDF_version.pdf)

				• set-up reducing emissions from deforestation and forest degradation (REDD+ national strategy and support final users in obtaining certificates and carbon credits) (REDD+ MRV (monitoring, reporting and verification)); • perform cost-effective and accurate forest inventory, at national or local scales; • conservation and enhancement of forest carbon stocks, baseline mapping and stock change; • damage assessment; • …
Energy and mineral resources	Users in energy and mineral resources deal with the harvesting of energy from **renewable resources** and **extractive industries** including **oil and gas and raw materials**. EO information helps them in exploring potential locations to build new mines or power plants, in identifying risks from infrastructure and in managing the environmental impact of their operations. Uses that apply to the extractive industries: a study of landforms, structures, and the subsurface, to understand physical processes creating and modifying the Earth's crust.	**Renewable energy**	Solar energy providers, wind energy providers, tidal energy providers, energy and carbon traders, local and regional planners, and national policy makers.	• successful management of renewable resources as the selection and development of exploration areas; • detection and quantification of renewable energy potentials; • solar radiance data for renewable energy project planning, and nowcasting for extreme weather events; • assess environmental impact assessment for industrial permitting and monitoring purposes; • aspects of energy planning, production, and distribution within bioenergy and thermal power, wind, solar, renewable energy and energy-efficient heating and cooling solutions; • …
		Oil & gas	Offshore and onshore exploration and production, drilling and support services, oil and gas commodities trading, and energy planners.	• assessments and monitoring of environmental impacts related to energy exploration, extraction, transportation and consumption; • establishment of an environmental baseline, or snapshot, for planning and design; • monitoring conditions over time (via change detection, feature mapping or geophysical parameter measurement) to understand environmental impacts and trends; • hazard assessment (risk assessment and post-event analysis, including operational and situational awareness); • oil spill and pollution monitoring; • assess pack ice and icebergs, and internal wave/soliton mapping to help mitigate potential risks posed to offshore activities; • improved representation of the subsurface, optimize field development and achieve more efficient oil and gas production; • …
		Raw materials	Mining and quarrying companies, exploration and survey specialists, commodities traders, exploration and extraction equipment	• challenges focus on lifecycle phases of the mineral extraction: areas of poor coupling, baseline historic mapping of environment and ecosystems, continuous monitoring of changes throughout the

			suppliers, drilling, excavation and support services, and regional planners / policy makers.	lifecycle, engineering geological evaluation, facility siting, pipeline routing and roads, identification of adverse terrain for trafficability, infrastructure monitoring, land motion relating to fault lines or other causes, lithological discrimination, mapping geological features, monitoring of assets, natural hazard risk analysis, reservoir management, risk assessment, structural interpretation, support to surveying crews for planning surveys and H&S, terrain evaluation and geo-morphology characterisation; • on-site field data and calibration information; • change detection and time series analysis; • risk management and environmental impact analysis; • geological mapping, mining management; • selection and development of exploration areas, detection and mapping of illegal mining activities, or monitoring assets; • …
Infrastructure & transport	Users in transport and infrastructure apply to all manufacturing and physical supply in **land** but also **marine** domains including **transport & logistics, utilities, construction, communication & connectivity**, and **tourism.** They oversee assets, monitor competition, build competitive advantage and source ground-truthing data.	**Construction**	Construction companies, civil engineering consultancies, architect and design companies, planning authorities, and national land agencies dealing with structures, tunnels, etc.	• assessments of key infrastructure changes and construction developments; • continuous mapping and monitoring of critical infrastructures across multi-site projects; • continuous monitoring to detect encroachment events, including intentional damage to infrastructure or a threat to staff safety; • engineering development, planning, monitoring and controlling of infrastructure solutions at all levels of scale and complexity to optimize the processes and results; • demand and suitability analysis; • assess the environmental impact of human activities (detect land movement, subsidence, heave, and monitor land-use statistics); • intelligence on the location, extent, magnitude and evolution of deformation; • …
		Utilities & supplies	Operators of utilities such as water, electricity, waste, power stations (including hydroelectric), water plants, landfill and waste, a well as survey companies, regulatory bodies, distribution companies, regional planners / policy makers.	• monitoring electrification planning, renewable energy resource assessment, distributed generation, grid operation and reliability, and disaster risk reduction and recovery efforts; • identify risk hotspots on and around the rights-of-way and mitigate risk by monitoring vegetation around power lines; • improve the safety and reliability of their network; • understand and plan tree trimming cycles and verify vegetation maintenance completion. Reduce the risks of power outages, asset damage, and other economic losses, as well as environmental and safety hazards from storms or wildfires;

				• improve access to reliable electricity and resilience infrastructure, incorporate renewable energy into the electric sector, and improve energy governance; • dynamic water availability and change monitoring, water demand and usage assessments; • …
		Communications & connectivity	Construction companies, civil engineering consultancies, architect and design companies, planning authorities, and national land agencies.	• support operations of communications networks through information to set up infrastructure settlement networks and coverage; • assessing changes to urban/rural areas, and mapping line of sight visibility; • …
		Transport & logistics	Road transport operators, haulage, road infrastructure operators, tolls, airport operators, rail operators, airlines and airline services, and transport engineers.	• corridor assessments and route / network planning; • reliable maps for transportation management systems to guide decision-making, determine how/where to engage across large supply chains in transport and logistics (rail, roads, highways); • assess and monitor high-risk areas by providing more information on geological hazards along with rail and road networks; • …
		Marine & maritime	Ports & Harbours administration, bulk cargo carriers, cruise liners operators, ferry operators, naval operations, and rescue and safety at sea.	• contribute to more efficient marine operations and further development of the Blue economy[68] comprising all the activities related to oceans, seas and coasts, that cover established sectors (e.g. exploitation and preservation; aquaculture, fisheries, water quality, coastal tourism, maritime transport, etc.) and new ones, e.g. blue bioeconomy and biotechnology, coastal and environmental protection, etc; • weather monitoring for vessel detection and identification; • policy objectives such (bath water quality, integrated coastal marine directive, marine strategy framework directive, UNEP regional seas; • …
		Travel & tourism	Tour operators, leisure service providers, hotels, parks etc., offices of tourism, travel agencies, ski and coastal resorts, surfers & sailors.	• forecast of weather conditions over a particular environment such as coastlines (safety of tourists and holidaymakers through operational weather observations and providing a picture of changing circumstances, natural features and their characteristics;

68 2018 Annual Economic Report on EU Blue Economy (https://ec.europa.eu/maritimeaffairs/sites/maritimeaffairs/files/2018-annual-economic-report-on-blue-economy_en.pdf)

				• validate the assessment of resorts, evaluation of conditions for safety for outside activities (biological reserves areas (cannoping), improved mapping for tourists with classification and other advanced automated processing technologies; • cultural heritage, displacement monitoring (detection of slow movements and structural failures of historical buildings and structures and of terrain in the surrounding areas); • assessment of land use change (e.g. pollution in rivers and lakes); • …
Financial & digital services	Users in financial and digital services cover a broad area of activity that touches on many other market sectors such as **insurance & real estate, retail, news & media and digital interfaces**. They look to better understand risks, accelerate claims, and detect fraud. The categories included are identifiable as a "service" for the tertiary sector which provides advice, access, experience activities and knowledge and there are not part of the physical supply of goods.	**Insurance & real estate**	Primary insurance companies, re-insurance sector, insurance brokers, insurance service suppliers, commercial banks, major projects, and international financial institutions).	• detection and monitoring of hazard-prone locations, including vulnerability assessment; • better management of risk exposure, assessment (capital/risk) to natural disasters such as hurricanes, earthquakes, and floods; • key analytics reports and alerts of risks (such identification of risk); • assess situations for predictive analysis or risks on a property basis; • …
		Retail & geo-marketing	Retail centres and advertising and marketing agencies. They use EO/GI data in the field of navigation and Location Based Services (LBS), shopping chains or logistics.	• leverage geospatial intelligence to take management decisions leading to reduced costs on, e.g. new location selection, practices or processes through e.g. implementing dashboards to integrate and visualize spatial variables & information such as reliable NRT data, stores and localized areas, identification of public segments of interest, location of establishments, billboards and their influence on online advertising, customer dynamics, study of competitors, price strategy design etc; • …
		News & media	Television companies, broadcasting providers, news and information agencies, web service providers, and entertainment software providers.	• bringing together images, videos, and visualisations from the Earth onto known platforms (digital, print, radio, television) to inform society on the ecosystems, environments, emergency, risk and safety of people or socioeconomical impact; • …
		ICT, knowledge & digital interfaces	Fixed and mobile telecommunications providers.	• assist with data processing and enhancements, and provide a range of specialist analysis ready data solutions to help final users maximize intelligence from imagery; • basemap data for radio network analysis; • …

Urban development	Users in urban development and users involved in the development of rural settlements perform tasks at local and regional scales (to the scale of nations) on mapping land use and monitoring urbanization. These users benefit from EO information to manage the use of land & its impacts. Users include experts in e.g. urban planners, architects, spatial planning offices, urban policy makers in public/private sectors in **smart cities** or **generic urban** local/regional **planning** belong to this category.	**Smart cities**	Urban planners, architects, spatial planning offices, urban policy makers.	• baseline inventories for site suitability studies, city infrastructure monitoring, information on green urban areas and peri-urban ecosystems; • estimate distribution of the population, economic activity, property ownership and valuation, land use/ land cover inventories; • sustainable cities and communities creating places where the environments enhance liveability and quality of life; • classification tools using administrative vector data as reference for supervised image classification; • map and assess urban adaptation to climate change, environmental/socio-economical characterization and map green urban areas in and around cities; • map risk of land change and ground deformation and its temporal evolution; • water and sanitation planning to support water related infrastructure projects and waste management; • …
		Local & regional planning	Spatial planning departments of municipalities, spatial planning offices, and spatial planning policy makers	• inventories of informal settlements, integrating different data streams into the map-based products (cadastral maps for land administration and mapping); • mapping of building footprints and building blocks as well as classification of building/infrastructure types; • optimize planned routes for transport and infrastructure, and when combined with mapping solutions, can help mitigate the impact of natural hazards whilst minimizing project costs; • interactive analysis, simulation and visualisation tools for urban policy implementation; • socio-economic and demographic analysis and impact assessment, facility planning; • …
Defence & security	Users in **defence** and **security** work in the field of **military, emergency and social protection** and define, collect, analyse information to provide intelligence & safety (monitor events, improve response and drive resilience).	**Emergency & social protection**	Coast guards, ambulance services, fire services, police services, civil protection organisations, and rescue services. They benefit from increased efficiencies and effectiveness through monitoring, detecting and assessing natural risks/disasters.	• mapping disaster areas for situation awareness and detecting sensitive risk areas; • economic and social vulnerability assessment to natural hazards and climate change (monitoring, action and adaptation); • assess loss (€/m2) mostly for assets combined with in-situ data; • …

	Some examples are activities under **Humanitarian response** such as border control organisations, police and rescue forces, coast guards, civil protection, military services, and intelligence services which can use EO services to detect and monitor high risk areas produced naturally or by humans, monitor border incursions or maritime movements.	**Security, defence & military**	Border control organisations, police and rescue forces, military services, and intelligence services.	• defence mission (naval forces): intelligence, support to troops, manoeuvres, support to aerial operations, interception of suspicions activities (assist with trapping/catching traffickers in the act); • support the detection of illegal or irregular activity and to make land /maritime operations safer and more efficient (situational awareness), overall citizens' security; • …
		Humanitarian operations	Humanitarian aid and support organisations such as; at European level (DG RELEX, DG ECHO, DG ENV/ MIC), at UN level (OCHA, UNHCR, UNDPKO, UNDP, UNOPS, UNITAR, UNICEF, UNESCO, WFP), International (IFRC, WHO, WB, donor organizations), and national level (Civil Protection Agencies, Ministries of Internal Affairs/ Civil Protection Department, Development and Aid agencies).	• improve emergency response and assessing pressures on populations and migration, monitor & tracking displacement population and humanitarian movement and camps; • assessment and support to aid actors dealing with hazard assessment (risk assessment and post-event analysis), including operational and situational awareness as well as those involved in recovery, disaster risk reduction and preparedness activities; • disaster resilience and assessing geo-hazard vulnerability of cities & critical infrastructures; • reach actionable information to send the right people and supplies to the most vulnerable sites; • …
Environmental, climate & health	Users in the **public administrations** or **private organizations** using EO to increase the **environmental or climate change** impact on policy making decisions which are key to our safety and our economy i.e., assisting in developing monitoring to evaluate and deliver policy goals, provide an assessment of ecosystems, rapid response to major environmental risk events, or those associated with **health security** & care. These users are largely related to international treaties and hence a strong international collaboration.	**Environmental ecosystems & pollution**	Environmental ecosystems & pollution users include coast guards, ambulance services, fire services, police services, civil protection organisations and rescue services.	• assist with the preservation of the natural environment such as reservoirs, inland water monitoring, water management systems (hydrological, hydrogeological maps, water point); • solutions that safeguard the environment such as environmental impact assessment, strategic environmental consultancy, sustainability, waste & resources); • resilient & sustainable ecosystems including continuous monitoring of ecosystems such as wetlands; • …
		Health care	Public administration personnel, civil servants, public health community, etc working on health issues such as air quality, forecasting sunlight exposure, forecasting epidemics, diseases.	• site-specific field conditions as well as import phenological timing events, which helps to make predictions on air quality, which impacts on the health of citizens; • pandemics highlight the need for a comprehensive and integrated approach to human health. Enhancing environmental health through better air quality, water and sanitation, waste management, along with efforts to safeguard biodiversity, will reduce the vulnerability of communities to pandemics and thus improve overall societal well-being and resilience; • …

		Meteo & climate	Meteorologists in a range of downstream sectors.	• disaster resilience and assessing extreme weather; • monitor, understand, evaluate and assess the impact of the climate change; • prediction of conditions of atmosphere reliable weather forecasts; • mitigation actions preventing/reducing the emission of greenhouse gases into the atmosphere; • climate change data modelling (aerosol, biomass, cloud, fire, greenhouse gases (GHG), glaciers, ice-sheets, land cover, land surface temperature, ocean colour, ozone, permafrost, salinity, sea ice, sea level, sea state, soil moisture, snow, sea surface temperature (SST), water vapour); • renewable energy production prediction, all kinds of commodities market trading, inventory management; • …
Citizens & society	Citizens and society in general use and engage with EO services through **mobile devices, social media platforms and apps**. We also categorize in this section the users in **education, research and training** providing knowledge and learning outcomes.	**Consumer solutions**	Mobile devices, social media platforms, apps developers.	• adoption by society of mobile devices, social media platforms, internet connectivity, Internet of Things (IoT), machine learning, portable and low-cost sensors to interact and visualise scientific research for their interest;…
		Leisure	People oriented to basic public understanding on EO services for their leisure activities	• citizen interest on particular environments and ecosystems such as beach area estimation, (understand and check protected areas where sports may be regulated), wind, water depth, water salinity, etc; • information on textures and landscapes for video games, such as flight simulators, augmented reality, 3D; • …
		Education, training & research	Schools and education authorities, universities, research organisations, and professional training organisations	• through environmental research, academics make discoveries that impact on environmental and social outcomes; • enabling the education and research community to find and consume EO services, data access, processing tools, analytics, etc for their research field; • growing the awareness of EO services in researchers in disparate fields leading to new use cases; • promoting the use of EO in schools to foster innovative thinking and ideation of the applications and services of tomorrow; • …

4.2.Thematic (provider) view on the taxonomy

4.2.1. Thematic: Taxonomy classification

Earth Observation (EO) is nowadays considered as an operational tool to contribute to the detection or quantification of a phenomenon which fits users' needs in numerous markets or thematic areas. A "thematic-oriented approach" focuses on the products and services a company/organization offers and the thematic similarity of these. A service list provides a standard way of referring to each service when communicating within and between organisations.

