User-driven applications and tools for Climate-Informed Maritime Spatial Planning and integrated seascape management, towards a resilient & inclusive Blue Economy

D1.4 – Report on technical requirements for the core technology modules

WP1 – Project Management

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1 Executive Summary

This document will give a detailed overview of the deliverable "D1.4 Report on technical requirements for the core technology modules" for the OCEANIDS project. This deliverable is connected to Task 1.2: "Data management plan (DMP)" of Work Package (WP) 1 "Project Management", led by Geosystems Hellas (GSH). The deliverable D1.4 is considered as one of the outputs of T1.2 more indirectly, as it is created in parallel with the DMP preparation. The former provides an analysis of the technical (functional and non-functional) and user requirements, while the latter establishes all the guidelines and directives to be followed to ensure the interoperability, both of the core technology components and the final technological and data outcomes of the OCEANIDS project. To this end, this report outlines the essential technical and end-user requirements for the development and implementation of the core technology modules, especially the technologies developed under WP3. Meeting these requirements is crucial to ensure the success and reliability of these technologies as the project moves forward.

As the OCEANIDS project is currently in its first stages of implementation in M4, it is important to mention that only some preliminary discussions have been initiated in WPs monthly meetings. Therefore it was considered essential to move forward smoothly to first identify the synergies among the technological modules, and by having this information available then each partner to introduce and identify preliminary requirements for the core technology modules and platforms. The identified requirements are more basic and general, and they will better be summarised later on. It is essential to use this deliverable as a first step in identifying each Task's responsibilities and creating the first workflow depicting the synergies that shall be established among WP3 and WP4, once the insightful information from WP2 is available and ready to use. To be in the position to set the requirements within this deliverable, input from the end-users collected under WP2 is required which is developed in parallel to identify some end-user requirements under T2.2 "Assessment of current gaps between stakeholders' needs and existing applications and services available" by exploring the needs, challenges and set priorities and goals of each partner. The time of this deliverable is not optimal, as the Engagement Plan and the interviews with the OCEANIDS stakeholders are still in progress, and will be finalised by M6. To this end, it was decided that the MS1 "Stakeholders identification and system specifications definition" (Milestone 1) in M6, will be used to provide the updated and successfully gathered information, setting the needs and requirements for the developed application, module, or platform, in collaboration with D2.1 "Stakeholders engagement plan and existing applications/services report".

Thus, the main focus of this deliverable is to provide a complete preliminary overview of the main modules and workflows developed under WP3 and the requirements from a technical perspective, but not exclusively limited to that. It is essential to maintain an integrated approach considering that the core technology modules created under WP3 will be ultimately integrated into the platforms generated under WP4. Therefore, this report will also extend to the introduction and description of WP4 platforms.

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Table 1. List of Acronyms/Abbreviations

Acronym Abbreviation	Explanation
AI	Artificial Intelligence
API	Application Programming Interface
CC	Climate Change
CAP	Climate Adaptation Planning
CRS	Coordinate Reference System
DSS	Decision Support System
EO	Earth Observation
FMI	Ilmatieteen Laitos
GA	Grant Agreement
GSH	Geosystems Hellas
HCMR	Hellenic Centre for Marine Research
ICCS	Institute of Communication and Computer Systems
JSON	JavaScript Object Notation
ML	Machine Learning
MS	Milestone
NorCP	Nordic Convection Permitting Climate Projections
ODC	OCEANIDS Data Cubes
O-DSP	OCEANIDS Decision Support Platform
O-DSS	OCEANIDS Decision Support System
OGC	Open Geospatial Consortium
OHB	OHB Digital Services
PaaS	Platform as a Service
RG	Resilience Guard GmbH
UI	User Interface
UX	User Experience
VM	Virtual Machine
VPN	Virtual Private Network
WP	Work Package

2 Introduction

Coastal regions are often characterised by strategic socio-economic assets (i.e., linked to tourism, fisheries, harbours, and shipyards). This makes coasts particularly sensitive to Climate Change (CC) impacts, which primarily expose infrastructure and local population. Human activities are also responsible for additional pressures on coastal ecosystems, often generating more immediate impacts than those expected from CC by aggravating existing vulnerabilities. The need for CC adaptation in coastal areas is evident and is predicted to become progressively more significant over time due to the grim long-term forecasts of climate variables. Coastal area adaptation strategies should be iterative and dynamic, due to the evolving dynamics of coastal territorial systems. Furthermore, CC adaptation measures should consider local ecology, economy, society, politics, and technology. Therefore, the definition of Climate Adaptation Planning (CAP) must consider specific local socio-economic contexts. The OCEANIDS project aims to develop the tools and applications that enable a more resilient and inclusive society in coastal regions via better-informed and integrated seascape management. The central concept is to collect, harmonise, and curate existing climate data services, making data accessible, reusable, and interoperable for developing local adaptation strategies.

The role of WP1 "Project Management" is to coordinate and monitor efficiently all the progress of the OCEANIDS project towards the objectives, ensuring compliance of the activities with the Grant Agreement (GA), the optimal completion of scientific activities conducted, as well as collect and set the technical and non-technical requirements of the technologies generated throughout the project. The WP1 consists of the following tasks:

- Task 1.1: "Project management and coordination towards objectives" [M1-M32]
- **Task 1.2: "Data management plan (DMP)" [M1-M32]**
- Task 1.3: "GDPR and Ethics (social, gender and inclusivity) aspects" [M1-M32]

This document is the report presenting the core technology modules developed under WP3, as well as the platforms generated under WP4. It is in fact, one of the outputs of **Task 1.2: "Data management plan (DMP)"**, based on the GA (Grant Agreement) and represents the fourth deliverable of the WP1. The following sub-sections present the scope and objectives, as well as the structure of the document.

2.1 Scope and Objective of the deliverable

The main objective of deliverable D1.4 "Report on technical requirements for the core technology modules" is to collect and outline the essential technical and end-user requirements for the development and implementation of the core technology modules, and especially the technologies developed under WP3. Meeting these requirements is crucial to ensure the success and reliability of these technologies as the project moves forward. It is essential to maintain an integrated approach considering that the core technology modules created under WP3 will be ultimately integrated into the platforms generated under WP4. Therefore, this report will also extend to the introduction and description of the platforms in WP4. However, to be in the position to set the requirements within this deliverable, input from the end-users collected under WP2 is required. The time of this deliverable is not optimal, as the Engagement Plan and the interviews with the OCEANIDS stakeholders are still in progress and will be finalised by M6. To this end, it was decided that the MS1 "Stakeholders identification and system specifications definition" (Milestone 1) in M6, will be used to provide the updated and successfully gathered information, setting the needs and requirements for the developed application, module, or platform, in collaboration with D2.1 "Stakeholders engagement plan and existing applications/services report".