Previous discussions revealed the need to define each of the levels used during the upgrade of the "**thematic taxonomy"**. The structure presented in Table 17 allows four levels/tiers. This structure is firstly discussed at Section 2, Definitions Section. By composing the elements from level 1 (domain) while expressing the elements of level 2 (areas), 3 (EO services) and 4 (a generic description defining the prodcuts and parameters that make up the EO service), we can represent concepts without any conflicting interaction between them and independently in the knowledge base. The hierarchy represents different granularity and goes from:

Table 18- EO services structure

Level 1	**Thematic classes (DOMAIN)**	Single block of knowledge (big category of objects)	Largest conceptual category (typically nouns) covering all known areas of EO services from the supplier's point of view. The EARSC taxonomy contains 6 classes.
Level 2	**Thematic segment (AREA)**	Set of EO services (greater detail of objects)	Classifies concepts in greater detail, i.e. different segments. The upgrade proposes 31 areas compared with the 25 in the previous taxonomy. Description is tackled in the thematic section.
Level 3	**EO Service (SERVICE)**	Purpose of the information	EO services (sometimes considered applications by service providers) propose an action or a sequence of actions (specific events appropriate in a given situation, e.g., "assess the environmental impact of farming". For example, it unifies major entities such as environment, agriculture or deeper in granularity such as crops. The range today covers more than 80 services (see the section "Structuring the EO services" and the thematic taxonomy at the EARSC portal[69])
Level 4	EO Application	Specific for a geographical area, timeline, etc.	This level presents set **keywords** which in effect define the **products** which make up a service (key words are also considered in our taxonomy to represent **products, parameters** or **essential variables**).
	Products	Describe tangible satellite-based data products	
	Parameters & Essential Variables for the land, atmosphere and ocean	Information elements derived from EO data key *parameters* of the *Earth* and the environment	

It must be noted that within both the service provider and user communities the terms service and application tend to be used interchangably. We seek here to apply some structure to their use. As shown in Section 2.1: Using a common language, we define a service as being a process incorporating e.g. sets of algorithms, EO data, model outputs etc. that are applied to give information or knowledge of the Earth, and an application as a specific implementation of that process, i.e. a service may offer to Assess and monitor water bodies, which could be applied (i.e. algorithms trained) to deliver water quality information on the Black sea, or another application to deliver water quality information on the Baltic Sea. In reality the the line between "EO service" and "application" can sometimes be very

[69] EARSC portal (https://earsc-portal.eu/pages/viewpage.action?pageId=15794378)

narrow or inexistent in some cases. Below we present two examples of the complete structural definition of EO services. To illustrate the methodology and terminology described in Table 18 (above).

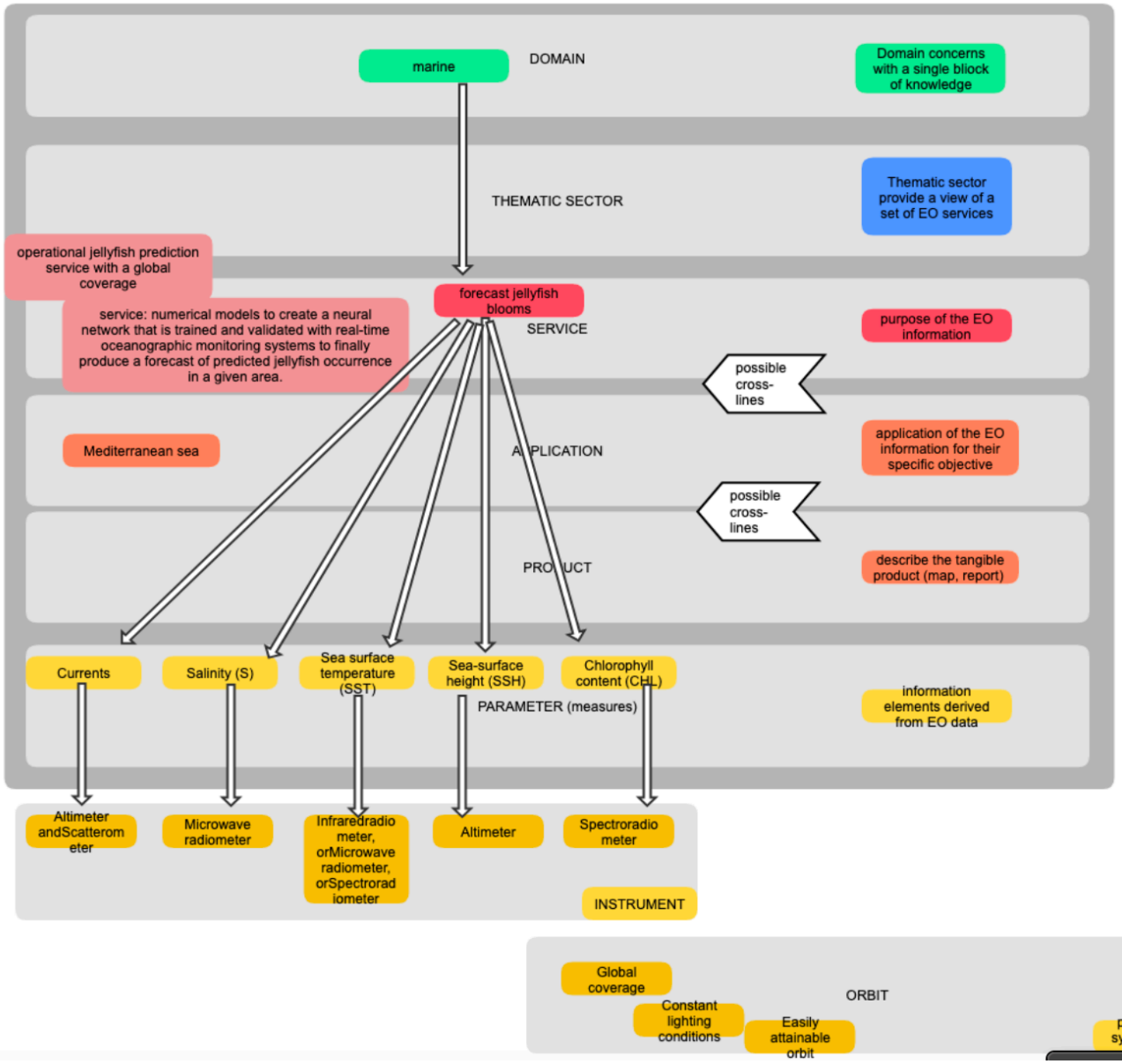
Figure 14, below, shows the structural levels for a jellyfish monitoring service. This service may be requested by local authorities, fishermen's organizations or tourism industry players which have the need to monitor coastal waters for the safety of tourists. Each of these potential users requires a picture of changing circumstances of these jellyfish blooms and their characteristics (coastal degradation, raise of sea surface temperature). In addition to EO-derived data this service needs in-situ data and numerical models to create a neural network that is trained and validated with real time oceanographic monitoring systems on one particular location. Concretely the structure for the example looks like:

- Domain: Marine
- Area: Coastal
- EO Service: Forecast jellyfish blooms
- Application: It could be applied for example in the "Mediterranean Sea" (Malaga coastal area)
- Product: it will describe maps with the information of the parameters but not relevant on this service
- Parameters: currents, salinity, SST, chlorophyll content

Figure 15 represents a service predicting and mapping the risks associated with potential diseases using environmental and climatic parameters which can be used to support surveillance, prevention and control activities. This is a service that may be of interest for healthcare professionals to better understand e.g. "health security events". For example, a pandemic highlights the need for a comprehensive and integrated approach to human health. Enhancing environmental health through better air quality, water and sanitation, waste management, along with efforts to safeguard biodiversity, will reduce the vulnerability of communities to pandemics and thus improve overall societal well-being and resilience. The use of EO can inform the estimation and monitoring of environmental and climatic determinants, and thus disease prediction and risk mapping. Hence a service detecting risk areas will inform about the geographical distribution of the risk of climate-related infectious diseases, providing an estimation of the population at risk, target areas of surveillance or the ones related to control and prevention, i.e.:

- Domain: Defence, security (inc. safety)
- Area: health security
- EO Service: monitor and detect sensitive risk areas
- Application: May be geographically or temporally indicated
- Product: overall risk maps (vector habitat maps, exposition to infected vector risk maps, disease transmission, etc)
- Parameters: precipitation, humidity, T, characterization of environmental and climate variables

Notice the examples described above and shown figuratively below are just to provide some examples of the structure of a service, not to analyse the service itself. More examples of the EO services are shown in Annex 7.4: EO services & structure.



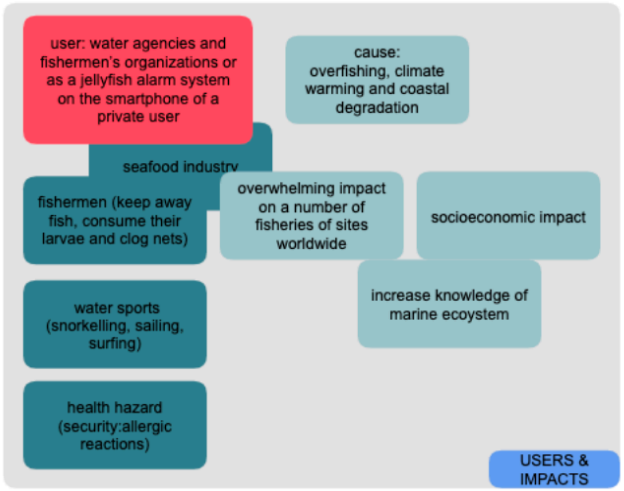


Figure 14: Forecast jellyfish blooms

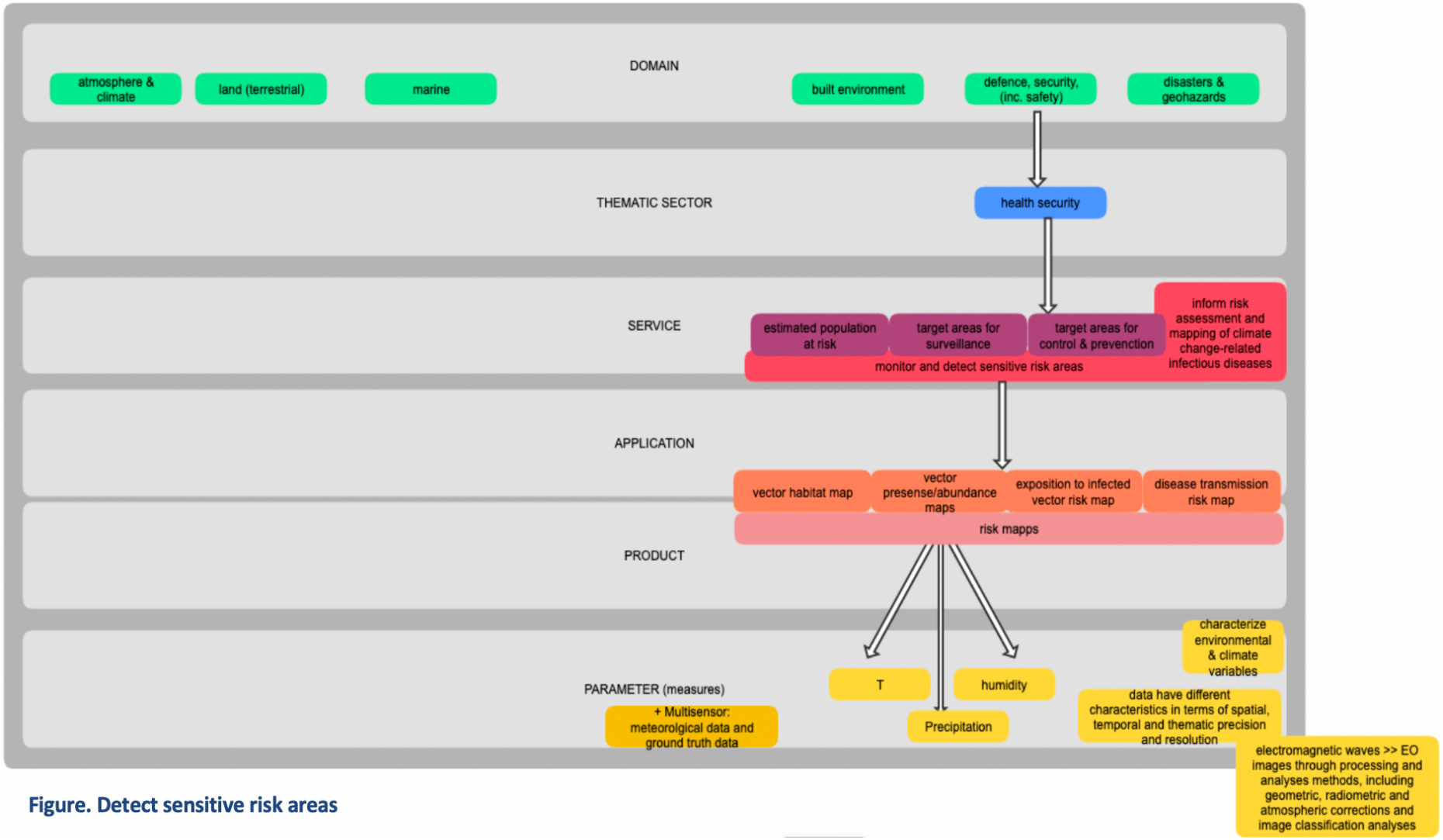


Figure. Detect sensitive risk areas

Figure 15: Detect sensitive risk areas

Table 19 shows the evolution of the Areas (or segments) in this update of the taxonomy, adding more complementary segments in some domains such as the “security and safety”. The main evolutions are marked in “bold”.

Table 19- Evolution of the Thematic taxonomy

EARSC taxonomy (thematic) (2015-2019)		**EARSC taxonomy (thematic) (2020)**	
Thematic Classes (DOMAIN)	**Thematic Segment (AREA)**	**Thematic Classes (DOMAIN)**	**Thematic Segment (AREA)**
atmosphere & climate	climate atmosphere meteorology	atmosphere & climate	climate **change** atmosphere ***(emissions & surface fluxes)*** meteorology
built environment	urban areas infrastructure	built environment	urban areas infrastructure transport *networks* **waste**
disaster & geohazards	floods landslides volcanos fires earthquakes	disasters & geohazards ***(emergency)***	floods landslides volcanos fires earthquakes **multihazard**
land	agriculture inland water snow & ice topography geology land forests land use	land	agriculture *(fields)* forests inland water snow & ice land use/land cover **biodiversity** & land ecosystem topography & **motion** geology
ocean & marine	metocean coastal marine ecosystem fisheries sea-ice ships	marine & maritime	metocean coastal **biodiversity** & marine ecosystem fisheries sea-ice & icebergs ships marine **pollution**
security	security	security & **safety**	**critical assets** **customs & border *(migration)*** **health *(epidemics & diseases)*** **food security & production**

The figure 16 represents the update of taxonomy from the market/user perspective.

Figure 16: EARSC Taxonomy (Thematic perspective)

4.2.2. Thematic: Domains terminology

The description for the domain terminology is enforced by action verbs which are describing the observed object. By definition, “Remote Sensing” is the acquisition of information about an object or phenomenon. The object of remote sensing may be a well-defined natural or anthropogenic target such as a bridge, or it may be a geographical area such as a defined landscape (farm, forest, sea…). Thematic services provide knowledge related to the production of information of relevance to different stakeholders. Table 20 presents a generic overview of the static geoinformation products and dynamic monitoring services on the six major domains (atmosphere & climate, built environment, disasters & geohazards, land, marine, security). The description highlights the use of verbs and its harmonization to the major group highlighted in the section related to actionable services.

Table 20- Definition of major thematic domains[70]

Domain (1st level)	Description	Thematic Areas (2nd level)	Key words thematic[71]
Atmosphere and climate change	The atmosphere and climate domain encompass all atmosphere and climate change focused services/applications which **assess, monitor, forecast** and provide timely, continuous and independent data (e.g. emissions, climate forcing, greenhouse gases, reactive gases, O3, solar UV radiation, aerosols…) which affect temperature, air quality and the transmission of solar radiation. These services/applications closely monitor each of the Earth's different subsystems and help to better **understand** and **evaluate** the impact of climate change and its impacts on the atmosphere, meteorology or hydrological cycles.	atmosphere	…quality-controlled information related to air composition, pollution and health, solar energy, greenhouse gases (GHG) emissions and climate forcings.
		climate change	…long-term datasets (also linked to weather forecasts) on key indicators of climate change systematically generated and preserved to better understand climate change and associated adaptation and mitigation measures and risk management (i.e., large-scale ecological response to global climate change such greening of the Arctic). The assessment of climatic variations may persist over decades or more. This is measured through geophysical quantity/quantities associated with climate variations and change as well as the impact of climate change onto Earth (time series analysis, anomaly detection, missing data reconstruction, forecasting). Climate change is triggering factors on geohazards or direct effect for many land and ocean processes.
		meteorology	…seasonal preparedness, forecasting of meteorological variables e.g. air temperature, wind, humidity, cloud coverage, precipitation and evapotranspiration (related to numerical weather prediction models, in-situ observational data and machine learning techniques).
Built environment and human factors	The urban environment domain covers applications/services addressing all **planning, modelling, monitoring** and **understanding** of urban environments and infrastructure. These can include identification of new structures, ground movement, movement of structures, land cover/land use, and identification of urban water bodies and be applied to a range of applications such as transport networks or energy provision, or waste monitoring**.**	urban areas	…monitoring urban expansion (site development information and urban growth monitoring), sustainable urban development (highlighting urban 'hot spots', town planning, identification of urban risk management priorities, land management, insights into human settlement layers or green/smart spaces (tree canopy cover, urban forest diversity and air quality), community dependency assessments.
		infrastructure	… infrastructure health, asset optimisation and monitoring such construction of new buildings, energy, water supply (i.e., hydropower in snow reservoir), sewer systems or information networks susceptible to vulnerability due to engineering works, industrial activities or other effects which can develop land subsidence due to landslip, mining or other.
		transport networks	… monitor the stability of rail and road networks by analysing/predicting and assessing track/terrain settlement behaviour including the identification of possible 'hotspots' or high-risk areas (geological hazards, weather forecasts…) in the network that is under threat.
		waste	…monitor spatial and temporal changes in legal waste sites and detect illegal dumping sites providing a series of reports and/or alerts with evidence of the location and extent of the waste site identified.