2.2 Project Workflow - Connection with other WPs

In **Figure 1**, the OCEANIDS overall Project Workflow and the connection among the WPs are depicted. WP1 serving as the main Work Package of the overall project management, plays a pivotal role in managing all activities conducted under the other WPs. Within this context T1.2, provides a clear analysis of the technical (functional and non-functional) and user requirements, establishing all the guidelines and directives to be followed to ensure the interoperability, of both of the core technology components and the final technological and data outcomes of the OCEANIDS project. WP2 serves as the primary source and the baseline analysis of needs and problems through extensive stakeholder engagement. The collected information is fed into the WP3 and WP4, where all the technology modules and platforms are developed, aiming to provide a CC Risk and Hazard Risk Assessment Platform, an integrated EO (Earth Observation) and spatial data platform as well as, the final Decision Support System (DSS), to facilitate decision makers.

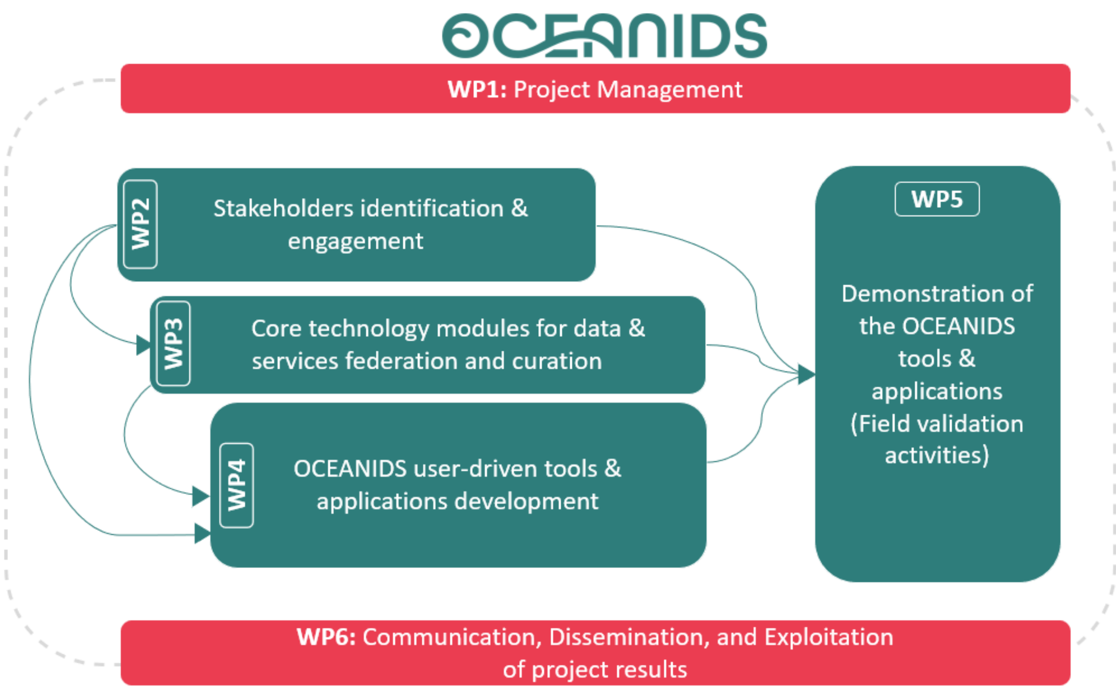

Figure 1. OCEANIDS WP structure workflow

2.3 WP3 and WP4 structure

It was considered essential at this point to set the baseline, agree on a preliminary plan between WP3 and WP4, provide a complete preliminary overview of the main modules and workflows developed under WP3, and describe the requirements from a technical perspective, but not exclusively limited to that. It is important to maintain an integrated approach considering that the core technology modules and the collected requirements created and gathered under WP3 will be ultimately integrated into the platforms generated under WP4. Therefore, this report will also extend to the introduction and description of WP4 platforms.

The Workflow depicted in **Figure 2** was constructed in collaboration between partners involved in WP3 and WP4, which are GSH, RG, OHB, ICCS, FMI and HCMR, responsible for the activities undertaken within these WPs. Discussions held within the first WP monthly meetings, as well as in combined ones, led to the creation of this flow that describes the providers and receivers of information, aiming to identify some requirements valuable to modules/platforms, considering that the requirements from the end-users will be established officially in M6.

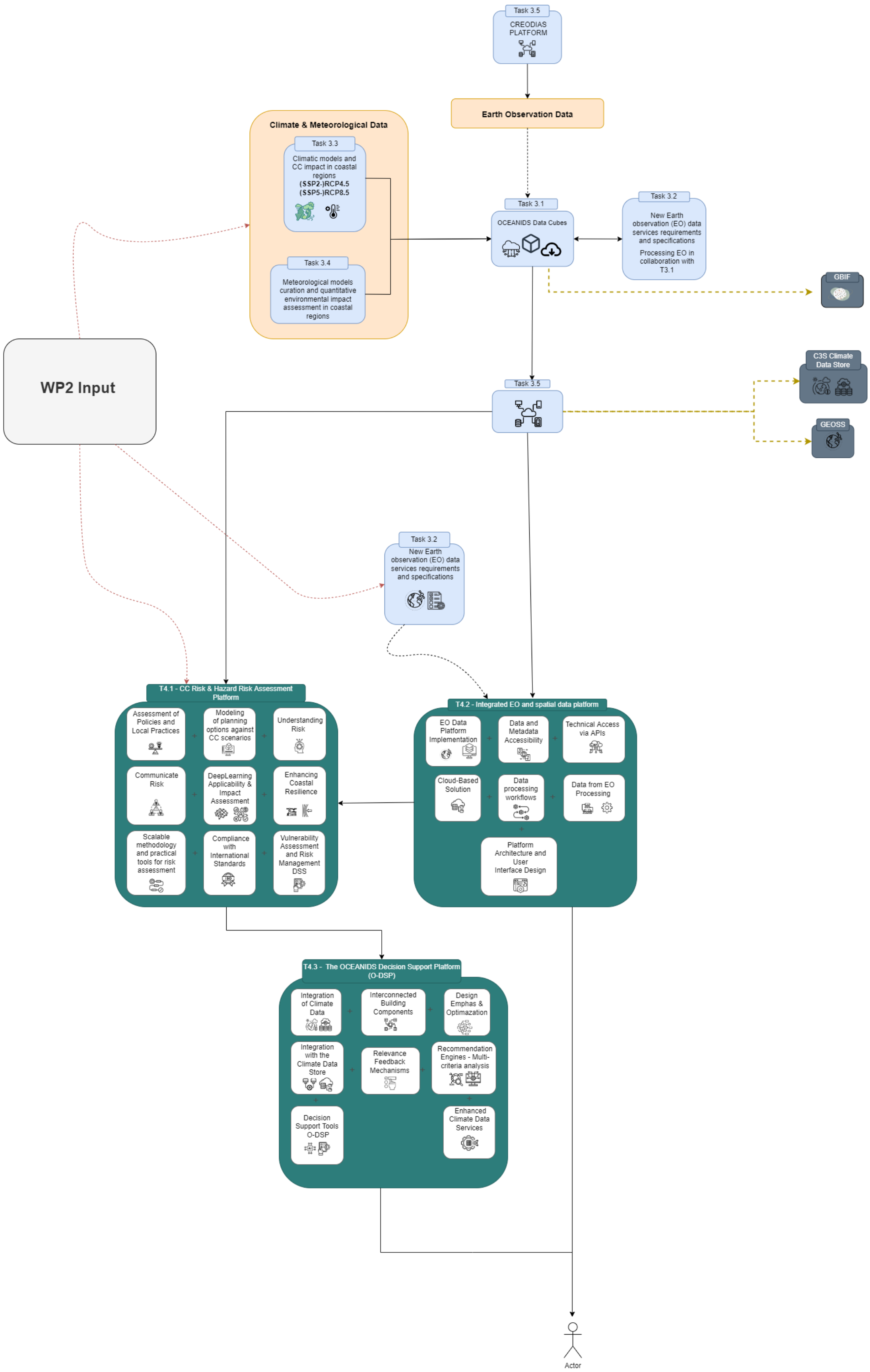

Figure 2. Synergies between WP3-WP4

2.4 Partners involved in WP3 and WP4 - Contribution

ICCS will be responsible for the implementation of the OCEANIDS Data Cubes (ODC) within the context of WP3, in T3.1. A complete Geoserver framework environment in the form of Docker or VM is going to be implemented to provide easy access to a ready-to-use environment providing all the necessary tools for data harmonisation and analysis. This Geoserver will provide capabilities, such as local storage, dynamic retrieval from online sources, data harmonisation and communication with other OCEANIDS' tools (i.e., send the final product to the application). The data harmonisation will be achieved through the generation of the ODC, which is going to be a core product of the OCEANIDS project. To be more precise, the ODC product file(s) involves the combination of several collected data products (e.g., geospatial data, satellite images, climate data, etc.) into a common product template of NetCDF4 type, which is a state-of-the-art file format readable from several GIS software. Moreover, the ODC implementation will be accompanied by a complete documentation for describing the installation of the necessary frameworks to systems, as well as providing examples and guidelines for running the necessary algorithms, including testing results.

OHB, within the context of WP3 and T3.2 OHB, will define requirements and specifications for new EO data services by surveying state-of-the-art services covering the following responsibilities: OHB will define software-related and technical requirements and specifications for new EO data services considering user needs (identified within T2.2), provider capabilities and related potential added value. This analysis will encompass the assessment of appropriate hardware configurations and software system components, data management strategies, storage capacities, specific technology providers (cloud, frameworks), data availability and technical risks taking harmonisation of data for OCEANIDS Data Cubes (T3.1), cloud framework independence and further INSPIRE and OGC standards into account.
The requirements and specifications will be elaborated for data and services which can already be gathered from the Data & Services Federation component, but also for the New EO data services, which will process stakeholder-oriented data with data from existing EO Data Services and may include index-calculations, data fusion, and ML applications (e.g., downscaling). Additionally, interfaces to upcoming data products (CO2M, EnMAP, Sentinel-4) will be considered. In conclusion, the analysis will comprise an initial high-level architecture design of the EO and Spatial Data Platform (development conducted within T4.2), considering processing workflows and main technical decisions, as well as continuous integration and deployment strategies. This will also encompass the integration of the EO processing component, in which the New EO Services will be implemented.

HCMR will be responsible for assessing the impacts of climate change on coastal regions, particularly focusing on key factors that affect maritime activities and planning. Port-affecting climate change impacts include changes in sea level extremes and flooding; wind (routing thresholds); precipitation (cargo loading); and sea ice conditions (ice breaking needs). Maritime planning in general is also invested in maritime route conditions, shallow water wind farms, aquaculture sites, and commercial fisheries. Utilising the multi-model assessment of probabilities for crossing the threshold values, indicators will be produced to that end based on the critical thresholds and variables identified in WP2. No model data will be produced; instead, existing climate model data for (SSP2-)RCP4.5 and (SSP5-)RCP8.5 Representative Concentration Pathways will be used. Data will be downscaled statistically, from regional climate models to high resolution. This approach benefits from Euro-CORDEX data available through Copernicus C3S and Nordic Convection Permitting Climate Projections (NorCP) data over the Nordic domain.

FMI will be responsible for providing access to relevant data and models and assisting in the transformation of said data to actionable intelligence, and re-usable tools for regional stakeholders within the context of WP3, T3.4. Moreover, the SmartMet Server[1] is a data and product server for MetOcean data. It provides a high capacity and high availability data and product server for MetOcean data. The server is written in C++, and since 2008 it has been in operational use by the Finnish Meteorological Institute- FMI. This server will be used in close collaboration with the OCEANIDS Data Cubes developed under T3.1.

CREO, will be responsible for ensuring that the data gathered for the OCEANIDS project, obtained from various geodata providers, is valid, reliable, and accessible for the project's mission users within the context of WP3, in T3.5. CREO will leverage CREODIAS to facilitate the provision of Earth Observation (EO) data for the OCEANIDS Data Cubes project. This provision encompasses both existing data products available on the platform and raw input data. Task 3.5 involves a comprehensive process of gathering, validating, and making data accessible for the OCEANIDS project. This includes acquiring additional data products from other providers if necessary. CREO will ensure that the data is error-free, meets project criteria, and can be easily accessed and queried by users through a standardised API. Furthermore, metadata extraction enhances the usability and searchability of the data, facilitating efficient utilisation by project stakeholders.

Taking into consideration that these core technology modules will ultimately integrated into the platforms generated under WP4, it is important to specify, collect and maintain an integrated approach. Therefore, the partner’s contribution under WP4 is also considered essential.

RG will be responsible for the development of the Hazard Risk and CC Impact Assessment Platform within the context of WP4, in T4.1. This aims to develop a system enabling regional stakeholders to understand the effect of various planning options in response to climate change scenarios, particularly focusing on quantifying the impact in coastal areas. The task will result in the design and implementation of a risk assessment platform serving as a Decision Support System (DSS) for

[1] https://github.com/fmidev/smartmet-server

multi-hazard planning and response. The outcomes will inform further platform development and contribute to decision-making processes regarding climate change impacts.

OHB, within the context of WP4 and T4.2 OHB will be responsible for the creation and the deployment strategy of the integrated EO and spatial platform following the definitions and specifications for new EO data services from T3.2. The platform will provide comprehensive access to spatially enabled data for decision-making support via a single-access user-oriented graphical user interface, and further for expert usage, via APIs following OGC standards.
Related responsibilities encompass the following aspects:

- Implementation of the platform into a cloud-based solution.
- Access to EO and spatial data (e.g., time series, historical data, near real-time data) via a user-friendly graphical user interface
- Technical access to the same data via APIs for expert users and developers
- Cloud Framework independent integration of the solution, while ensuring scalability
- Assure periodic and on-demand workflows via carefully chosen platform components, incorporating high-security standards through established authentication and authorization principles.
- Provision of processed EO Data assessing climate change and environmental impact on coastal regions. This will encompass the integration of the EO processing component and the respective New EO data services.

Developing an elaborate plan for the platform's architecture and the User Interface design.

GSH will be responsible for the design and implementation of the O-DSS (OCEANIDS Decision Support System) running in the backend, in seamless connection with the Risk Assessment Platform, and the O-DSP (OCEANIDS Decision Support Platform) within the context of WP4, in T4.3. This includes the integration of Climate Data and the integration with the Climate Data Store[2], following a methodological approach, ensuring that each component interacts with the inputs from the other OCEANIDS platforms, in collaboration with T3.5 and the CREODIAS Platform. GSH aims to give special attention to the overall design, by incorporating relevant feedback mechanisms, recommendation engines, and decision-support tools. The ultimate objective is to facilitate an optimal decision-making process within the context of OCEANIDS.