[70] Descriptions have been contrasted with the conceptual activities undergoing at the Body of Knowledge (BoK) under the EO4GEO project (www.eo4geo.eu)
[71] Key descriptions extracted from EARSC membership (www.earsc.org/members)

Disasters & geohazards	The disasters & geohazards domain provides information for an emergency response concerning to different types of disasters. It includes a wide array of EO services for the **mapping, monitoring** of geohazards and how cascading impacts of disasters can affect the security of every citizen. These tools can be applied to a range of disasters/hazards such as landslides, volcanoes, fires, earthquakes and cascading hazards. Other types of disasters such as ground subsidence, tsunamis, cyclones/hurricanes may be tackled under the land/marine/atmosphere domain respectively. Such EO services help on the improvement of crisis management, risk reduction including early warning systems for mitigation of disasters and emergency response, re-establishing services after such events and planning tools to help in understanding emerging problems that may be critical in the mid-term. Services in this domain typically consider the Sendai Framework for Disaster Risk Reduction[72] with the priorities for action; understanding, governance, reduction for resilience, preparedness for effective response, recovery, rehabilitation and reconstruction.	floods	… assess the scale and/or extent of actual or potential flooding events (closely associated with modelled or measured rainfall and cascading geohazard models).
		landslides	… detection, monitoring and interpretation of different types of terrain motions such as ground displacement or landslide flows through e.g. characterization of scale, slope stability, surface/surface deformation, properties of the material (such as rock, soil, ice), meteorological (rainfall, temperature), hydrogeological parameters.
		volcanos	… identifying volcanic hazards (data for detection, discrimination & distribution of volcanic ash) and assessing associated risks for human settlements and the environment, detecting and self-directing observations of an eruption arising from volcanic activity such as lava flow, ground fissures, earthquakes and mud slides, as well as the environmental effects of the gas and ashes released by an eruption, monitor precursors to volcanic eruptions (colour changes in crater lakes, damage to vegetation, and ice melting on ice-capped volcanoes) leading up to a possible eruption and assess their significance.
		fires	…observation and measurement capabilities for monitoring fire events (fire management, post-fire erosion monitoring, the basis for risk assessment, evaluation based on tree cover/type density maps), and estimating risks (areas that are dry and susceptible to wildfire outbreak, actively flaming and smouldering fires, burned area, and smoke and trace gas emissions), and extent of burnt areas for rapid damage estimation and recovery planning.
		earthquakes	…understanding, mapping and responding to active tectonics, surface ruptures and quantifying earthquake risks, estimating the distribution/depth of ground motion and slip on faults.
		multi-hazard	… early warning systems and multi-hazard disaster risk information and assessment (identify, analyse, evaluate, treat, monitor and review) in the different phases of multi-hazard risk management such as safety, the provision of a synoptic view of the region of interest, pre-event baseline mapping extending back several years and, in many cases, damage estimates.
Land	Land resources and its management form the basis of all societies. It includes all services/applications that are focused on **monitoring, assessing** quality & availability**, managing, planning** and improving the use of land areas and its ecosystems (land, soil and inland water). The key **track** on the evolution of the land surface (use, cover, seasonal and annual changes and monitors its variables) even if it involves human intervention (environmental challenges, impact evaluation or suitability analysis).	agriculture (fields)	… includes monitoring of information on the physical configuration of the surface and any change of that surface over time such as monitor fields, mange crops, farm management, tillage scheduling (soil treatment), irrigation scheduling (know when and how much), pest and disease alarm (early warning system for pest and disease infection risks), crop growth monitoring (define a different crop management zones or detect field problems such as pest infestation or soil nutrients deficiencies), improve crop yield estimation (estimate field productivity, make better financial decisions, improve income, insight of market opportunities and solve some modern agriculture problems), and comprehensive crop monitoring and modelling systems. Land variables which affect crops (along with a host of weather and climatic variables) include; land cover, surface soil moisture, dry matter productivity, surface temperature, a fraction of absorbed photosynthetically active radiation (FAPAR), normalised difference vegetation index (NDVI), leaf area index (LAI), a fraction of green vegetation cover (FCOVER), and weed or pest infestations.
		forests	…efficient use and management of forest resources (inventory & timber harvesting), providing intelligence & insights into forest composition like tree species, tree height and diameter (DBH), tree growth & productivity, tree cover density, wood inventory, harvest planning. Insights into forest health (biodiversity, protected areas) & threats, e.g. deforestation, drought, insect plagues, soil health, storm damage, and other forest disturbances.

[72] The Sendai Framework (https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030)

		inland waters	…monitor the extent of reservoirs and lakes, observe seasonal activity, track resource utilization (reliable, repetitive, and low-cost information for water supply management) and environmental benefits, provision of temporal and spatial information on parameters which provide insight into the ecological status, dynamics and trends of inland waters. Key parameters of water quality assessments include turbidity, suspended matter, chlorophyll-a, harmful algal blooms and trophic state classification.
		snow & ice	…verification of snow-related processes in land surface models, the impact of snow cover changes on ecosystems/biodiversity/human activities (e.g. road or mountain safety), analyse impacts of changes in the snow on water availability and permafrost, the role of snow in climate-related changes to the hydrological regime/cycle/ surface-atmosphere energy fluxes. Monitor snow cover (snowpack conditions such as depth, wetness), ice mass balance.
		biodiversity & land ecosystem	…data assimilation techniques to combine satellite observations of the land surface with radiative transfer and other physical models to provide best estimates of biophysical parameters, improving understanding of ecosystems and ecosystems and assessing vulnerability, etc.
		land use/land cover	…LU/LC - land use (biophysical coverage of land), land cover (socioeconomic use of land) - and land-use change (LUC) data are often used to detect ecosystem change risk factors.
		topography & motion	…topographic measurements deliver consistently digital elevation models (DEMs) for the mapping of large areas and in the monitoring of elevation changes in areas of land subsidence or uplift, ground subsidence, assets and infrastructures stability monitoring.
		geology	…multi-scale geological mapping and mineral exploration of any terrain and climatic environment, including services such elevation data sets which suit their study objectives in terms of scale, resolution and environment. Properties of soils, surface lithology can be detected.
Marine and ocean	The marine & ocean domain covers the **tracking, measuring, observing, modelling and assessment of** all maritime & marine focused activities across a broad range of applications such as marine safety, e.g. marine operations, oil spill combat, ship routing, defence, search & rescue; marine resources, e.g. fish stock management; marine and coastal environment, e.g. water quality, pollution, coastal activities; climate and seasonal forecasting, e.g. ice surveys, seasonal forecasting… Concerning the concept of "Digital Ocean" improving the monitoring of the Blue, Green, White and Brown Ocean, the classification may be linked as blue (metocean, marine pollution, water quality, ships & navigation...etc), green (fisheries, ecosystem and biodiversity) and white (sea ice & icebergs) while brown is related to coastal zones	metocean	…observations for quality meteorology over oceans (offshore weather and sea state monitoring) complemented with NRT data collection of variables such as wave height and frequency, wind speed and direction and ocean current velocity on global and regional scales.
		coastal	…coastal mapping (i.e. on land) represents an integrated approach in relation to environmental monitoring, incorporating such fields as urban development and coastal wetland loss, land-use cover and change, wetland mapping, coastal geomorphology (barometric pressure, on/off-shore wind, the slope of beach), maritime safety and security issues (hazard, disaster). The coastal zone (water ecosystem) may cover water depth-bathymetry and water optical properties, waterbody nutrients / productivity (chlorophyll-a concentration), littoral and subtidal habitat (mangroves, coral reefs, seagrass canopy density), erosion and sedimentation mapping, long time series of ocean colour products including uncertainties estimates or health issues such as algal bloom detection… Can be closely related to marine, land and inland water monitoring products.
		biodiversity & marine ecosystem	… monitoring and improving the understanding of the complexity of the global marine ecosystem (physical, chemical, biological and ecological processes) through critical observations in the health of and changes to marine biodiversity.

		fisheries	… improve understanding (through bio-geochemical analyses and forecasts for global and regional seas, topography, ocean colour, sea-surface temperature and ocean currents, key inputs for fish stock numerical modelling) of fish stock (including resilience and vulnerability) to natural and anthropogenic factors such as over-fishing effects (surveillance capabilities for the detection of illegal, unreported and undetected fishing activities).
		sea-ice & icebergs	…monitoring and forecasts of sea ice, including its extent, thickness, motion and ridges, hydrodynamic forecasts, ice monitoring and forecasting to allow for safe and efficient transportation route planning, improve the precision of ice thickness measurements.
		ships	…fleet tracking, provide real-time sea-ice data to ensure navigation safety in polar shipping routes, shipping route optimisation, marine reserves and protected area monitoring, illegal activity detection.
		marine pollution	…detection of marine oil spills through SAR, support research on marine litter with forecasts of sea currents and sea-surface heights (altimetry), sea-surface salinity, sea-surface temperature, ocean colour and sea-ice data.
Security & safety	It is the provision of EO services **defining, collecting, analysing** information to provide intelligence & safety (understand events, anticipated impacts and quick respond). It also includes political boundaries such as borders. Receive and share information quickly, understanding of complex operating environments such as border surveillance, maritime surveillance, support to EU External Action, ensuring security and sovereignty.	critical assets	… monitoring environmental and man-made risks to assets, such identify failure for dams, pipeline networks, roads, nuclear power stations by helping on decisions about assets through the analysis of remotely-sensed imagery and data to reduce the cost of monitoring and predicting land use change and environmental risk. Needs assessments for response, recovery and reconstruction areas are also important.
		customs & border (migration)	…basic maps (digital, paper, using both EO and non-EO sources), crisis and damage mapping, situation maps, refugee/IDP support maps, thematic maps, communication reporting, alert services.
		health (epidemics & diseases)	…monitoring, identification and predict threats to human health. environmental and climate influences on appearance of unusual spreading of disease provoked through zoonosis (such Covid19), proximity to hazardous locations (such as toxic or nuclear waste sites), changes in biodiversity, land use, and land degradation, etc. can influence health outcomes. air quality, risk maps, etc combined with analytics and modelling are applied to improve health security.
		food security & production	…better monitoring and targeting of food aid and security issues through e.g. water monitoring (droughts), early warning system for pest and disease infection risks, crop losses associated with certain environmental conditions, e.g. temperature, rainfall, humidity.

4.3. Alignment with Copernicus services

The European Copernicus programme[73] is also an important element that will influence the future market for EO services. Copernicus is a key programme in Europe, and we should ensure that the Copernicus Services can be found a place within the taxonomy. The Copernicus services have already been defined each of which offers a number of products. Nevertheless, the Copernicus programme is dealing primarily with public sector information needs and hence a workable taxonomy must go beyond Copernicus since many other elements of the market are not addressed, more specifically those addressing built environment and links with other market sectors. Therefore, we propose this generic alignment at a high level, as shown in Table 16, which associates very well with the EARSC taxonomy, and often incorporate the Copernicus Services as it is shown in next chapter structuring the EO services.

Table 21- EARSC thematic perspective vs Copernicus services

EARSC thematic perspective	Copernicus Services	Copernicus components/areas/applications
Atmosphere & climate EO services	Copernicus Atmosphere Monitoring Service (CAMS)	-air quality and atmospheric composition -ozone layer and ultra-violet radiation -emissions and surface fluxes -solar radiation -climate forcing …
	Copernicus Climate Change Service (C3S)	-support adaptation and mitigation policies by providing consistent and authoritative information about climate change (assessment of climate change impacts, risk management, sustainable human iterations within the environment…)
Built environment EO services	Services related to Copernicus Land Monitoring Service (CLMS) but specific for built environment	
Disasters & geohazards EO services	Copernicus Emergency Management Service (Copernicus EMS)	-a mapping component; (e.g. as digital or printed map outputs) -an early warning component (The European Flood Awareness System (EFAS), The European Forest Fire Information System (EFFIS), The European Drought Observatory (EDO), Global Flood Awareness System (GloFAS), Global Wildfire Information System (GWIS) and Global Drought Observatory (GDO) …
Land EO services	Copernicus Land Monitoring Service (CLMS)	-systematic monitoring of biophysical parameters -land cover and land use mapping -thematic hot-spot mapping -imagery and reference data …
Marine EO services	Copernicus Marine Environment Monitoring Service (CMEMS)	-Marine safety -Marine resources -Coastal and marine environment -Weather, seasonal forecasting and climate …
Safety & security EO services	[Copernicus security service(s)]	crisis prevention, preparedness and response -Border surveillance -Maritime surveillance -Support to EU External Action …

4.4. Structuring the EO services

This section shows the layer where the Market view and the Thematic views meet – the level of EO services. We present these services aligned with the thematic perspective as we have had the most

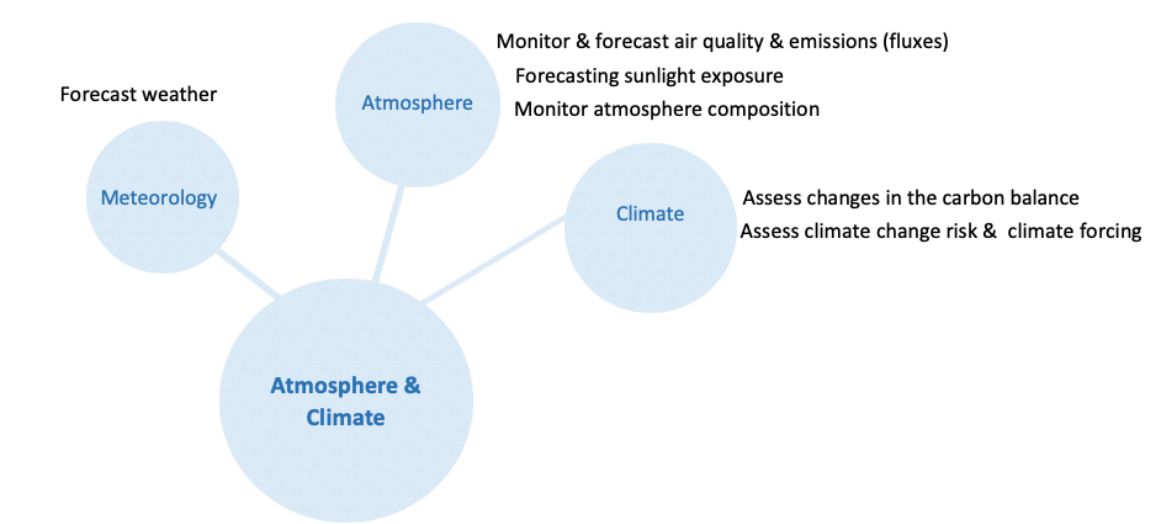
[73] www.copernicus.eu/en/about-copernicus

in-depth discussions with the thematic sector experts through the course of this update. Since our main goal is to classify and structure the market for EO services, we provide as much continuity from previous taxonomies but allowing flexibility to understand the change in the market and also provide a classification within which the Copernicus and other key programmes could fit. Tables 22 to 21 below show a range of keywords describing EO services in each of the Domains and Areas in more detail and show consistency with EO programmes.