[2] https://cds.climate.copernicus.eu/api-how-to

2.5 Structure of the Deliverable

This document consists of the following chapters:

- **Chapter 3** provides information regarding the Requirements Specification.
- **Chapter 4** includes information regarding the preliminary Technical Requirements.
- **Chapter 5** presents the Core Technology Modules.
- **Chapter 6** presents the OCEANIDS User-Driven Tools and applications
- **Chapter 7** summarises the conclusions of this deliverable.

3 Requirements Specification

In this section a general overview of the systematic process of requirements specifications will be analysed, as well as the presentation of the followed methodology will be described.

The a-priori use of a common methodology to gather, classify, and assess the requirements is important. To this end, to effectively collect, manage and organise the requirements for the OCEANIDS project, the Volere methodology will be followed as a starting point, adapting its requirements specification template to the needs and particularities of the project. The template can be seen in **Figure 3**, tailored to enable the set of defined requirements to be standardised, trackable and prioritised. Volere is an excellent methodology to extract conclusions and provide results following a systematic approach.[3]

#Requirement	Description
ID	Unique ID
Summary	A one-sentence statement of the intention of the requirement
Requirement Type	**User:** End-users feedback **Functional**: Something the system should do **Non-functional**: How the system works (several sub-types are pre-defined)
Priority	A rating of the customer value. Scale: Blocker, Critical, Major (= default), Medium, Minor, Trivial, Nice to have
Rationale	A justification of the requirement. Why is the requirement important? What contributions does it make to the product's purpose?
Source	From where this requirement was extracted or presented (could be a report, a publication, a survey, etc.)
Fit Criterion	A measurement of the requirement such that it is possible to test if the solution matches the original requirement
Originator	The person or partner who raised this requirement
Custom Labels	Any labels that can further help
Description	A more detailed description of the requirement if needed
Component/s	Components defined

Figure 3. Template of the Volere methodology

The requirements specification is the systematic process of collecting and documenting all User and System Requirements in an integrated formal document. This document ultimately serves as a comprehensive report consisting of the project's needs and problems. The requirements are gathered from diverse sources, analysed, evaluated, validated and then documented clearly and accurately. The requirement specification document must be clear, complete, comprehensive, and

[3] *Giménez, P., Llop, M., Gonzalez-Usach, R., Llorente, M.A. (2021). INTER-IoT Requirements. In: Palau, C.E., et al. Interoperability of Heterogeneous IoT Platforms. Internet of Things. Springer, Cham. https://doi.org/10.1007/978-3-030-82446-4_2*

consistent to ensure a shared understanding among all stakeholders involved in the project.[4] As has been already mentioned above, the process of collecting the end user's requirements is still in progress under WP2 and will be delivered in M6. The Volere templates will be distributed in parallel with the ongoing interviews organised for the end-users, to identify their priorities, needs and requirements.

In this deliverable, three types of requirements will be documented as a baseline to facilitate the process: (1) User Requirements, (2) Functional, and (3) Non-Functional Requirements. The User Requirements are a combination of functional and non-functional requirements, designed in such a way that they are easily understandable by end-users. Thus, they need to be provided in a natural language using simple and clear formats, tables, and/or diagrams. The Functional requirements, mainly describe the functions of the system that will be designed, focusing on what this system will be and how it will function to satisfy the end-user needs. The Non-functional requirements describe the constraints and limitations of the system to be deployed, having no impact on the general functionalities of the implemented system. All the experts involved in these WPs focused on documenting and setting some preliminary requirements to identify the synergies among their modules and platforms. All the requirements will be detailed and documented in MS1.

4 *S. W. Ali, Q. A. Ahmed and I. Shafi, "Process to enhance the quality of software requirement specification document," 2018 International Conference on Engineering and Emerging Technologies (ICEET), Lahore, Pakistan, 2018, pp. 1-7, doi: 10.1109/ICEET1.2018.8338619*

4 Technical Requirements

In this section, a brief description of the technical requirements, including the End-User's requirements, and Functional and Non-Functional requirements is presented based on the input gathered from the technical partners of the OCEANIDS project. Later on, these results will be verified and reviewed by the end-users participating in the project and documented in MS1.

In section 4.1 the end-user's requirements (**Table 2**) are presented each one related to a unique ID **<UR>**. Similarly, in section 4.2 (**Table 3**) and section 4.3 (**Table 4**), the Functional and Non-Functional requirements are documented with a unique ID **<FR>** and <**NFR>**, respectively.

4.1 End-user's requirements

Table 2. End-User's requirements

ID	Name	Short Description	Importance	Related module/platform
UR-1	User Interface	Provides interaction between users and the system	Critical	O-DSP, EO Platform, OCEANIDS Data Cubes (+SmartMet Server)
UR-2	Search Functionality	Allows users to find specific information in the system	Critical	O-DSP, EO Platform
UR-3	Documentation	Provides detailed information about the system	Critical	Risk Assessment Platform, O-DSP
UR-4	Data Visualization	Provides a graphical representation of system data	Critical	Risk Assessment Platform, O-DSP, EO Platform
UR-5	Usability	Ensures the system is easy to use and intuitive	Critical	O-DSP, EO Platform
UR-6	Accessibility	Ensures system usability for all users, including those with disabilities	Major	O-DSP, EO Platform
UR-7	Reporting	Generates detailed reports based on system data	Major	Risk Assessment Platform
UR-8	Configuration	Allows system settings to be customized	Major	Risk Assessment Platform, O-DSS
UR-9	Mobile Support	Allows the system to be used on mobile devices	Major	O-DSP, EO Platform
UR-10	Cross-platform Support	Allows the system to run on different operating systems	Major	Risk Assessment Platform, O-DSP, EO Platform
UR-11	User Feedback	Collects user feedback for system improvement	Nice to have	O-DSP, EO Platform
UR-12	Localization	Adapts the system to different languages and regions	Nice to have	O-DSP, EO Platform

4.2 Functional requirements

Table 3. Functional requirements

ID	Name	Short Description	Importance	Related module
FR-1	Authentication	Verifies user identity	Critical	O-DSP, EO Platform
FR-2	Authorization	Controls user access to system resources	Critical	O-DSP, EO Platform
FR-3	Error Handling	Manages and resolves system errors	Critical	All modules/platforms
FR-4	Data Validation	Checks the correctness and completeness of data	Critical	CREODIAS, Data Cubes
FR-5	Multi-user Support	Allows multiple users to use the system simultaneously	Critical	O-DSP, EO Platform
FR-6	API Support	Allows other systems to interact with the system	Critical	All modules/platforms
FR-7	Interoperability	Ensures system compatibility with other systems	Major	All modules
FR-8	Integration	Allows the system to work with other software or systems	Major	All modules
FR-9	Data Import	Allows data to be moved in the system	Major	All modules/platforms
FR-10	Data Export	Allows data to be moved out of the system	Major	All modules/platforms
FR-11	Data Synchronization	Ensures data consistency across the system	Major	CREODIAS, Data Cubes, O-DSS, Risk Assessment Platform, OCEANIDS Data Cubes
FR-12	Data Analysis	Provides tools for analyzing system data	Major	Risk Assessment Platform, Data Cubes, O-DSS, O-DSP
FR-13	Real-time Processing	Processes data as it is entered into the system	Major	Risk Assessment Platform, O-DSS, O-DSP
FR-14	Workflow Management	Manages the sequence of tasks in a business process	Major	All modules/platforms
FR-15	Data Archiving	Stores old data that is not frequently accessed	Nice to have	CREODIAS, OCEANIDS Data Cubes
FR-16	Notification System	Informs users about important system events	Nice to have	O-DSP, EO Platform