4.4.1. Atmosphere & Climate (Monitor)

Table 22- Atmosphere and Climate EO services

Atmosphere & Climate (Monitor)



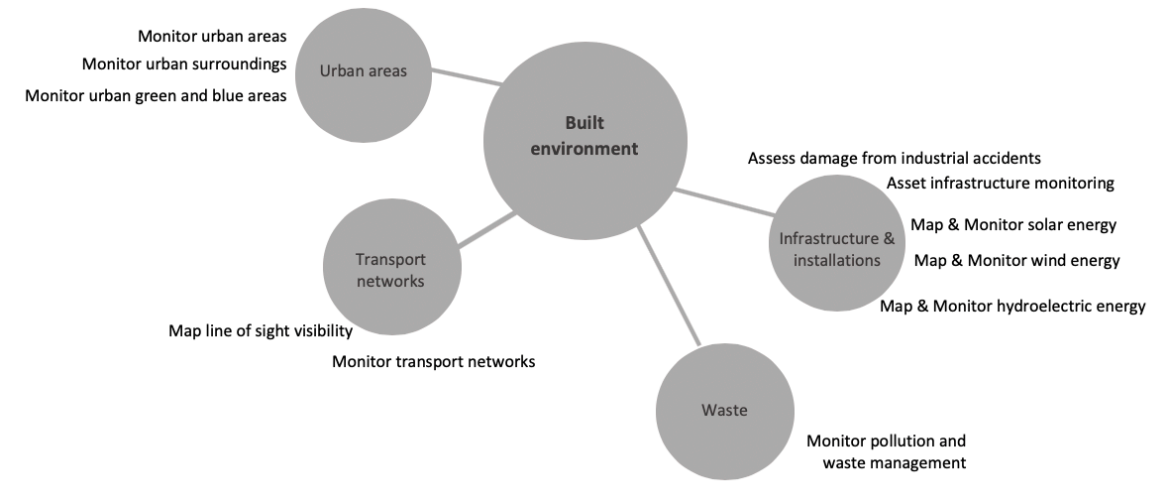
Thematic area	EO services	Description & keywords
Monitor the atmosphere	Monitor and forecast air quality & emissions (fluxes)	Pollution and greenhouse gas emission monitoring. Measuring atmospheric concentrations and characterizing the micrometeorology or using atmospheric dispersion models to back-calculate the emission rates that gave the concentrations observed. Air quality/pollution source maps (CH4, CO2, NO2 & SO2, Particulate Matter, maps of average pollutant flux PM2.5, PM10).
	Monitor atmosphere composition	Monitoring present conditions and forecasting the distribution (transportation), for a few days ahead, of both anthropogenic and naturally occurring key greenhouse gases (GHG) like carbon dioxide (CO2), methane (CH4), or reactive gases such as nitrogen dioxide (NO2), sulphur dioxide (SO2), ozone (O3), etc.
	Forecasting sunlight exposure	While the solar radiation impacting the top of the atmosphere can be well modelled, the solar radiation arriving at the surface is dependent on the atmospheric transmission and turbidity and aerosol optical depth. Forecasting and risk assessment amount of solar (sunlight) radiation which reaches the surface of the planet (UV, radiation measures, models).
Monitor climate change	Assess changes in the carbon balance	Measuring carbon stocks, especially aboveground biomass and providing an overview of a range of approaches that have been developed and used to map biomass across a diverse set of conditions and geographic areas (quantifying stem volume and carbon stock changes). It also includes historical climate data.
	Assess climate change risk & climate forcing	Assess current and future vulnerability to climate change including variability caused by a perturbation of the climate system and associated atmospheric composition (aerosol, ozone and greenhouse gases) driven by human activities). The radiative forcing measures the imbalance in the surface solar irradiance and is a useful predictor of globally averaged temperature change.

Forecast the weather (meteo)	Forecast the weather	Monitor and forecast weather conditions such as temperature, storms, precipitation, heat waves and tropical cyclones – as well as other hazards influenced by weather, like floods or dispersion of atmospheric or marine pollution.

4.4.2. Built environment (Monitor)

Table 23- Built Environment EO services

Built environment (Monitor)



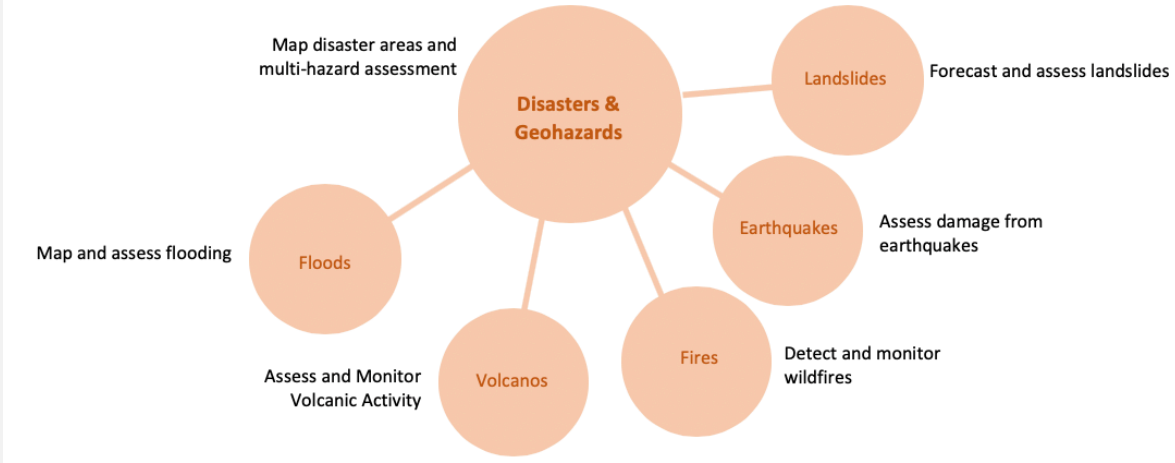
Thematic area	EO services	Description & keywords
Monitor the built environment	Monitor urban areas	Observation, identification, mapping, assessment and monitoring of urban areas and their dynamics at a range of spatial and temporal resolutions. Digital imaging processing methods such basic thresholding, unsupervised classification or products such urban heat island, impervious surfaces, land use change (residential, commercial, other), building density (3D city modelling), high photovoltaic penetration at the urban scale.
	Monitor urban surroundings	Understanding human settlements on the outskirts and near rural areas. Mapping and evolution characterization of human interactions (environmental, population and habitat fragmentation, soil sealing and socio-economic) of rural areas and surroundings, urban sprawl, green urban areas.
	Monitor urban green and blue areas	Monitor green and blue urban areas (in relation to urban form, energy use and carbon emissions). It is about the estimation of urban energy fluxes at a neighbourhood scale (urban energy balance) using land cover, Digital Surface Models (DSM), surface roughness parameters (such as plan area index, frontal area index, roughness length and zero-displacement height), urban ecosystem restoration, urban heat island effect, green corridors, garden monitors.
	Monitor construction and buildings	Construction site surveying and progress mapping, comprising surrounding ground as well as displacements of key components of such structures. There is a need for Near Real Time (NRT) data delivery and measuring stress.
Monitor infrastructure & installations	Assess damage from industrial accidents	Assess structural integrity of the infrastructure, site suitability and vulnerability. Connection with disaster risk reduction (emergency response, recovery, rehabilitation and reconstruction).
	Asset infrastructure monitoring	Industrial activity assessment, monitoring of functional planning zones, exploit correlation with industrial activity to improve the

		model of subsurface, site suitability and vulnerability, land cover, infrastructure, dyke monitoring, emergency airport planning, etc.
	Map and monitor solar energy (solar farms)	Urban solar mapping and understanding the basic characteristics of solar radiation over specific monitoring locations including estimating the variability of solar radiation for site selection and grid data/operators. Solar monitoring services use time series, Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI) and Global Horizontal Irradiance (GHI), shadow mask.
	Map and monitor energy (wind farms)	Understand where wind farms can be sited most cost-effectively and monitor and map wind energy fields (design and operation), wind roses, wind speed & direction.
	Map and monitor hydroelectric energy	Hydrological network mapping (drainage navigation erosion) including hydropower grid monitoring and resource assessment. Water resource (reservoirs) monitoring, hydrological modelling and flood forecasting and mapping (dams).
Monitor transport networks	Map line of sight visibility (land surface)	Landscape visibility mapping and analysis, including spatial planning, terrain mapping (DTMs), land surface, map transmission and land routes.
	Map and monitor transport networks	Transportation systems, interdependencies and industrial progress planning including site, soft ground and network mapping, highway environmental monitoring and assessment, identification of road or track for logistics planning.
Monitor waste	Monitor land pollution and waste management	Identifying illegal dumping and waste management and disposal for law enforcement. Landfills and dump sites emit large quantities of methane, quantify the emissions from these large sites in a single snapshot (maps) and do it frequently, surface and subsurface soil contamination monitoring, Land use/Land cover (LU/LC) maps which depict the physical characteristics of the surface, dry matter productivity, migration of pollutants and imperviousness land surface are parameters needed for this service.

4.4.3. Disasters & Geohazards (Assess)

Table 24- Disasters & Geohazards services

Disasters & Geohazards (Assess)



Thematic area	EO services	Description & keywords
Assess disasters & geohazards (emergency)	Map and assess flooding	Map and assess the extent of the flooding event (floods map, exposure), floodplain mapping, flood risk dynamic assessment and management of water buffer areas (overflow). Measure a variety of

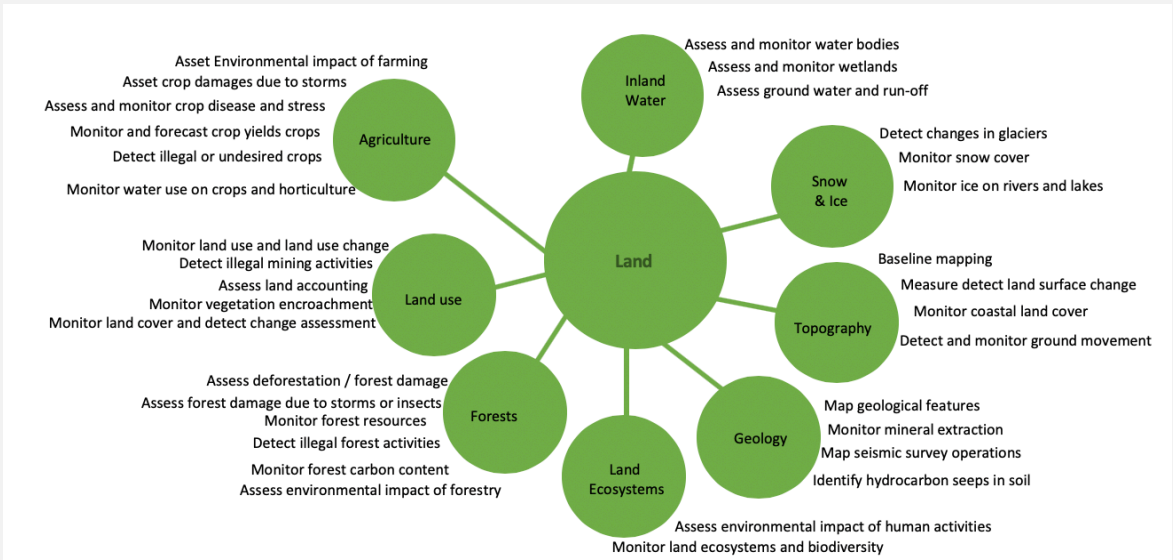
		physical and biological parameters (incl. turbidity levels) in aquatic ecosystems over small and large areas. Products look into the flood impact and extent in phases such as early warning (early/quick/rapid detection), response and recovery monitoring.
	Forecast and assess landslides	Mapping, monitoring, early warning (quick/rapid detection) and assessment of trigger events, unstable areas (rainfall influence) such as landslides (dynamic risk damage, slope instability, subsidence detection, fault and discontinuity maps (vector or raster), ground deformation and motion). Associated services include support for the evacuation of areas prone to collapse or the identification of suitable areas for urban replacement.
	Assess and monitor volcanic activities	Assess ground deformation associated with volcanoes, seismic activity, volcanic eruptions (pre-eruptive, sin-eruptive, gas emissions, atmospheric ash, dispersion, heat flux). Rapid damage estimation (prevention), earthquake damage extent (loss adjuster dispatch). Impact on land cover and landscape (changes). Early warning (quick/rapid detection) and tracking of unrest / eruptive activity using satellite data in support of hazards mitigation activities. Map of the recent lava flows.
	Detect and monitor wildfires	Use optical data to detect and monitor the heat emitted by the fires [forest fire risk (extent, burnt scars) under rapid damage estimation, fire weather index[74] damage, fire protection, rapid damage estimation (prevention, insurance)]. Impact on global atmospheric emissions, with biomass burning to contribute to the risk on human health (besides direct effects, PM2.5, PM10 health impacts) and also to global budgets of greenhouse gases (GHG) like carbon dioxide etc. Monitoring of risk prevention factors [early warning (early/quick/rapid detection)] and issuing alerts for high risk locations.
	Assess damage from earthquakes	Mapping and monitoring of seismic exposure (e.g. population distribution and density in high-seismic-hazard areas). Earthquake disaster prevention, early warning (early/quick/rapid detection), recovery (reconstruction monitoring, residual risk assessment, dynamic risk assessment, information, damage). Extracting background information on seismic, inter-seismic deformations, slip rates & active faults, stress transfer on faults, rapid damage estimation (prevention), change detection and preliminary damage map earthquake damage extent (loss adjuster dispatch).
	Map disaster areas and multi hazard assessment	Assess overall disaster risk maps in an appropriate format by using space, in-situ and location-based disaster risk information, vulnerability, capacity, exposure, hazard characteristics and their possible sequential effects at the relevant social and spatial scale on ecosystems, in line with national circumstances. Products will include disaster recovery maps and rapid mapping for crises, humanitarian aid maps (population density, infrastructure, logistical information), vulnerability assessment, damage assessment. Important to note the Sendai Framework for Disaster Risk Reduction 2015-2030.

4.4.4. Land (Monitor / Assess)

Table 25- Land EO services

Land (Monitor / Assess)

[74] Fire weather index: Copernicus emergency management service: Fire danger forecast https://effis.jrc.ec.europa.eu/about-effis/technical-background/fire-danger-forecast/



Thematic area	EO services	Description & keywords
Monitor agriculture	Assess environmental impact of farming	Assess how yields and production are evolving and how agricultural activities are impacting the environment (i.e. the monitoring of farm-produced dust and particulate matter, polluted runoff, etc).
	Assess crop damage due to storms	Protect crops from extreme weather events (hailstorms, lightning and extreme temperatures) using early warning systems. Accurately and repeatedly assess current and historic losses for crop insurance, identify the plant growth stage, warning-service loss assessment, food-security, impact.
	Assess and monitor crop disease and stress	Map agricultural areas and crop health production (disease and stress). The vegetation indices are used to understand the amount of farmland in stressed conditions taking as inputs weather forecasts or climate factors, and being used in harvest predictions, agricultural forecasts, monitoring terrain for irrigation or the use of fertilisers.
	Monitor and forecast crop yields	Monitor and forecast specific crop types i.e. predicting certain crop characteristics on a day-by-day basis after a planting date, near-real-time data which helps make day-to-day farming decisions, to assess crop status, and predict how changes in the plant growth stage will affect crop acreage and yield harvest (inventories / statistics), crop types (extent, growth, health, stress), land surface and temperature. Seasonal forecasts with adaptive decisions such as (choosing crop varieties, crop–grazing balancing, commodity trading and food emergency preparedness, return on investment (nutrients & fertilisation monitoring)).
	Detect illegal or undesired crops	Crop planting area monitoring, crop area information acquisition, multi-temporal data and multi-spectral time series are two major aspects for improving crop identification accuracy and illicit crops, estimates, cultivation patterns, hyperspectral thematic crop type mapping.
	Monitor water use on crops and horticulture	Monitoring of run-off, improved agricultural water management, overall irrigation, taking into account soil water index, surface soil moisture, map vegetation index, etc.
Monitor the forest	Assess deforestation / forest degradation	Assessment and monitoring of forest biomass (above-ground, deforestation, reforestation, afforestation and degradation). Time series analysis of forest loss, disturbance index, carbon emissions, greenhouse gas (GHG) emissions, disturbance, measurement reporting and verification (MRV), Reducing Emissions from Deforestation and Forest Degradation (REDD+).