4.3 Non-Functional requirements

Table 4. Non-Functionalities requirements

ID	Name	Short Description	Importance	Related module
NFR-1	Users' Data Encryption	Protects sensitive data	Critical	All platforms
NFR-2	Backup and Recovery	Ensures data safety and system continuity	Critical	All modules/platforms
NFR-3	Data Storage	Stores user data and system information	Critical	Data Cubes, CREODIAS
NFR-4	Security	Protects the system and data from unauthorized access	Critical	All modules/platforms
NFR-5	Compliance	Ensures the system meets legal and regulatory requirements	Critical	All modules/platforms
NFR-6	High Availability	Ensures the system is always accessible	Critical	All modules/platforms
NFR-7	Fault Tolerance	Allows the system to continue operation in case of a fault	Critical	All modules/platforms
NFR-8	Performance	Ensures system responsiveness and efficiency	Major	All modules/platforms
NFR-9	Logging	Records system events for troubleshooting and analysis	Major	All modules/platforms
NFR-10	Load Balancing	Distributes workload to optimize system performance	Major	All modules/platforms
NFR-11	Disaster Recovery	Ensures system recovery in case of a disaster	Major	All modules/platforms
NFR-12	Version Control	Manages changes to system components	Major	All modules/platforms
NFR-13	Scalability	Allows the system to handle increased workload	Nice to have	All modules/platforms
NFR-14	Modularity	Allows system components to be independently developed and updated	Nice to have	All modules/platforms

5 Core Technology Modules

5.1 OCEANIDS Data Cubes

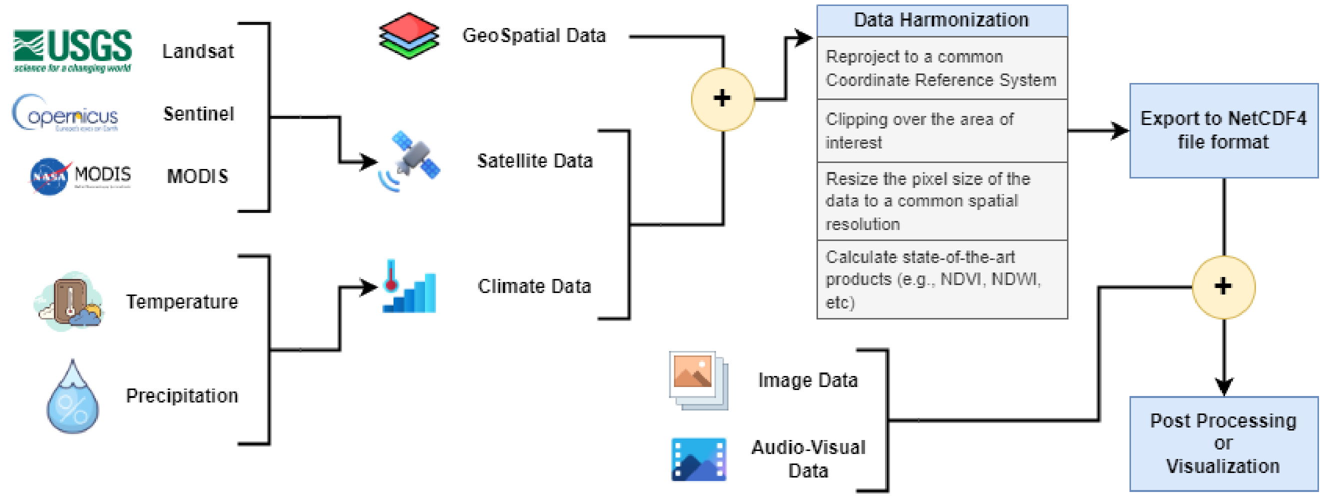

Figure 4: The OCEANIDS Data Cubes Generation Workflow

The ODC implementation is one of the core products of the OCEANIDS project, for providing data harmonisation and homogenization. Furthermore, the ODC will be easily shared among the project's partners for post-processing (i.e., development of machine learning algorithms) or visualization needs. In addition, the ODC algorithm needs to be able to be implemented for all the pilots of the project, thus the implementation must work dynamically for any area of interest considering all the available information.

Figure 4 illustrates the ODC generation workflow, summarizing all the necessary steps. As a pre-step for the workflow, it is considered the data collection. The data harmonisation and homogenization are achievable on data with similarities (i.e., georeferenced data such as satellite data, climate data and geospatial data). The information of the geospatial data is a necessity for the ODC implementation because it provides the boundary for the area of interest. It is worth noting that the rectangle is considered the final boundary of the area of interest, which is defined by the minimum and maximum coordinates (latitude and longitude) of the geospatial geometry. In addition, it is necessary to provide at least one satellite or climate-georeferenced data product for the implementation of the ODC.

The Data Harmonisation algorithm is divided into the following four steps:

1. **The reprojection to a common Coordinate Reference System (CRS):** The CRS of the geospatial data boundary is considered as the base coordinate reference system is considered as it usually refers to the local CRS. Thus, all the other data are reprojected to this CRS.

2. **Clipping over the area of interest:** The satellite and climate raw data are produced for a wide region (bigger than the area of interest). To minimize both the data size and the processing time, it is necessary to clip over the area of interest. In addition, the clipping process provides data homogeneity because it takes into consideration, as well, the possibility of the scenario of the area of interest being into the boundary of the satellite image, thus it is split into several images. In this case, the null region is represented by the "nan" value (i.e., blank area).
3. **Resize the pixel size of the data to a common spatial resolution:** The satellite and climate data spatial resolution is produced in different resolutions by default (i.e., Sentinel-2 images are produced on 10m, 20m, and 60m per pixel, depending on the spectral band). The OCD implementation addresses this problem by using a pseudo-resolution of 10m per pixel. For example, this can be achieved by splitting a pixel of 20m into 4 pixels of 10m, using the same pixel value for all four pixels.
4. **Calculate state-of-the-art products:** The satellite image data can be used for generating indices and climate information by combining several spectral bands. Some indicative examples are the NDVI, NDWI, and Land Surface Temperature. The calculation of such products during the generation of the ODC can significantly minimize the effort of post-processing analysis and provide a ready-to-use product in most cases.

The final step of the process is to export the ODC product to NetCDF4 file format. This file format is state-of-the-art and can be imported to several GIS software such as QGIS for further processing and visualization. In addition, during the visualization of the ODC product, other non-georeferenced data (i.e., camera footage, drone-produced images) can be added for producing complex visualization structures, that can be used as the final products (i.e., interactive, or thematic maps), that can be used for indicating a phenomenon.