	Assess forest damage due to storms or insects	Assessing and managing damaged timber due to events such as storms, fires, insect damage etc. Elaboration of impact maps including sudden changes in forest stock volume, pest infestations modelling, ice and snow damages, etc.
	Assess, monitor & manage forest resources	Mapping forest and classifying forest type/cover change (classification/capacity) such as biomass (diversity, health, height, volume stress, location, extent), tree cover density (canopy coverage) and tree species, tree height and diameter), growth predictions, harvesting analysis (timber volume, inventory, clear cuts, accreditation and certification), forest condition mapping, time series, change detection monitoring of moist, etc.
	Detect illegal forest activities	Detect and identify illicit logging, change-detection, forest cover, forest types, biomass, density, etc.
	Assess environmental impact of forestry	Assess changes in the forestry and tree line (fragmentation, capacity, location, extent and tree cover density, atmospheric deposition and GHG emissions, transboundary atmospheric pollution, climate change effects on forestry, etc.).
	Monitor & assess forest carbon content	Monitor carbon balance, carbon tracking, global carbon stocks, greenhouse gas emissions from deforestation and forest degradation, land use, land use change and forestry (LULUCF). Support to the UN Framework Convention on Climate Change, REDD+.
Monitor bodies of inland water	Assess and monitor water bodies	Provides qualitative and quantitative information (e.g. time series and/or/of maps) concerning inland water quality, regarding chlorophyll content (algal blooms), suspended matter (turbidity, suspended sediment concentrations), and the water body (surface water extent, water quality, pollution, temperature, volume, level, alkaline water, evaporation, surface temperature) for permanent, ephemeral, inland water bodies.
	Assess and monitor wetlands	Water bodies monitoring and assessment, surface water dynamics, wetland ecosystem extent, water quality, ecosystem service mapping (e.g. carbon sequestration, flood regulation).
	Assess groundwater and run-off	Assess water run-off (water quantity), hydrological network and catchment areas (water catchment), hydrological simulations, run-off season, groundwater, integrated water management, soil moisture as relevant on the threshold runoff response in a small headwater catchment.
Monitor snow & ice	Detect changes in glaciers	Long term monitoring of glacial variations especially at the glacier margins and terminus location. Mapping and charting fluctuation, ice caps, landslides, etc. or measuring parameters such as ice thickness, surface ice velocities, and changes in surface elevation over time.
	Monitor and assessment snow cover	Monitoring snow cover area extent (depth, temperature), fractional snow cover, snow water equivalent and snow mass.
	Monitor ice on rivers and lakes	Monitor grounded and floating ice covers on shallow water and lakes (ice cover concentration, extent and phenology, inland ice, ice sheets, thickness, freezing period, melting period, land fast ice, ice/lake extent, snow/ice surface temperature).
Assess land ecosystems	Assess land ecosystems and biodiversity	Assessment of the ecosystem condition and pressure mapping of biodiversity with critical habitat maps, monitoring wildlife corridors, linear features (hedges and boundaries), soil moisture, vegetation indices (e.g., normalized difference vegetation index (NDVI), greenness and biomass, leaf area index (LAI), estimation of stem volume, etc.
	Assess environmental impact of human activities	Monitoring anthropogenic impact on land resources; LU/LC, productivity, Soil Organic Carbon (SOC), burnt area mapping, Forest & wooded land, Cropland, Pasture (improved grassland), Wetland, Settlements (villages, urban), Cropland/ grazing land management, Long-term cultivated; improved pasture, unimproved pasture, new set

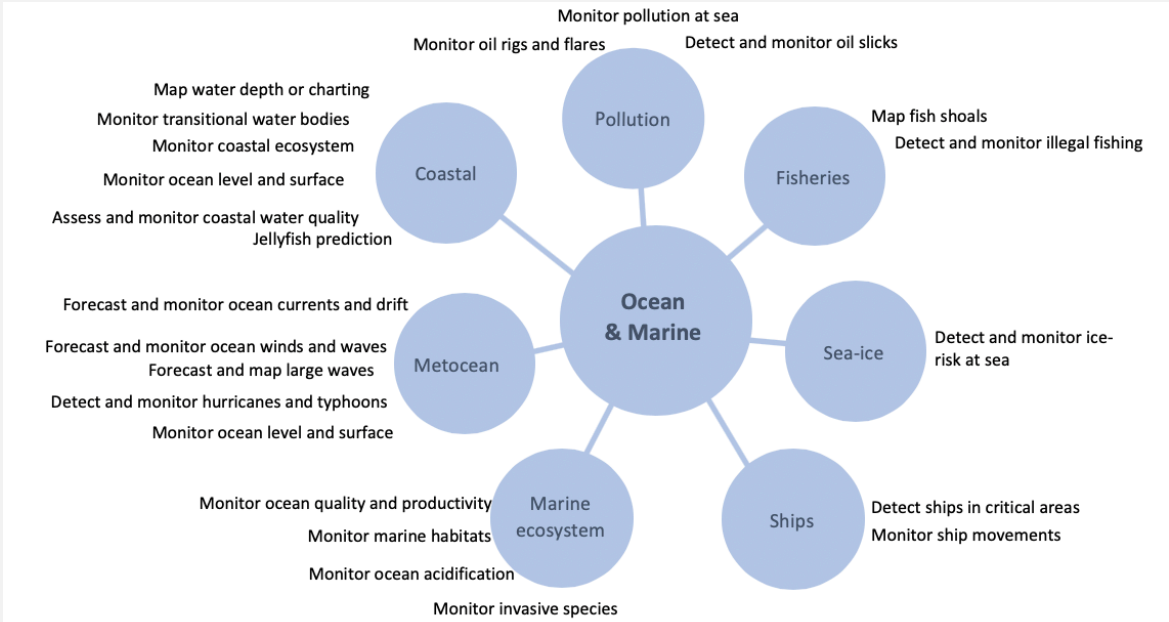
		aside, old set aside, wetland/paddy, shifting agriculture, abandoned/ degraded, etc.
Monitor land use	Monitor land use and land use change	Monitoring Land Use (LU) and Land Cover Change (LC) is the measure available to monitor pressures on terrestrial ecosystems and biodiversity; mapping surface imperviousness, canopy structure phenology, etc., its classification and change detection (accuracy assessment procedures), Land Use, Land Use Change, and Forestry (LULUCF) reporting, land use studies, baseline map, etc.
	Detect illegal mining activities	Monitor and address various impacts of mining and hydrocarbons extraction studying environmental changes like acid mine drainage, illegal surface mining supporting law enforcement and allowing the regulatory agencies helping to avoid or minimize the adverse effects of illegal mining. These activities monitor the progression of disturbance caused by illegal mining, identifying and tracking reclamation sites, and assessing land use and land cover changes.
	Assess land accounting (land value, ownership, type use)	Measure land use statistics and land accounting (land administration, baseline map, land use studies and statistics; life populations, human settlement patterns, impact of drought on agricultural production, impact of loss of agricultural land on production, pollution caused by use of fertilizers/ pesticides, threats to wildlife due to habitat destruction, land evaluation for agriculture, areas at risk to land degradation, remedial measures to counter inappropriate land management, soil sealing). Monitoring human–environmental interactions such as landscape changes e.g. land use land cover (LULC), soil and terrain forms, surface hydrology (including shallow lakes, rivers, marshes and swamps) as well as ecological services (conservation), anthropogenic usage and land take (urban planning and management), land accounting and land administration, land use studies and statistics (use, parcels), cadastral.
	Monitor vegetation encroachment	Monitoring terrain surrounding infrastructure such as railways, pipeline and high voltage power line corridors. Major products to support this service are vegetation condition index (VCI), ancillary data, risk identification layer, prioritization layer.
	Monitor land cover and detect change assessment	A range of direct and indirect measurements to monitor pressures on land cover which is changing over time. Land cover assessment includes mapping from wide coverage (land cover and use) to locally or regionally focussed (habitat mapping). High-resolution Layers (characterization & classification), soil sealing, arid areas, wet areas, erosion potential, LCCS (Land Cover Classification System), imperviousness (e.g. CORINE land cover inventory).
Monitor topography and motion	Baseline mapping	Surface deformation maps and profiles elevation data products such: Digital Elevation Models (DEMs), Digital Surface Model (DSM), Digital Terrain Model (DTM), terrain roughness measure, slope stability (curvature, aspect), etc
	Measure & detect land surface change	Measure ground and infrastructure displacements (change detection monitor), surface movement (sand dunes, pipeline routes, corridor status, soil erosion) or landslides and subsidence.
	Monitor coastal land cover	Monitor coastal land cover, coastline, shoreline change and coastal morphology (coastal terrain models), including pollution by oil, litter etc.
	Detect and monitor ground movement	Detect reservoir compartmentalization & optimization, permafrost zone stability, ground displacement: fault identification, reactivation & discontinuities, uplift, subsidence, heave, thawing, landslides, earthquakes.
Extract information about subsurface geology	Map geological features	Detect and map features extraction, near surface features, lithology features, linear disturbance features (faults & discontinuities).

	Map seismic survey operations	Map seismic (survey, coupling, logistics), gravity-seafloor classification maps, onshore seismic survey operations (hydrocarbon exploration), satellite derived bathymetry products (water depth, water clarity - turbidity).
	Monitor mineral extraction	Monitoring the environmental impacts of mineral resources exploitation (ground surface), illegal activities, recovering abandoned sites, mine waste mapping and monitoring (erosion, land subsistence, biodiversity/habitat loss, destruction & disturbance of ecosystems).
	Identify hydrocarbon seeps in soil	Identification of hydrocarbon seepage (oil seeps) detection (near surface geology: faults, fractures, unconformities or carrier beds) as indicators of petroleum charge.

4.4.5. Ocean & Marine (Monitor)

Table 26- Ocean and Marine EO services

Ocean & Marine (Monitor)



Thematic area	EO services	Description & keywords
Meteocean	Forecast and monitor current movement and drift	Ocean water forecasting including ocean dynamics and circulation: tides and ocean currents (surface current models for tides), sea level, sea surface salinity (internal waves, eddies and frontal areas), upwelling, sea state, etc.
	Forecast and monitor ocean winds and waves	Wind resource mapping, derived winds (speed, direction, stress) and waves (current veins, swell-maps, sea surface height), wave exposure (fetch, averaged directional wind speed and bathymetry). The sea surface roughness is impacted by wind (waves) and rain cells.
	Forecast and map large waves	Forecasting extreme waves / tsunami, inundation forecasting (flow depth distribution), vulnerability maps, bathymetry, current velocity.
	Detect and monitor hurricanes and typhoons	Monitoring atmospheric front, local weather phenomena, cloud structure, winds and waves, sea-surface temperature and sea-surface height.
	Monitor ocean level and surface	Monitor (changes in) sea level, physical characteristics such as gravity, currents, temperature and salinity, ocean circulation (currents and eddies at the edges of holes and bumps), seasonal or inter-annual

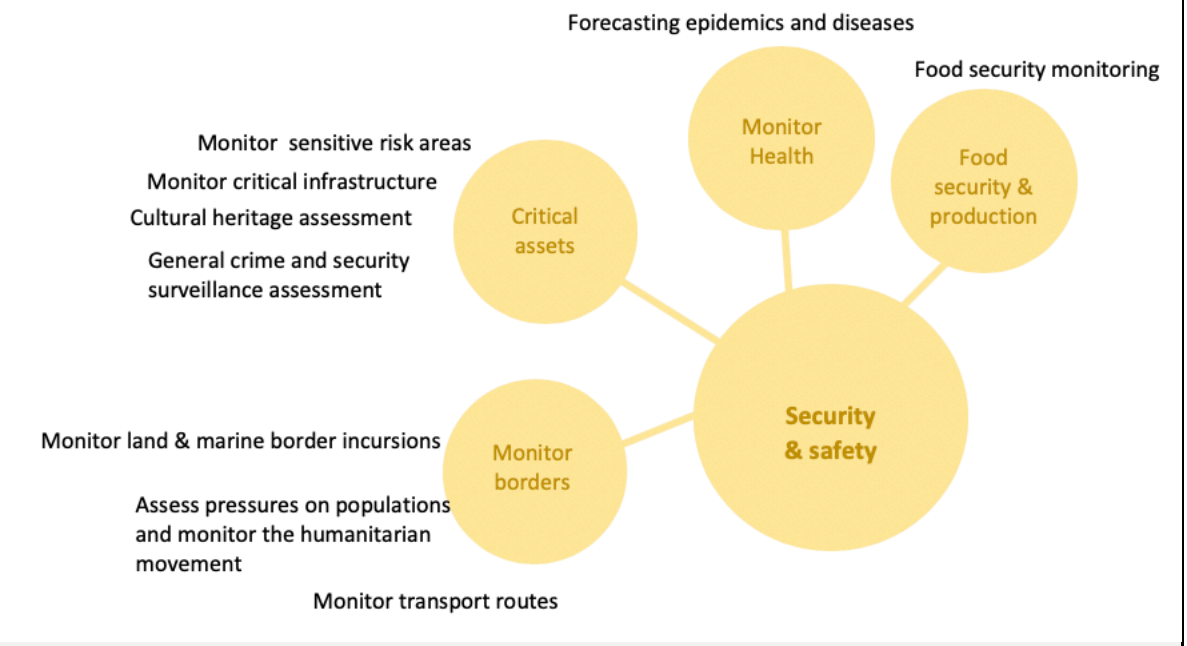
		variations, or even longer periods (long-term rise in sea level), hindcasting.
Monitor coastal areas	Monitor water depth or charting	Satellite derived bathymetry mapping and charting. Surveying shallow waters.
	Monitor transitional water bodies	Essential environmental monitoring and management in aquatic ecosystems focus on rivers (inland waters, watershed) and lagoon/estuary-coastal region-ocean/Sea. Research projects now aiming to harmonise monitoring approaches across different water bodies.
	Monitor ocean level and surface	Monitor sea level rise and ocean circulation (currents and eddies at the edges of holes and bumps) seasonal or inter-annual variations, or even longer periods (long-term rise in sea level), hindcasting. Physical characteristics such as gravity, currents, temperature and salinity, height, etc.
	Assess and monitor coastal water quality	Detecting and mapping suspended sediment concentrations sediment (qualitative, quantitative), turbidity (quality, quantitative), visibility, chlorophyll-a concentration, suspended sediment may be indicative of estuarine processes, re-suspension or pollution.
	Jellyfish prediction	Assess the impact of jellyfish in human activities through ocean physics analysis maps (salinity, currents, sea level (SS hight), temperature (SST), ocean colour), ocean biogeochemistry analysis maps (ocean chlorophyll), policy objectives (marine policy, coastal management, common fisheries policy, marine strategy framework).
Monitor the marine ecosystem	Monitor ocean quality and productivity	Assessing water-related ecosystems. Water quality status (sea surface temperature (SST), transparency or turbidity, and ocean colour ocean colour composite (chl-a, transparency, swath, qualitative, quantitative), which enable eutrophication assessments and the detection of algal bloom (phytoplankton, harmful blooms - HABs), ocean productivity (carbon content, primary production).
	Monitor marine habitats	Monitoring generic life marine ecosystem (algal blooms, marine mammals...), sea surface temperature, sediments, plumes, nutrients, dredging operation, coral reef health assessment (bleaching), marine non-indigenous species (NIS), etc.
	Monitor ocean acidification	Monitoring the ocean carbonate chemistry, bio-geo-chemical cycles, ocean salinity, insitu (partial pressure of carbon dioxide in the water, dissolved inorganic carbon, alkalinity and pH).
	Monitor invasive species	Sargassum detection for seasonal planning (estimate drift and eventual landings on the coasts), Products such as drifting simulation modelling, together with weather and surface currents.
Monitor fisheries	Map fish shoals	Fish-shoal location, fish population dynamics fed by-catch reports (ERS-Electronic recording and reporting system) and catch efforts estimated from VMS (Vessel Monitoring System), collection of catch reports. Other products in consideration such bathymetry, waves, current movement and drift, pollution, ocean colour, surface temperatures (SSTs), sea surface height anomalies and sea surface colour revealing the abundance of chlorophyll a).
	Detect and monitor illegal fishing	Track and localization of licensed fishing vessels movements and detect suspicious activity, fleet management services (ocean colour, PP, SST, etc).
Monitor sea-ice and icebergs	Detect and monitor ice-risk at sea	Detect sea-ice and icebergs (ice cover, sea ice thickness, height of the ice surface, water body extent) during ship routing.
Ships monitoring, detection and tracking	Detect ships in critical areas	Detect and monitor the movement of ships and activity at associated ports and infrastructures (baseline activity), shipping and navigation.

	Monitor ship movements	Monitor sea-traffic, shipping lanes, ship-source pollution, discharges, sea surface temperature (SST).
Monitor marine pollution	Monitor pollution at sea	Monitoring turbidity & pollutants at sea such marine litter, marine plastics, hazardous and noxious substances (HNS) with relevant parameters (altimetry, sea-surface salinity, sea-surface temperature, ocean colour and sea-ice data) and policy objectives (integrated maritime policy, environmental action programme, etc).
	Detect and monitor oil slicks	Detect and monitor size, extent and location of oil spills, as well as providing information on wind, current and waves to predict oil movement. The oil spill threats are on early warning stages of natural oil seepage and during the disaster monitoring and characterization).
	Monitor oil rigs and flares	Monitoring of methane and other gases flared from gas flares and oil rigs, oil wells due to possible malfunctioning. Typically service accompanying forecast weather conditions.

4.4.6. Security & Safety (Monitor/Assess)

Table 27- Security & Safety EO services

Security & Safety (Monitor)



Thematic area	EO services	Description & keywords
Monitor critical assets	Monitor sensitive risk areas	Geospatial intelligence analysis, sensitive risk areas (mines, unexploded objects (UXO), de-mining) mapping, high risk areas mapping, precision mapping, activity detection, auxiliary research and judgment on anti-terrorism in important areas of public security.
	Monitor critical infrastructure	Risk evaluation, threat analysis, vulnerability assessment, dams monitoring, water treatment monitoring facilities monitoring, oil fields monitoring, pipelines monitoring, pumping stations monitoring, airports monitoring, governmental buildings monitoring, transport networks monitoring.
	Cultural heritage assessment	Mapping heritage sites and in supporting the archaeological investigation, understand the scale, impact, opportunities, responses and tools for conserving world heritage and mitigating threats, vulnerability assessment, damage assessment, risk evaluation, looting tracking. Detect ground deformation and

		monitor subsidence at archaeological sites, monuments and historic urban centres to detect different types of surface changes caused by erosion, floods, vegetation or human actions.
	General crime and security surveillance assessment	Border control monitoring, terrorism threat risk assessment, piracy, illegal cropping analysis, cross-border state disputes analysis.
Monitor borders	Monitor land & marine border incursions	Border area monitoring, coastal area monitoring, migration monitoring.
	Assess pressures on populations and monitor the humanitarian movement	Monitor movement of people, population pressures, monitoring of settlements, evolution, characterization, situation maps, migration and cleansing monitoring, population pressures, displacement of population assessment, planning of contingency operations and operations security & coordination maps (moving objects such vehicles), impact on the surrounding environment, humanitarian camps.
	Monitor transport routes	Monitor economic activity, transportation of legal and illegal goods monitoring, tracking and identification (drug trafficking monitoring), smuggling location, maritime traffic assessment.
Monitor health	Forecasting epidemics and diseases	Health maps and epidemic vector control mapping (daily disease risk maps, NDVI, land cover, soil type), environmental monitoring of endemic diseases and chronic diseases, public health emergencies disaster/danger, pollution-health risks profiling in the urban environment.
Food security & production	Food security monitoring	Map and assess the extent and intensity of the drought. support food security throughout the cycle, from design to implementation, monitoring, evaluation, and adaptive decision making. Assess a variety of physical and biological parameters in ecosystems and economy; maximize sustainable yield and productivity by providing timely and accurate information (early warning system) like; drought, insect plagues, pest and diseases, infection risks, storm damage. Monitor crop's growth, monitor groundwater and water levels in rivers, radiation and soil, etc.

The **RESULTS CHAPTER** presents the 2020 taxonomy evolution leading to improving the organisation, accessibility, and findability of the EO services. It provides value as the authoritative source for stakeholders (as users). It reflects on both views on the taxonomy: market and thematic, concerning the classification and terminology.

It presents the **Market (user) taxonomy** categorised into the main Markets and Sectors in the classification which are divided by who is buying/using the services (from the needs to the elaboration of the EO services). The updates are clearly presented. The purpose is to increase the reliability and uniformity of the services from the perspective of the users. Related industries are aggregated into a few major sectors.

It discusses the **thematic (provider) taxonomy** structure and defines the main elements from the **domain > area > services > applications > products > parameters (essential variables)**. It also provides major updates concerning the evolution of these services, especially under the security domain. It goes from the domain to the thematic segment, to the EO services which are described in the "key words" section using (applications, products and parameters). Some examples of structures are provided which presents the **Structuring of the EO services** indicating a description of the EO services.

The two views on the taxonomy converge in the **EO services level**. Descriptions & keywords for each service have been developed through interaction with sector experts. These descriptions are presented arranged by Domains and Areas. This section is also about sharing a common understanding

of the structure of information among the EO/GI stakeholders (i) enabling reuse of the knowledge gathered by the taxonomy (ii) making thematic domain assumptions explicit per definition of their concepts (iii) analysing thematic domains knowledge.

5. Uptake

Engaging researchers, scientists and private sector in a common project is an efficient way to improve the understanding between communities, share best practices and support the exploitability of research outcomes. This section introduces and responds to the question on this applicability in user groups. CopHub.Ac and EO4GEO projects are federating communities to increase the knowledge and the awareness of EO capabilities and new approaches.

5.1. Applicability in CopHub.AC

This update of the EARSC taxonomy has been conducted as part of the CopHub.Ac project. In this section we present the alignment of the EARSC taxonomy with the project's own grouping of Academy offerings.

One of the key project objectives is to efficiently structure the information gathered by the CopHub.AC project through the "knowledge landscape[75]" and make this information accessible to the target users. This information is made available to these users through the CopHub.AC gateway[76], an online Knowledge portal that facilitates easy retrieval of the Academy member's capacities and expertise for potential users (regional and international cooperation partners). The gateway facilitates this access through a series of filters, also using a two-level approach. The first level corresponds to the six thematic streams of Copernicus services: Atmosphere, Marine, Land, Climate Change, Security and Emergency. The second level has been defined based on the range of services in the Academy partners' portfolio and the Societal Benefit Areas and the Horizon Europe digital and skills agenda. These second-tier classifications are:

- Climate change mitigation & adaptation
- Biodiversity & ecosystems
- Digital agenda & new skills
- Energy transition
- Sustainable agriculture & food production
- Infrastructure & transport
- Health surveillance
- Emergency, security & defence
- Sustainable urban development
- Water sustainability

The EARSC thematic taxonomy showed that the first two levels of the structure in Table 28 were sufficiently robust that practically any new service under Horizon Europe or covering Societal Benefit Areas, which are the focus of CopHub.AC, can find its place within the EARSC taxonomy. The updated

[75] CopHub.AC Knowledge landscape (www.cophub-ac.eu/knowledge-landscape/). It is built on data collected in the Gateway and stored in a common database

[76] CopHubAC gateway (http://www.cophub-ac.eu/application/)

taxonomy, as presented herein, is a living work which will continue to evolve to include the full richness of newly developed products and applications.

Table 27 presents the updated EARSC thematic view on the taxonomy and highlights the overlap with the CopHub.Ac thematic application areas. These map to both Domains (first level) and Areas (second level) in the EARSC thematic taxonomy. The terms in bold show the corresponding CopHub.Ac first and second tier categories (the asterisks show those EARSC categories that were added or adapted in this update based on expert feedback). This table shows that all categories identified in the CopHub.Ac approach are also present in the EARSC thematic taxonomy.

Table 28- Domains and Areas of the EARSC thematic view on the taxonomy with CopHub.Ac categories identified in bold

1st level Thematic domains	**2nd level Thematic segments (areas)**
atmosphere & climate	**climate change (*)** atmosphere (emissions & surface fluxes) **(*)** meteorology
defence, security, (inc. safety)	customs & border **(*)** **health** (epidemics & diseases) **(*)** food security & production (droughts) **(*)**
disasters & geohazards **(emergency)**	floods fires earthquakes landslides volcanos
land	**agriculture** forests inland **water** snow & ice **biodiversity & land ecosystems (*)** land use / land cover **(*)** topography geology (extractives) **(*)**
built environment	**urban areas** **infrastructure & transport** networks (TBC) **(*)** **energy (*)** waste **(*)**
marine	**biodiversity & marine ecosystems (*)** coastal fisheries meteo-ocean ships sea-ice icebergs marine surveillance

5.2. Taxonomy adoption under EO4GEO Body of Knowledge

According to Wikipedia, a Body of Knowledge (BoK)[77] is "the complete set of concepts, terms and activities that make up a "professional domain", as defined by the relevant learned society or professional association". Following the work done by DiBiase et al. (2006) and Katifori et al. (2007), the ontologies[78] have been used as a means of knowledge-sharing among different user communities, thus improving interoperability among different "geographic databases". The ontology together with a set of individual instances of classes constitutes a knowledge base as the work described by Sun et

[77] Wikipedia (BoK) https://en.wikipedia.org/wiki/Body_of_knowledge
[78] https://www.researchgate.net/publication/221430748_Creating_an_Ontology_for_the_User_Profile_Method_and_Applications

al. (2019)[79] on the geospatial data ontology. Overall a Body of Knowledge is an inventory of the sector represented by a structured knowledge in a form of a complete set of concepts, i.e., a theory, a method, a technology, etc., that can be used by members of discipline to guide their education and work practice.

To enable such a description within the Earth Observation sector, we need to formally specify which are the new components (objects), classes, attributes and relations as well as restrictions that we will integrate. A network of experts under the EO4GEO project has been put in place[80] to identify concepts, methods and techniques relevant for the sector, and to develop and enrich the BoK with the description of these concepts. The construction of an ontology for EO services uptake is a labour-intensive process with rich and complex terminology and its relationships. This exercise provides the EO component to the BoK describing the vocabulary related to user communities but also the thematic perspective.

The complex part concerns the separation of the domain knowledge identified by "concepts" from the operational knowledge being the last one to hook the bridge to the user communities. The exercise bridging with the user point of view is novel in the sector and there are currently discussions on what is technically possible under the Living TextBook which is hosting the EO4GEO BoK[81] and what is correct in an ontology-based approach. The EO4GEO WP2 (Developing the Ontology based for EO/GI) contemplates the work on thematic and application orientation under a working group which bridge with the market segmentation perspective and defines the type of customer while also provides a tool to help describe and classify the products that are offered by the service providers, therefore, facilitating the market uptake. Other groups where the products description may have connectors are under the WG5 (Platforms, Sensors and Digital Imagery) and WG6 (Image Processing and Analysis). As a result, the new BoK has started to gather the knowledge and skills covered by the Earth Observation and Geoinformation sector.

In the context of CopHub.AC the taxonomy fits with the BoK as one of the means to achieve a 'common understanding' and embracing the user community by identifying these concepts. The knowledge exchange among "users of geoinformation" services presents many challenges and the development user approach is considered under the BoK through structuring the 'offer' of the sector, its products and services for the actual use of the communities for whom it is intended, the 'uptake' (see Table 28). Therefore, the definition of these user communities (market (user) taxonomy section) has been integrated as concepts. For doing so, this exercise is integrated under the EO4GEO thematic group on applications where the relationships between "noun" objects and their "attributes" give structure to knowledge.

Table 29- Example user description at the BoK

Taxonomy and BoK concept description
Users in **managed living resources** refer to human activities exploiting natural organic resources. Knowledge and information products to forge a viable strategy for the user's operations such as the assessment of the status of the resource due to natural or human activity for effective commercial exploitation and conservation. This includes **agriculture, fishing and forestry** occupations for our society.

[79] K.Sun, 2019 (https://www.tandfonline.com/doi/full/10.1080/20964471.2019.1661662)
[80] Body of Knowledge for the Earth Observation and Geoinformation sector: a basis for innovative skills development. Submitted to ISPRS congress 2020.
[81] EO4GEO revised ontology-based approach (http://www.eo4geo.eu) (https://bit.ly/37FlfOB)

Users in **defence** and **security** work in the field of **military, emergency and social protection** and define, collect, analyse information to provide intelligence & safety (monitor events, improve response and drive resilience). Some examples are activities under **humanitarian response** such as border control organisations, police and rescue forces, coast guards, civil protection, military services, and intelligence services which can use EO services to detect and monitor high risk areas produced naturally or by humans, monitor border incursions or maritime movements.

5.3. Relationship with SDGs

In September 2015[82], the UN General Assembly ratified the 2030 Agenda on Sustainable Development, a new transformative, integrated and universal agenda that aims to end poverty, promote prosperity and people's well-being while protecting the environment. The core of the 2030 agenda is the 17 sustainable development goals (SDGs) and their 169 associated targets, which should be achieved by 2030. The SDGs are being launched with an emphasis on collecting data that will be extensive and specific enough to serve these needs. They are designed to balance the three dimensions of sustainable development: the economic, social and environmental.

Earth observation (EO) is a powerful instrument to support the reporting on Sustainable Development Goals (SDGs) and indicators and the provision of relevant information to effectively monitor progress towards the SDG targets, and the degree of compliance with the International Agreements. It helps on the provision of critical information on natural resources, government operations, public services, or population demographics. This actionable information helps on the SDG implementation role, monitoring, reporting, and the facilitation and shaping of reporting methods, policy and tools. These insights can inform national priorities and help determine the most effective paths for action on national issues. EO is a critical data source for monitoring and driving progress against the SDGs,

Motivated by the alignment of EO services within the context of Sustainable development, EARSC initiated a mapping exercise as a first attempt to compare EO services and the most relevant SDGs schema at various levels of planning, monitoring, tracking, and reporting. EO services can help ensure that plans to achieve the SDGs are evidence-based, and that their outcomes are measurable. EO has a role to play in relation to goals, targets and indicators through a common denomination between the services proposed and the matching between the problem recognition and challenge presented and the identification of the services.

We follow the principle that a taxonomy empowers users to explore services by providing clear choices for browsing and accurate results for the search. So, the recognition of the EO taxonomy will allow improved matching between the challenges presented and the identification of relevant services.

To understand and propose how to address global sustainability challenges, timely and reliable access to environmental data and information is necessary. The 2030 Agenda for Sustainable Development stresses the importance of Geospatial Information and Earth Observations (EO) to monitor progress and achieve SDGs targets. Figure 15 represents 11 out of the 17 SDGs marked by the red circle where EO contribute to the monitoring or reporting of the indicated goal (SDG1, SDG2, SDG3, SDG6, SDG7, SDG9, SDG11, SDG12, SDG13, SDG14, SDG15).

[82] UN SDGs: https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Figure 17: Mains SDGs where EO services could make a contribution

Effective monitoring of the SDG and reporting of the progress towards the SDG targets require the use of multiple types of data such as EO which together with modern data processing and analytics, offer new opportunities to track sustainable development.

Amongst all the SDG targets, Table 29 relates those to sustainable use of for example natural resources (SDG7), sustainable cities (SDG11), life on land (SDG15), etc which are of particular importance since pressures on our Planet are increasing ,therefore, the advance of other patterns such intensification of food resources (targets related to SDG2), or the use of inland water under (SDG6). The table shows a first correlation of EO services helping with these targets.

Table 30- SDGs and Targets where EO services can make a contribution

(1) No poverty	(2) Zero hunger	(3) Good health and well being	(6) Clean water & sanitation	(7) Affordable & clean energy	(9) Industry innovation & infrastructure	(11) Sustainable cities and communities	(13) Climate action	(14) Life below water	(15) Life on land
1.1. Mapping spatial distribution of the risk of poverty	2.3. Management of farming	3.3. Assessment of diseases	6.1. Assess water use efficiency	7.1. Access to energy (status of settlements)	9.1. Inform on infrastructures development & planning	11.1. Understand and monitor slums & informal settlements	13.1. Identifying, monitoring and preparing for climate related hazards	14.1. Integrate data & monitoring for marine pollution	15.1. Monitor land use and land cover change on land ecosystems
1.2. Estimate economic activity, mapping areas and its resources	2.4. Agricultural productivity & env. impact of agriculture	3.9. Monitor the level of air quality data	6.3. Water quality detection & monitoring		9.4. Mapping & measurement of pollutants emissions	11.2. Assess production & efficiency for road infrastructures & shipping routes		14.3. Planning for setting targets for ocean acidification	15.2. Progress towards sustainable forest management (biomass, area of change, etc)
1.4. Estimate economic activity and access to basic services			6.4. Water user efficiency			11.3. Urban growth monitoring for sustainable use of land		14.4. Support fish stocks assessments	15.3. The proportion of land degraded (land cover, productivity and carbon stocks)

1.5 Build resilience of vulnerable populations contributing to the management of disaster risk reduction			6.6. Monitoring the extent of water related ecosystems over time			11.5. Mapping of vulnerable disaster areas & early warning systems			15.4. Conservation & sustainable management of mountain ecosystems (protected areas, green cover)
						11.6. Spatial mapping of cities & waste management			

EO-based services can provide imagery and data over the global geographic and daily temporal scales needed by stakeholders for monitoring, enforcement and tactical decision support. Monitoring progress and reporting on the SDG global indicator framework is key for supporting informed and evidence-based development policies by countries. Taking a first example of how the EO services should be mapped against the Global indicator framework, the SDG6 on Clean Water and Sanitation offers a good match. Table 30 shows the match Goals > Targets > EO services > Products.

Table 31- Targets/ Indicators and EO services

SDG6	Target	EO Services	Products
Clean Water and Sanitation	6.1. Assess water use efficiency		
	6.1.1: Proportion of population using safely managed drinking water services	EO to support the mapping and inventory of wet-lands as a basis for management-oriented assessment and monitoring	Soil moisture, wetland extension
	6.3.2: Proportion of bodies of water with good ambient water quality	EO support delineation of surface water bodies and partly monitoring requirements for a limited n. of parameters	Maximum Chlorophyll Index
	6.4.1: Change in water use efficiency over time	EO partly support the indicator by providing operational capacity for mapping irrigated water use efficiency	Land surface, Sea-Surface Temp.
	6.6.1: Change in the extent of water-related ecosystems over time	Water-related ecosystems that are most amenable to EO include the spatial	Soil moisture, wetland extension

		extent of wetlands as well as open water surfaces	

The **UPTAKE CHAPTER** presents a range of communities with which the EO community needs to communicate, in order to deliver value and support the realisation of the objectives of these communities. It shows how the taxonomy can be used as a bridge to those communities.

To enhance the mutual understanding of which capacities are available and what is offered under the **Copernicus Academy network**, a specific taxonomy is used and showed its alignment with the service providers taxonomy from EARSC. This taxonomy is not only considered as a process of naming and classifying above mentioned EO services and application areas but through its close link to the **EO4GEO Body of Knowledge** in the EO*GI sector (Stelmaszczuk-Gorska M.A. et al., 2020) and the EARSC thematic taxonomy (EARSC, 2015) a tool to improve the understanding between communities.

This section also reflects the nature of the taxonomy following its hierarchical structure and the ontology[83] based approach, which provides different relationships between terms and the Body of Knowledge (BoK) as a formal description of knowledge as a set of concepts within a domain and the relationships that hold between them that make up the professional domain of the Earth Observation and Geospatial sector. The call for collaborative cross-sectoral agendas encompasses the evolution of the BoK thinking where new applications related to the domain (integration of the EO) or area of expertise (**inclusion of the user context**) have been taken into account to create a general, comprehensive and extensible model including those communities.

The case of Sustainable Development Goals (SDGs) presents a matrix of SDGs and EO services that can contribute to the realisation of these. Ensuring a good matrix for the **EO services** and **SDGs** will support the tracking, monitoring and evaluating of the 2030 Agenda for Sustainable Development. The uptake of the EO services and products will thus support the realisation of the SDGs and a standardised taxonomy will help potential new users find these services and benefit from them.