5.1.1 Role in the project

The ODC implementation is a critical component of the OCEANIDS project. As noted above, the main characteristics of the ODC are data harmonisation and homogenization, which are achieved through (a) reprojection of the data to the same CRS; (b) clipping over the same coordinates over the area of interest; (c) using the same spatial resolution for all products; and (d) calculating several state-of-the-art remote sensing products. In addition, the final product is a NetCDF4 file that can be visualized in a series of GIS software.

The main contribution of the OCD product is that it will be used as input to other tasks. The harmonisation and homogenization characteristics can help the developers of other tools to create simple reusable routines for reading and processing this product for a variety of applications (i.e., machine learning models). Moreover, Task 3.1 will be accompanied by complete documentation describing the installation of the necessary components (i.e., python libraries), providing examples of possible applications, and their results.

5.1.2 OCEANIDS Data Cubes

The ODC implementation will utilise several components for the successful development of the framework. First and foremost, all the dependencies of the ODC framework will be free and open-source licensed, following the open standards of the OGC (Open Geospatial Consortium) community. Secondly, as presented in **Table 5** the ODC framework will be developed using recognized and state-of-the-art Python libraries for its development, such as Xarray, Rioxarray, and Eoreader. Finally, the output NetCDF4 file format will be visualized inside QGIS.

Table 5. OCEANIDS Data Cube provided values

Module Name	Description	Input Parameters	Output Parameters	Dependencies
OCEANIDS Data Cubes	The OCD framework will provide data harmonisation and homogenization among the various data sources of the OCEANIDS project.	Shapefiles, GRIB2, Landsat (*.tar/dir), Sentinel (SAFE/dir)	NetCDF4	Xarray (https://docs.xarray.dev/en/stable/) Rioxarray (https://corteva.github.io/rioxarray/stable/) Eoreader (https://eoreader.readthedocs.io/en/v0.21.0/) QGIS (https://qgis.org/en/site/)

5.1.3 OCEANIDS Data Cubes specifications

To successfully address the Functional and Non-Functional requirements of the ODC framework, the whole implementation is going to use open and free available data from several sources. As presented in **Figure 4** and **Table 5** several kinds of data, obtained from multiple sources, will be supported as input for the ODC implementation, such as Landsat-8, Sentinel-2, MODIS imagery data products and precipitation or temperature climate data. **Table 6** summarizes the technical specifications of the ODC implementation framework.

Table 6: The technical specifications of the ODC.

ID	Short Title	Description	Related FR(s)	Related NFR(s)	Related Material/Sources
1	OCEANIDS Data Cubes	The OCD framework will provide data harmonisation and homogenization among the various data sources of the OCEANIDS project.	FR(s) 6, FR(s) 8, FR(s) 9, FR(s) 11, FR(s) 15	NFR(s) 3, NFR(s) 4, NFR(s) 6, NFR(s) 8, NFR(s) 13, NFR(s) 14, NFR(s) 15	Earth Explorer: (https://earthexplorer.usgs.gov/) Copernicus Data Hub: (https://dataspace.copernicus.eu/) MODIS Data Hub: (https://modis.gsfc.nasa.gov/data/) Geospatial Data (https://geodata.gov.gr/, https://www.stat.fi/org/avoindata/paikkatietoaineistot_en.html, https://inspire-geoportal.ec.europa.eu/srv/eng/catalog.search#/home, https://research.csc.fi/open-gis-data)

5.2 Earth Observation (EO) data services

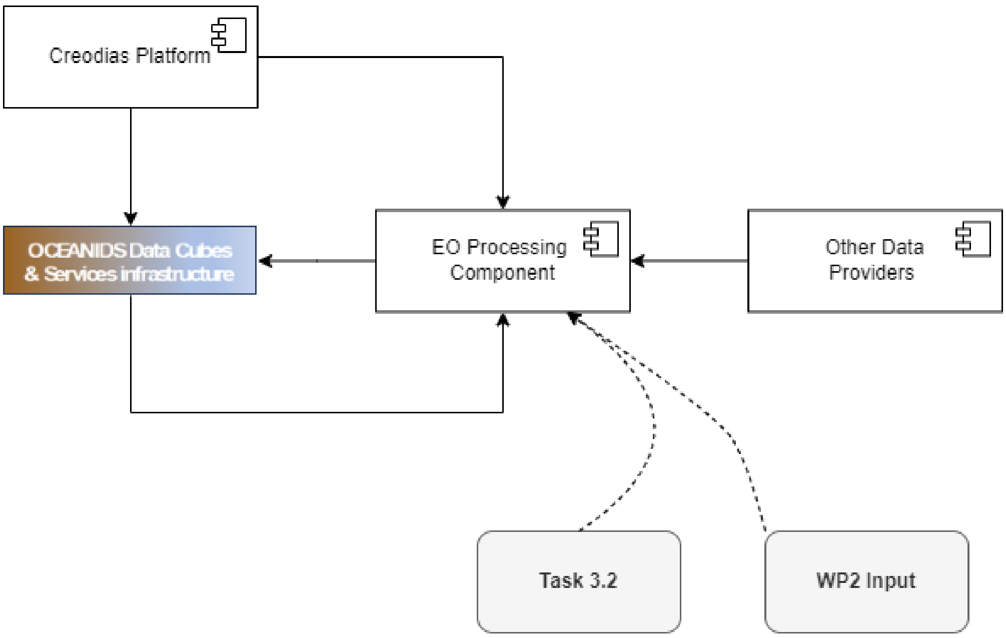

Figure 5: High-level workflow of the EO processing component and EO data integration.

As already depicted in **Figure 5** for synergies between WP3 and WP4 in section 2.3, the CREODIAS platform will be used to provide EO data for the OCEANIDS Data Cubes. This Provision will encompass already available data products on this platform as well as unprocessed input data. User requirements derived within WP2 and further technical requirements and specifications defined in Task 3.2 will be used for the design of the EO processing component to ensure meaningful data products with high relevance to the end-users. If required, additional data products will be acquired from other data providers.

5.2.1 Role in the project

The EO processing component will provide meaningful EO data to the OCEANIDS Data Cubes designed for assessing climate change and environmental impact in coastal regions. Based on the identified user needs and requirements (identified within T2.2), and the software-related technical requirements and specifications (specified within T3.2), these new EO data services will be implemented within the EO processing component. They will support the climate adaption and security of ports and port cities, regional and local authorities for their mitigation of climate impacts and other end-users with diverse use cases, based on data and knowledge. All EO data will further be available for the Multi-hazard risk assessment platform and the Decision Support Platform for maritime spatial planning and climate adaptation planning features.
Simple EO data processing as index calculations may be conducted within the OCEANIDS Data Cubes itself or on the CREODIAS platform, which generally serves as the provider of EO data. If the basic data products are not sufficient for the respective use cases, new EO data services will be implemented depending on the identified user needs. These new services may include complex index calculations, data fusion, ML (Machine Learning) applications (e.g., downscaling), image segmentation, change detection along other processing. Therefore, the EO processing component will gather data from the OCEANIDS Data Cubes, the CREODIAS platform or other data providers and store the results within the OCEANIDS Data Cubes. Further, interfaces of the EO processing component to upcoming data products (CO2M, EnMAP, Sentinel-4) will be considered as complementary information sources.