6. Conclusions

Earth Observation is influential and plays an increasingly important role in the value chain of many industries providing, not only sector-specific, timely and holistic data and information but overall intelligence on global supply sectors. There is an explosion of new business models arising to exploit the growth of space-derived data fuelled by: open data policies; reduction in cost of innovative satellite missions delivering daily high-resolution global coverage; and a massive increase in the accessibility of computer storage, computing power and complex algorithms laying the path to develop and deliver new EO solutions. These new solutions can provide benefit to a wide range of new and existing users of EO-derived products. This document and the taxonomy described herein attempts to make this landscape of new services navigable to these potential users through definition of a “common language”.

To define this common language, it is necessary to establish a formal and standardized representation of the interests and the knowledge of both the provider and the potential user communities. This

[83] https://www.ontotext.com/knowledgehub/fundamentals/what-are-ontologies/ and http://www.dpi.inpe.br/gilberto/papers/asprs_geo_ontologies.pdf

report aims to describe the process of updating the existing EARSC taxonomy, including an extensive stakeholder engagement process, and the main elements of the taxonomy update methodology.

The introduction section gives background information on different approaches to taxonomies, the objectives of the CopHub.Ac project and the role of the taxonomy update within that.

The Terminology and Methodology section first gives an overview of the shared language required to ensure that all stakeholders are on the same page in terms of what words and phrases, which will be used to define elements of the taxonomy, are considered to mean. These definitions, including the Domains and Areas of the Thematic view, the Markets and Sectors of the Market view, user language, in terms of Standardised verbs & comparison with other taxonomies such Bloom & DIWK as well as technical language used to define EO service construction are presented. This section goes on to outline the steps taken to update the existing EARSC methodology, which can be summarised as:

i. Definition: Defines the existing EARSC taxonomical approach, giving a validation for the two-view (Market and Thematic) approach taken and a comparison to other approaches in the community, including a description of how this stakeholder engagement process will be maintained to ensure that this taxonomy remains relevant in a fast-changing sector. The Market view of EO services is the view from the users' point of view and focusses on the market in which the users thinks of themselves in. The Thematic view gives a perspective on the services from the technical domain in which the provider thinks of themselves.

ii. The taxonomic levels are described: The Markets view is subclassified into sectors with more precision on the markets in which the user operates and the Thematic view (Domains) are sub-classified into Areas of more precision in terms of the technical domain from which the provider is coming. The third level is formed by the EO services themselves which form the bridge between the market and thematic views (both are views on the same set of services from the point of view of different stakeholders). These services are further described by the data, outputs and applications which comprise them. This section answers the questions 'What is the taxonomy?" and "How do we ensure it remains up to date?"

iii. Results – Taxonomy evolution: Describes the results of discussions with industry and academic stakeholders and the update to the categories employed in the market and thematic views on the taxonomy. The updated tables that form the EARSC taxonomy are presented in this Section. These include descriptions of the categories of both the Thematic (Themes and Areas) and Market (Markets and Sectors) views on the taxonomy as well as descriptions of the EO services which form the bridging layer between the two views. This section anwers the questions "How was the taxonomy upgraded?" and "What does it look like now?"

iv. Uptake: Describes the applicability of the updated EARSC taxonomy to a range of other industry stakeholder approaches to show the benefit of this unified approach which encompases all other approaches. This section includes an example of applicability of the taxonomy in other European projects and international inititaves such as the Agenda for a Sustainable Development (SDGs). This section answers the question "What is the applicability to other communities?"

In summary this document has presented th EARSC taxonomoy and answered the question "**How can an end user know what EO services are available that are relevant for their field/activity?"** with a goal to facilitating uptake of the new services being developed by a range of potential users.

7. Annex

7.1.References

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7.2. Glossary

This list of definitions has been extracted from shortlist of classification schemes[84] and eo4geo[85]

Table 32- Glossary

[84] http://www.taxonomies-sig.org/about.htm
[85] www.eo4geo.eu

Classification	Description
Area	(In the EARSC Taxonomy) Is the set of EO services (greater detail of objects) with similar characteristics and associated patterns. There corresponds to thematic segments in each of the domain. For example objects to be monitored in built environment such urban areas, infarstructre, transport, or waste. It may be also named as segment.
Body of Knowledge	Body of Knowledge (BoK) is a set of concepts and relations between them, that make up a professional domain, (in the case EO/GI BoK and the related learning outcomes), as defined by the relevant learned society or a professional association.
Controlled vocabulary	A controlled vocabulary is an authoritative list of terms to be used in indexing. Controlled vocabularies do not necessarily have any structure or relationship between terms within the list
Domain	(In the EARSC Taxonomy) Responds to the highest rank in the thematic perspective, categorises by type of activity for which the observations are being made ie, risk assessment, forecasting, responding, monitoring, detecting etc. for a particular domain. We propose 6 domains (atmosphere & climate, build environment, disasters & geohazards, land, marine, security & safety). It may be also named as thematic.
EO4GEO	EO4GEO is an Erasmus+ project which aims to help bridging the skills gap between supply and demand of education and training in the EO/GI sector. www.eo4geo.eu
Earth Observation	The term Earth Observation (EO) related services is taken to mean any geo-spatial information service activity which in some way involves data coming from EO satellites (including meteorological satellites) i.e. any satellite with one or more sensors that measure parameters coming from the earth's surface or atmosphere. The involvement may be direct i.e. processing or distributing imagery or indirect i.e. consultancy based around knowledge of the imagery or its use. It starts from the point where imagery is transmitted to the ground, so it does include reception and processing of imagery but does not include construction of ground stations or the satellites delivering the data. Note that it includes all geo-spatial information services activities where satellite EO data has been used and so extends to downstream information processing of geospatial information where data being used has been derived from EO imagery possibly in combination with other data types.
Geographic Information	Geographic Information (GI) is the data of a geographic location combined with non- spatial information (e.g. statistical data) and their representation as a map.
Inventory	An inventory typically lists all the physical content.
Market	(In the EARSC Taxonomy) Responds to the highest rank in the market perspective, describes a part of the economy activity, it is a group or groups of customers who require the products and services provided by an industry. Understand the major markets in which EO services are doing business. These major markets strcuture prove sufficiently robust to accommodate future sector segments. We can cite as an example the market super-category “managed living resources”.
Ontology	An ontology is a taxonomy with different relationships between terms (more than three kinds). Ontologies have been proven an effective means for make connectors. They can be a very useful tool, because they may present an overview of the domain related to a specific area of interest and be used for browsing and query refinement. An ontology is a formal explicit description of a domain, consisting of classes, which are the concepts found in the domain (also called entities). Each class may have one or more parent classes (is-a or inheritance links), formulating thus a specialization/generalization hierarchy; a class has properties or slots (also called roles or attributes) describing various features of the modelled class, and restrictions on the slots (also referred to as facets or role descriptions). Each slot, in turn, has a type and could have a restricted number of allowed values, which may be of simple types (strings, numbers, booleans or enumerations) or instances of other classes. Classes may have instances, which correspond to individual objects in the domain of discourse; each instance has a concrete value for each slot of the class it belongs to. An ontology together with a set of individual instances of classes constitutes a knowledge base. In Philosophy, Ontology is the basic description of entities in the world, the description of what would be the truth, and the term is used with an upper-case O. Guarino (1998) considers the philosophical meaning of ontology to be a particular system of categories that reflects a specific view of the world.
Representational vocabulary	Fundamental vocabulary (mean what they say, no more and no less)
Remote Sensing	Remote sensing means contact-free measurement of the object in question. The physical basis is the interaction of electromagnetic radiation with the surface of the earth and the gases and particles in the atmosphere.
Sector	(In the EARSC Taxonomy) It provides some granularity introducing a group of business activities (industry activities) that have similar characteristics. For example (agriculture, forestry and fisheries) all in the primary sector and helping to define the type of customers.
Taxonomy	A taxonomy is a (controlled) vocabulary with a hierarchical structure.
Thesaurus	A thesaurus is a controlled vocabulary, which follows a standard structure, where all terms have relationships to each other. There are typically three kinds of relationships: hierarchical, associative and equivalent.
Vocabulary	Define concepts and relationships. Less complex than an ontology

7.3. EO service providers business models

EARSC reflected in business models at the SEBS study[86]

Table 33- Classifying business models

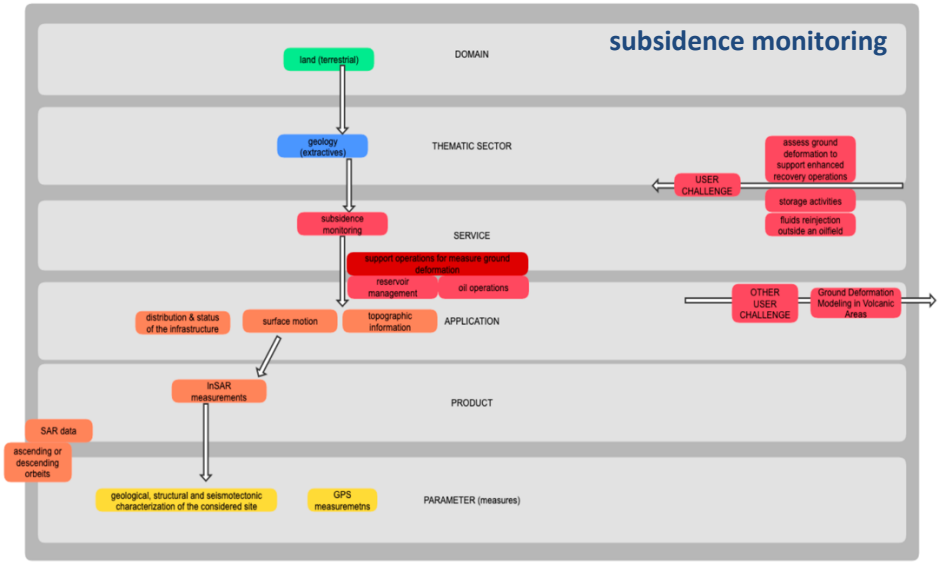
Business models	Description
Data-as-a-Service (DAAS)	Provides easy, timely and protected access to raw or processed Earth Observation data (space-borne, air-borne, in-situ)
Platform-as-a-Service (PAAS)	Provides users with an environment (incl. tools and software) where they can discover, visualise and process Earth Observation data (platforms)
Information-as-a-Service	On-line service providing customers with information (e.g. reports, maps or business intelligence) extracted from the analysis and processing of Earth Observation data
Software-as-a-Service (SAAS)	A method of licensing and delivering software in which centrally- hosted software is supplied to users, usually on the basis of subscriptions.
Software products	Provision of software under a more traditional model involving the supply of binary files (executables)
Provision of value-added geospatial information product(s)	Products such as static and dynamic maps, indices, alerts, and other information products with a geospatial component.
Provision of other (non-geospatial) information product(s)	Information products without a geospatial component
Consulting	Provision of expertise in the form of advice, analysis and/or recommendations

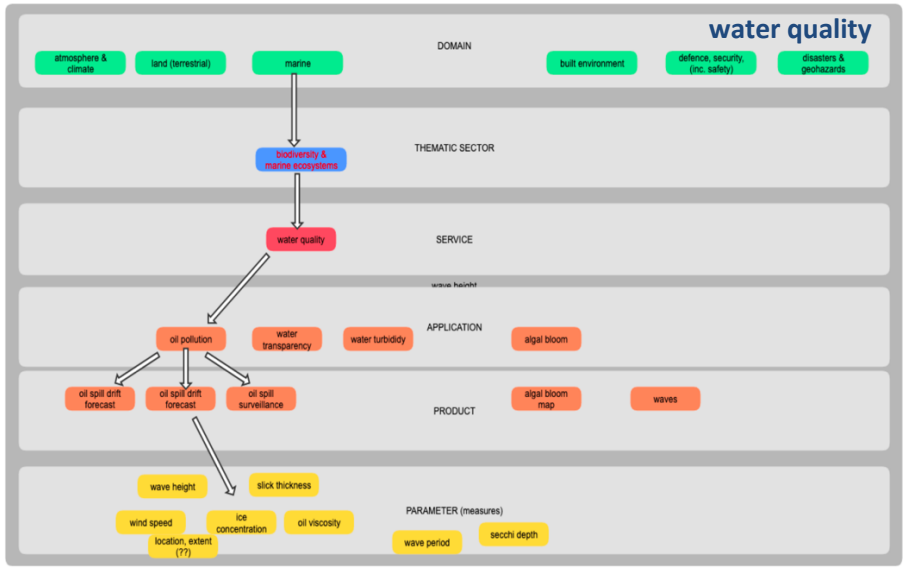
7.4.EO services structure examples

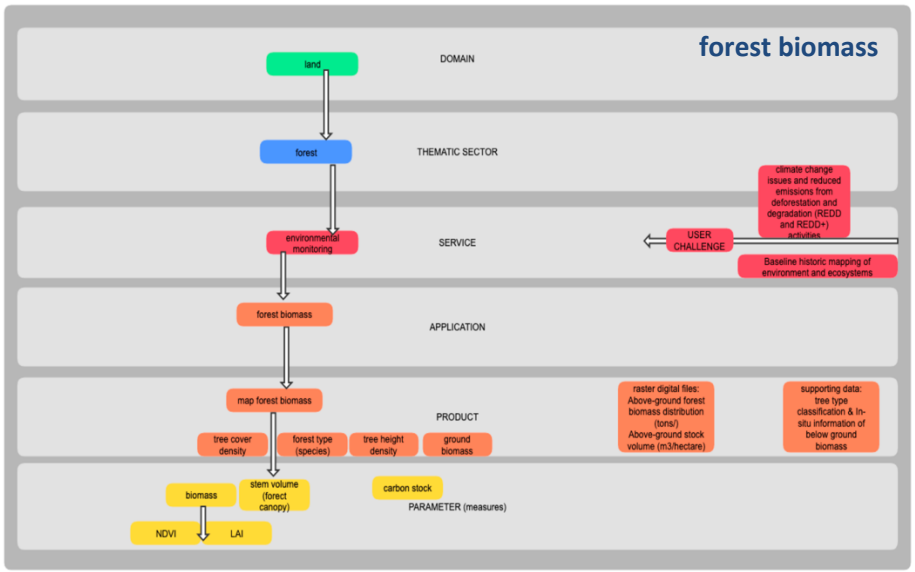
Notice the examples are just to provide some lightening to the structure of the service, not to analyse the service itself. The structure will be for each of the services selected: Domain / Segment / EO Service / Application / Product / Parameters. The Figures 16 to 22 how more exmaples.

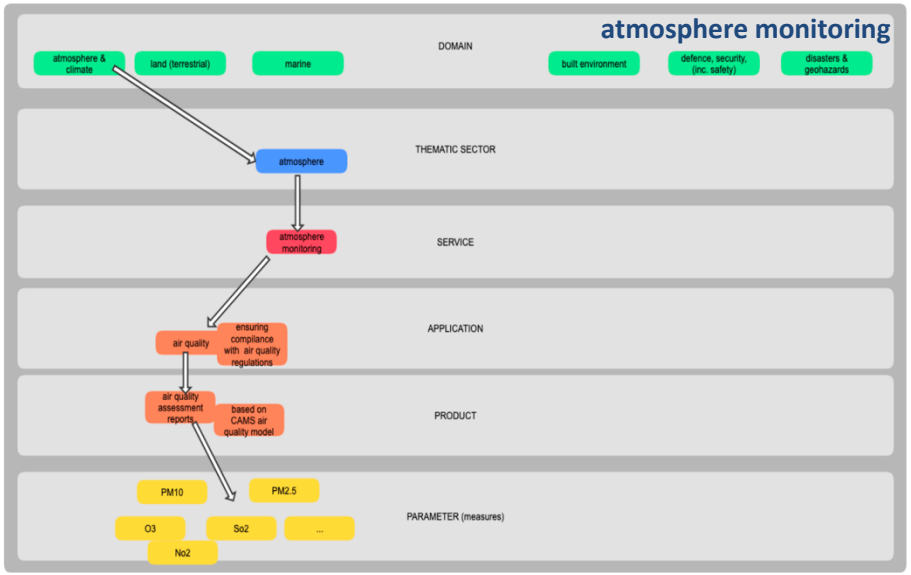
Figure 18: Subsidence monitoring
Figure 19: Water quality assessment
Figure 20: Forest biomass monitoring
Figure 21: Atmosphere monitoring
Figure 22: Detect ice risk at sea
Figure 23: Land monitoring
Figure 24: Land use classification

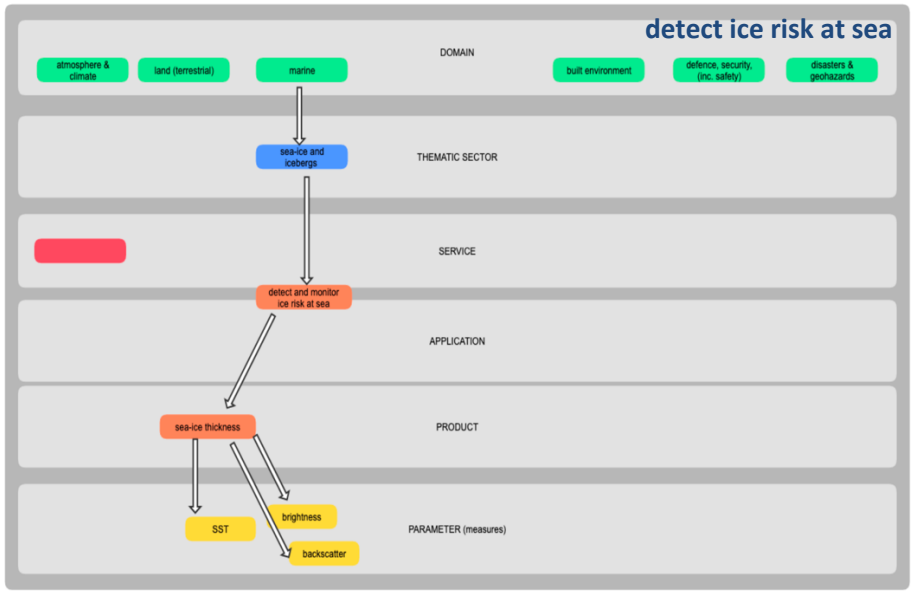
[86] http://earsc.org/Sebs/wp-content/uploads/2019/07/CopernicusSentinelBenefitsStudy_InnovationAndStartups_June2019_Preliminary.pdf

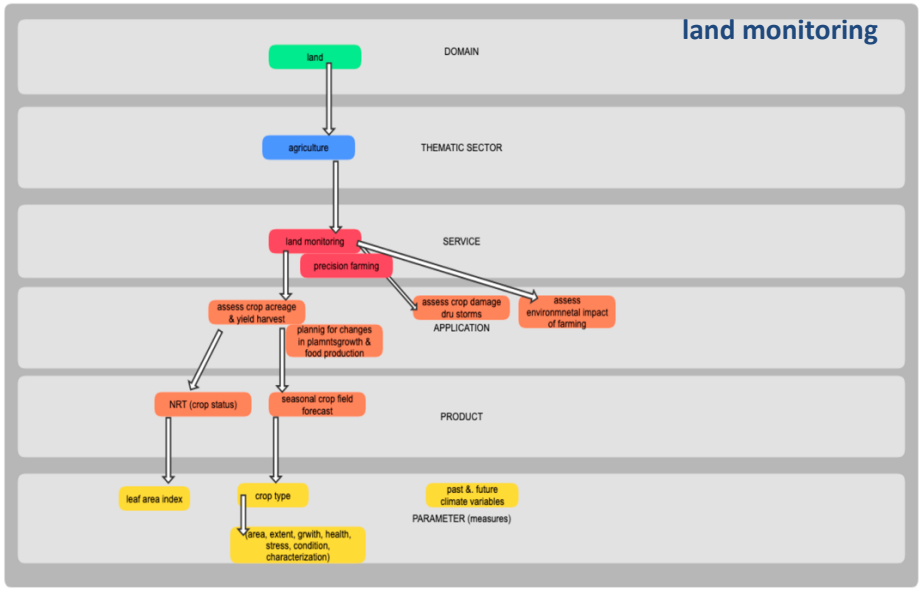

subsidence monitoring
land (terrestrial)
DOMAIN
geology (extractives)
THEMATIC SECTOR
USER CHALLENGE
assess ground deformation to support enhanced recovery operations
storage activities
fluids reinjection outside an oilfield
subsidence monitoring
SERVICE
support operations for measure ground deformation
reservoir management
oil operations
OTHER USER CHALLENGE
Ground Deformation Modeling in Volcanic Areas
distribution & status of the infrastructure
surface motion
topographic information
APPLICATION
InSAR measurements
PRODUCT
SAR data
ascending or descending orbeits
geological, structural and seismotectonic characterization of the considered site
GPS measuremetns
PARAMETER (measures)

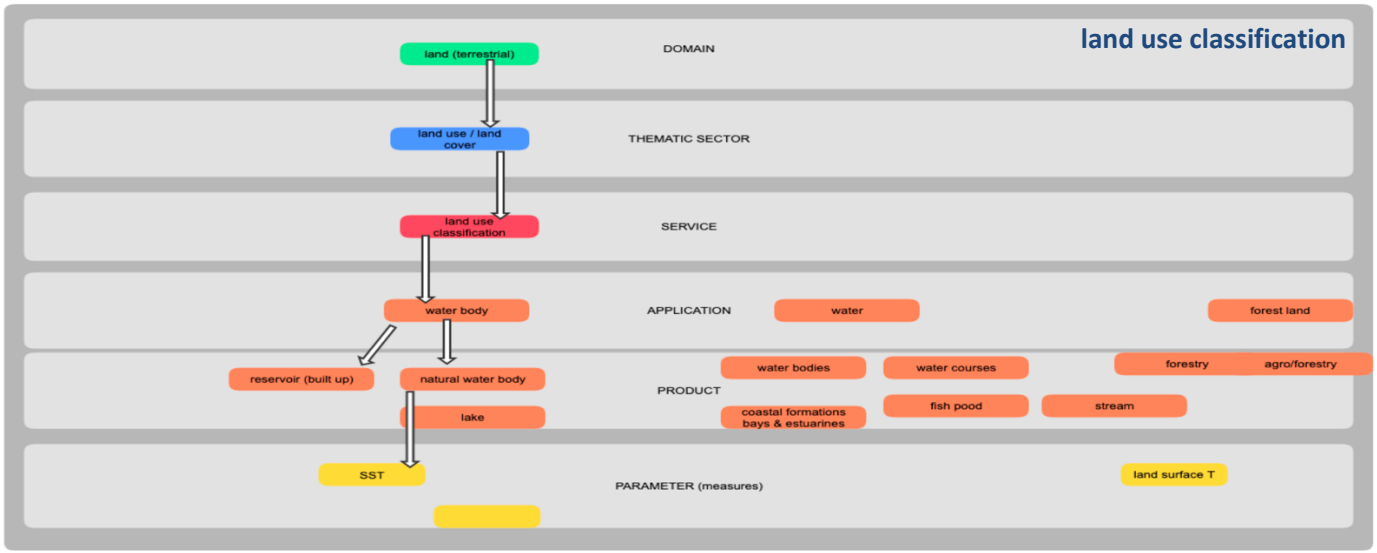

water quality
atmosphere & climate
land (terrestrial)
marine
DOMAIN
built environment
defence, security, (inc. safety)
disasters & geohazards
biodiversity & marine ecosystems
THEMATIC SECTOR
water quality
SERVICE
oil pollution
water transparency
water turbidity
APPLICATION
algal bloom
oil spill drift forecast
oil spill drift forecast
oil spill surveillance
PRODUCT
algal bloom map
waves
wave height
slick thickness
wind speed
ice concentration
oil viscosity
location, extent (??)
PARAMETER (measures)
wave period
secchi depth


forest biomass
land
DOMAIN
forest
THEMATIC SECTOR
climate change issues and reduced emissions from deforestation and degradation (REDD and REDD+) activities
USER CHALLENGE
Baseline historic mapping of environment and ecosystems
environmental monitoring
SERVICE
forest biomass
APPLICATION
map forest biomass
raster digital files: Above-ground forest biomass distribution (tons/) Above-ground stock volume (m3/hectare)
supporting data: tree type classification & in-situ information of below ground biomass
PRODUCT
tree cover density
forest type (species)
tree height density
ground biomass
biomass
stem volume (forect canopy)
carbon stock
PARAMETER (measures)
NDVI
LAI


atmosphere monitoring
atmosphere & climate
land (terrestrial)
marine
DOMAIN
built environment
defence, security, (inc. safety)
disasters & geohazards
atmosphere
THEMATIC SECTOR
atmosphere monitoring
SERVICE
air quality
ensuring compliance with air quality regulations
APPLICATION
air quality assessment reports
based on CAMS air quality model
PRODUCT
PM10
PM2.5
O3
So2
...
No2
PARAMETER (measures)


detect ice risk at sea
DOMAIN
atmosphere & climate
land (terrestrial)
marine
built environment
defence, security, (inc. safety)
disasters & geohazards
THEMATIC SECTOR
sea-ice and icebergs
SERVICE
APPLICATION
detect and monitor ice risk at sea
PRODUCT
sea-ice thickness
SST
brightness
backscatter
PARAMETER (measures)


land monitoring
DOMAIN
land
THEMATIC SECTOR
agriculture
SERVICE
land monitoring
precision farming
APPLICATION
assess crop acreage & yield harvest
plannig for changes in plamntsgrowth & food production
assess crop damage dru storms
assess environmnetal impact of farming
PRODUCT
NRT (crop status)
seasonal crop field forecast
leaf area index
crop type
area, extent, grwith, health, stress, condition, characterization)
past & future climate variables
PARAMETER (measures)


land use classification
DOMAIN
land (terrestrial)
THEMATIC SECTOR
land use / land cover
SERVICE
land use classification
APPLICATION
water body
water
forest land
PRODUCT
reservoir (built up)
natural water body
lake
water bodies
water courses
forestry
agro/forestry
coastal formations bays & estuarines
fish pood
stream
PARAMETER (measures)
SST
land surface T

7.5. Exchange with experts (info & feedback)

Background information submitted

EARSC considers the taxonomy as a tool to arrive at a common understanding of what "eo services" providers can offer. The aim of the taxonomy is to structure our activities promoting the capabilities of the industry but also to address those EO common products and services from two perspectives:

-Market taxonomy providing the customer (user) view.
-Thematic taxonomy is designated to provide the supplier view based on expertise on a specific thematic approach (qualitative capability).

EARSC has upgraded the “market taxonomy” reflecting on the overall evolution of the sector but also latest findings on the “survey into the state & health of the sector” revealed a significant increase in the activities specific for different groups of users, therefore we have modified the taxonomy accordingly.

EARSC is also developing further an upgrade of our “thematic taxonomy”. The previous discussions revealed the need to define each of the levels used and therefore an example of the structure of the thematic taxonomy will be presented (thematic classes (domains) > thematic segments > eo services/applications) . For the classification of the EO services, we do use a standard set of verbs to describe the needs of the user (and eventually the service on offer). Taxonomy has been, is, and will be an ongoing process trying to satisfy the understanding of a diverse group of communities.

You can access the current state of the thematic taxonomy on the EARSC Portal (https://earsc-portal.eu/pages/viewpage.action?pageId=15794378) where you can browse the different thematic domains, its sectors and the description of specific EO Services.

The detailed background document
(http://earsc.org/file_download/489/A+Taxonomy+for+the+EO+Services+Market+issue+2+%282%29.pdf)

Feedback survey
Was this webinar useful?
Was the presentation structured well?
What did you interest you most from the presentation?
Do you plan to follow up the activity in the future?
Did the webinar improve your knowledge about taxonomy?
How do you see the taxonomy useful for your work?
What the webinar too short, too long or the right length?
Do you like to follow a second webinar more detailed?
How likely are you to recommend our webinar on a scale of 1 to 10?
What was your biggest takeaway?

Extracted from the CopHub.AC Deliverable2.4: Experts actively contributed to the shared document with comments and suggestions. A follow-up survey revealed that i) 50% of found it very useful; ii) The work and discussion in the shared document was evaluated as the most useful and interesting part of the exercise; iii) All respondents plan do follow-up the activity in the future; iv) Two thirds of the respondents will clearly consider the taxonomy in the future.

7.6.Acknowledgements

More than 20 experts involved in the EO services webinars. They have been granted to access to the EO thematic services taxonomy document, specially through inputs & suggestions regarding the description of the EO services/applications (products, parameters or essential variables).

Acknowledge: Review section EO services:
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- IHCantabria (SP): F. Fernandez, A. Silió-Calzada, J.M. Alvarez
- Universita degli Studi della Basilicata Basilicata (IT): T. Lacava, V. Tramutoli, V. Satriano
- University of Bologna, DICAM (IT): G. Bitelli

- University Bonn (Geomatics Research Group (GRP), RSRG) (GE): M. Zarar
- University Charles Czechia, Faculty of Science (CZ): P. Štych
- University Cyprus (CY): M. Tzouvaras
- University Klaipeda, Marine Science and Technology Centre (LT): D. Vaičiūtė
- University Catholic Leuven (BE): D. Vandenbroucke
- University of Novy Sad, Faculty of Technical Sciences (SER): M. Govedarica
- University of Pavia, Dep. Electrical, Computer, and Biomedical Engineering (IT): F. Dell'Acqua
- University Salzburg (AU): S.Lang, D. Tiede, M. Sudmans
- University Maynooth (IR): R. Fealy

7.7.Future work the EO4GEO BoK

The EO4GEO BoK supports querying by conceptual terms selected from a formal EO/GI ontology. This support cross-domain or generalizations providing relationships form more general, more specific related. One challenge of the BoK evolution will certainly be the addition of the level about "thematic service" portfolios. The concepts structure to be included in the EO/GI Body of Knowledge for representing Thematic/ application domains + market/industry were discussed (i.e. the concepts for which WG7 is responsible)

Aim to ensure compatibility of the EO4GEO BoK with the EARSC taxonomy and the Cophub.AC categorisation of application areas. Therefore, the discussion focused on how to integrate these perspectives into the EO4GEO BoK. With the new structure, the following issues were addressed:

- Use a (primarily) hierarchical structure for the levels of the concepts. Consequently, most relationships are "superconcept – subconcept"
- We insert the relationship type "makes use of" where applicable, e.g. where user communities make use of specific applications.

In term of levels, the level 1 could be the node to distinguish between a "market/community view" and the "thematic view". Then level 2 would host "market & user categories" on the one side and "thematic service" domains (general) on the other side. On the market side, level 3 would contain "market sectors & user communities". On the thematic side, level 3 would contain "thematic service domains (fine granularity)". On level 4 would be the EO services that link to level 3 both on the market and thematic side. To emphasize the relevance of the "Market view", the "Default View" could be used.

This work aims at creating a user profile ontology that incorporates concepts and properties used to model the user profile. Existing literature[87], applications and ontologies related to the domain of user context and profiling have been taken into account in order to create a general, comprehensive and extensible user model. Our user/communities work is proposed to be based on a relations ontology instead of traditional domain ontology.

- The first layer (level 1) represents the profile of the user community. It is the high-level uptake concept and provides all relationships we need to represent communities structure "makes-use-of" or "is-used-by", or considering a very general relationship "is-associated-with" with other levels
- The second layer (level 2) represents the sublevel of users, and mainly is dedicated to roles of the user, the defined uptake
- The third level provides application domains as subclass

Relationship steps

[87] https://www.researchgate.net/publication/236669552_A_reference_profile_ontology_for_Communities_of_Practice

Typically, the process of building a domain ontology starts by collecting the domain terminology (domain-relevant terms). Therefore, the goal of this phase is to collect a domain terminology from tags. 1) Domain keywords 2) Set of resources 3) Concepts relationships 4) Connectors 5) Relationships (i) spatial: geographically located (ii) functional: essential parameters such temperature (iii) causal: wind, erosion (iv) temporal: stational for example grow crops (v) productive: biomass

Table 34- Possible keywords to be used for detecting pre-defined proposed relations[88].

Relationship	Typical patterns (connectors)
is a	is a/an, is a/an class of, describes a/an
same as	such as, refer to, known as, short for
has/part of	include, consist, contain, is part of
created by	developed by, designed by, created by, writing by, executed by
used for/in	used for, used by, designed for, used in, developed to
make use of	
is associated with	related, linked, connected, correlated

Connectors

Ontologies may be able to provide interoperability support and should be noted that those are consider evolving and extending concepts. There is no one correct way to structure a domain— there are always viable alternatives. One methodology for obtaining ontologies is to begin with the industry standard taxonomy based on services from providers. It will also depend on the levels that you have in mind and the extensions that you anticipate. In practical terms, developing an ontology focus on the user communities includes:

- defining the **concepts** or **classes** in the EO/GI ontology. The classes describe concepts in the domain. For example, specific EO services are instances of the class of service.
- defining the **properties** of each concepts/classes describing various **features** and **attributes** of the concepts (**slots/roles** or **properties**)
- defining restrictions/values for **slots** (**facets** or **role restrictions**)
- arranging the classes in a taxonomic (subclass–superclass) hierarchy. In this point we learnt that some of the relationships between levels might better be converted to different relationships than “subclass – superclass”. Examples for alternative relationship categories are “makes use of”, “is used by” or “is associated with”. This new opportunity very much helped our discussion for the integration of user communities

Visualization

The Living Textbook is a network tool/ontology tool that allows to map relationships of a concept to super-concepts, sub-concepts, as well as similar concepts on the same level. However, a plot of the network graph would be a rather complex visualisation. This is why ontology tools usually include a hierarchy view that looks like the folder structure of file systems. This makes the structure easier to read.

[88] https://www.sciencedirect.com/science/article/pii/S131915781730229X