5.3 Climatic models

Produce information from climate prediction model output based on WP2 outputs; Use statistical downscaling for more localized data. (Key Components): Coarse-resolution climate prediction outputs; Downscaling using regional reanalysis datasets and sub-grid-scale earth observations; Inclusion of climate indicators for user engagement; Analysis of downscaled ocean and observational data; Focus on environmental impact assessments based on end-user priorities.

5.3.1 Role in the project

HCMR is a partner with a role to provide access to climate data, process and analyze them to required metrics, and create relevant indicators and tools for regional stakeholders. The ultimate goal is to assess the impacts of climate change on coastal regions, with a focus on factors relevant to maritime activities and planning.

5.3.2 Climatic models

The data is based on high-resolution, dynamically downscaled, climate change scenarios datasets such as Euro-CORDEX simulations, which are available through Copernicus C3S and/or the Nordic Convection Permitting Climate Projections (NorCP) data over the Nordic domain.

5.4 Meteorological models

Produce information from climate prediction and seasonal forecasting; Use machine learning-based downscaling for more localized data. (Key Components): Periodic information generation; Coarse-resolution climate prediction and seasonal forecasting; Downscaling using sub-grid-scale earth observations; Inclusion of climate indicators for user engagement; Routine review of local conditions for planning on different time scales; Analysis of downscaled ocean and observational data; Focus on environmental impact assessments based on end-user priorities.

5.4.1 Role in the project

FMI is a technical partner, whose role is to provide access to relevant data and models, process and analyze data to required metrics, assist in the transformation of said data to actionable intelligence, and re-usable tools for regional stakeholders.

5.4.2 Meteorological models

The model data is based on CMEMS Baltic Sea Physical/Biogeochemical Reanalysis and downscaled climate change scenarios high-resolution dynamically downscaled datasets such as Euro-CORDEX simulations, which are available through Copernicus C3S and/or the Nordic Convection Permitting Climate Projections (NorCP) data over the Nordic domain.

5.5 CREODIAS Platform

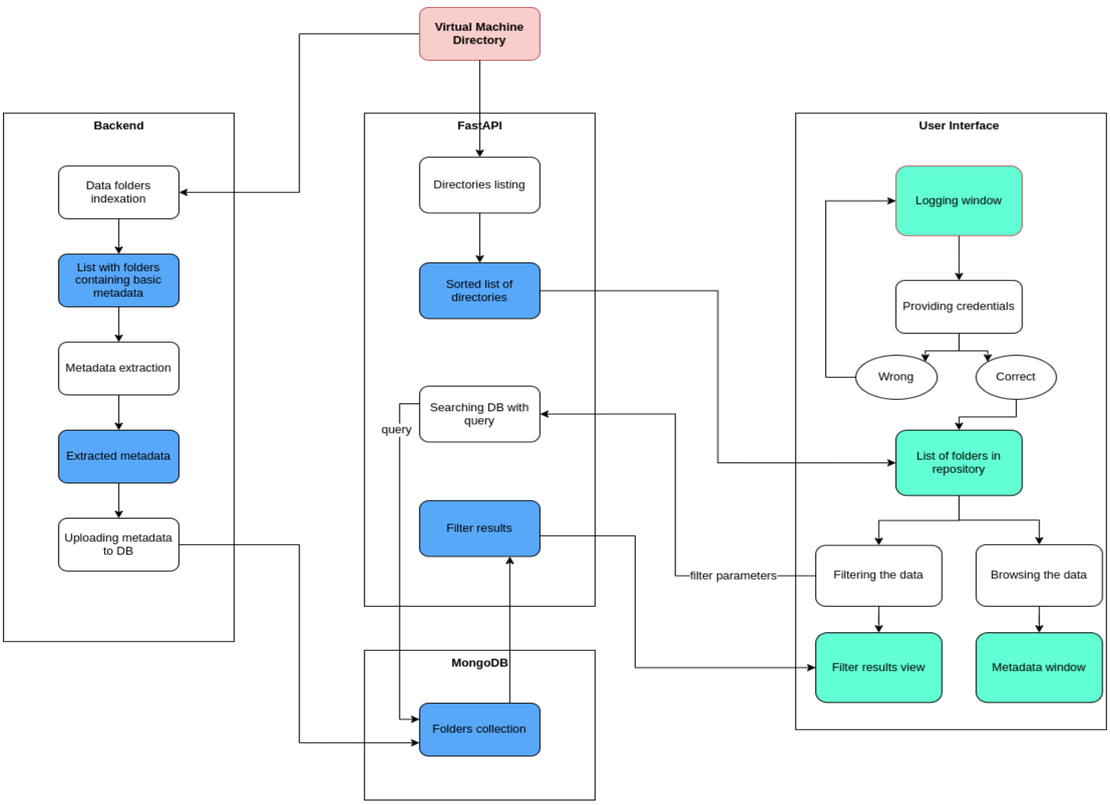

Figure 6. High-level workflow of the CREODIAS Platform's main functionalities

5.5.1 Role in the project

One of the main sources of data - EO Data for the OCEANIDS Data Cubes will be provided by the CREODIAS Platform. CREODIAS is an EO Data access and processing platform which provides quick access to COPERNICUS and open data (**Figure 6**).

5.5.2 CREODIAS Platform

CREODIAS is a seamless environment that facilitates EO data processing. It offers commercial services within the Copernicus Data Space Ecosystem. The platform provides immediate access to data from Copernicus Sentinel satellites, Envisat, ESA/Landsat, and other EODATA sources. Third-party users can prototype and build their value-added services using CREODIAS. The platform ensures simplicity, scalability, and repeatability through a set of pertinent tools. Additionally, CREODIAS offers integrated public cloud services for data processing and serverless processing.

The key features of CREODIAS:

- Big-data-enabled OpenStack cloud services
- Large repository of EO data, which includes data from Copernicus Sentinels (Sentinel Satellites: CREODIAS covers full data sets from the Sentinel satellite family, including Sentinel-1, 2, 3, and 5P), Landsat (Landsat-5, 7, and 8, SMOS, Envisat and others).
- Platform as a Service (PaaS) appliances.
- EO-based services: PGaaS, Sentinel HUB[5], openEO[6], Sen4CAP[7], Remote transfer for EODATA, Jupyter Lab, and a collection of VHR commercial data and services.

Key applications within the CREODIAS environment include:

- Portal: The central hub for account management and information handling, featuring FAQs and news updates.
- Data Explorer: the advanced search engine for selecting products based on specific variables (time, place, collection, processing level). It can be accessed via a JSON-based API.
- Cloud Dashboard: A tool for managing processing resources.

Data processing is a fundamental phase in CREODIAS' value chain, and the platform offers a comprehensive set of virtual resources to achieve efficient and favourable solutions. CREODIAS offers virtual machines with various operating systems. These VMs come with easily mountable storage volumes and object storage solutions. Additionally, users can set up virtual networks and utilise appliances like firewalls and VPN concentrators. A common solution in

[5] https://www.sentinel-hub.com/
[6] https://openeo.org/
[7] https://github.com/Sen4CAP/Sen4CAP

terms of authorization and authentication ensures single sign-on capability across all CREODIAS services. Copernicus Services are accessible locally through CREODIAS.

Combining CREODIAS with the project EO Data repository together with all tools and services creates a single point of data delivery for data cubes, facilitating access to and from it. Eventually, all data processing and access becomes much more highly efficient and rapid, though the use of common infrastructure for all data processing and gathering makes it an ideal solution for OCEANIDS.

The preliminary EO Data repository combining all data types should look like provided in the picture below, though the exact technology stack may vary after further investigations are done in the next phase.

6 OCEANIDS User-Driven Tools and applications

6.1 Risk assessment Platform

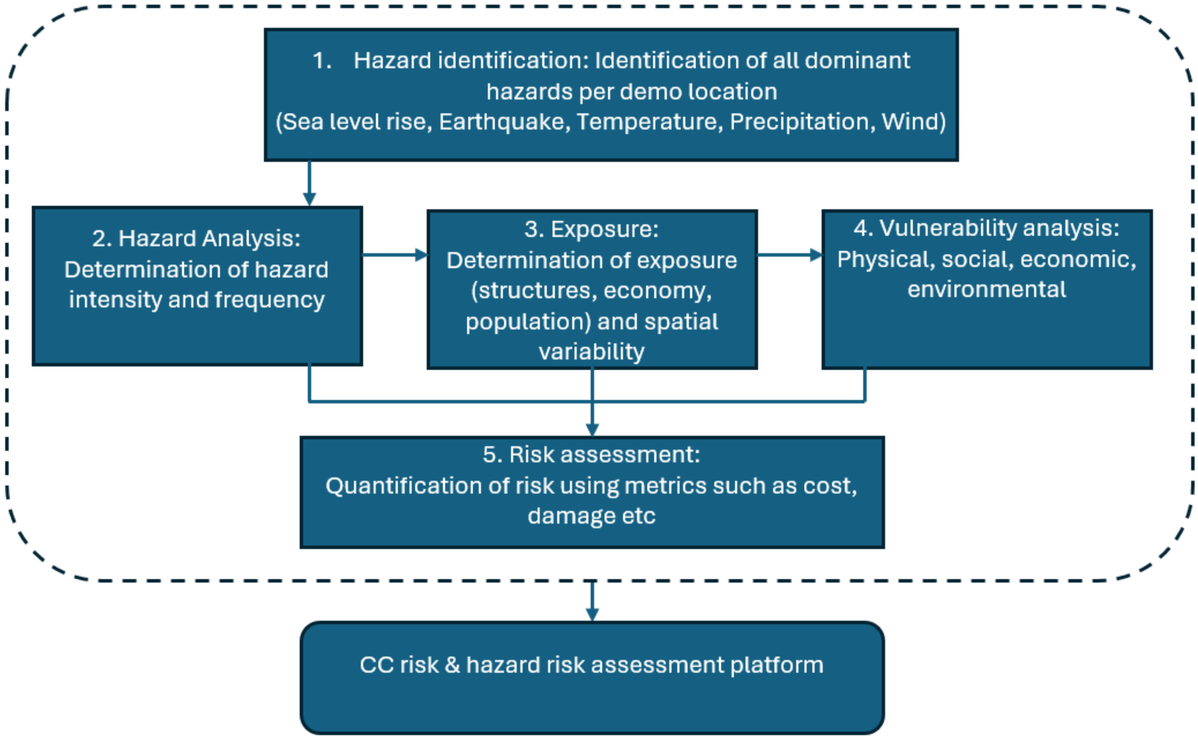

Figure 7: Risk assessment platform.

6.1.1 Role in the Project

The primary goal of the platform is to increase the resilience of coastal environments by using a vulnerability- and risk-based approach. This approach considers both foreseen and unforeseen incidents, crises, and climate impacts, thereby strengthening the preparedness and adaptive capacity of coastal regions (**Figure 7**).

The platform allows regional stakeholders to model various planning options against different climate change scenarios. This helps in understanding the potential impacts of different policies and practices, thereby enabling stakeholders to make informed decisions.

The platform acknowledges the dynamic and systemic nature of risk associated with climate change. It aims to deepen the understanding of these risks, especially considering the increasing complexity and interconnections within societies.

6.1.2 Risk assessment Platform

The CC risk & hazard risk assessment platform integrates various data sources and modelling frameworks to accurately quantify risk (**Table 7**). A breakdown of its components and functionalities is as follows:

1. Data Integration: The platform assimilates data from diverse sources within OCEANIDS, including:

- Asset exposure datasets: Information about the location, type, and characteristics of assets exposed to hazards.
- Population statistics: Data on the demographics and distribution of people in the region.
- Long-term hazard simulations: Predictions of hazard occurrences over extended time frames.
- Short-term hazard forecasting: Real-time or near-real-time predictions of imminent hazards.
- Vulnerability information: Historical records and simulation-based assessments of asset vulnerability.
- Impact assessment data: Data on the impacts of past events and forecasts of future events.

2. Modelling Framework: Utilises a comprehensive modelling framework to assess the magnitude of impacts, ensuring accurate propagation of uncertainties. This framework considers aleatory uncertainties (inherent randomness) and epistemic uncertainties (uncertainty due to lack of knowledge) from various sources, such as data quality, modelling methods, and parameter estimation.

3. Asset State Estimation: Applies modelling and simulation tools to estimate the state of assets, either individually or as groups. This estimation considers:

- Currently reported state of assets.
- States of interconnected assets.
- Nature of hazard pressure affecting assets.
- Characteristics of assets (risk mitigation measures, response capabilities, safety equipment).
- Types of interconnections between assets.

4. Risk Quantification: The platform accurately quantifies risk over a region by integrating information about hazard exposure and asset vulnerability. This enables:

- Improvement and optimization of safety measures for complex infrastructures.
- Actionable metrics for regional planning, insurance, and natural catastrophe prevention/mitigation.

5. Applications:

- Safety Optimization: Enhances safety measures for complex infrastructures by providing insights into operational processes and interactions.

- Regional Planning: Offers actionable metrics for informed decision-making in regional planning initiatives.
- Insurance: Facilitates risk assessment and pricing for insurance purposes.
- Natural Catastrophe Prevention/Mitigation: Supports efforts to prevent and mitigate the impacts of natural catastrophes through proactive measures.

Table 7. Risk Assessment Platform provided values

Module Name	Description	Input Parameters	Output Parameters	Dependencies
Risk Assessment Platform	Quantifies risk associated with climate change (CC) and associated hazards	Asset exposure datasets; Population statistics; Hazard maps and exceedance curves; Vulnerability information	Probabilistic distributions of consequences; Damage state probabilities; Loss metrics	EO Data services; Climatic models; meteorological models

6.1.3 Risk assessment platform specifications

Table 8. Risk Assessment Platform specifications

ID	Short Title	Description	Related FR(s)	Related NFR(s)	Related Material/Sources
1	Exposure	Modelling of exposure	FR-3, FR-6, FR-9, FR-10, FR-11, FR12, FR-13, FR-14	NFR-1, NFR-2, NFR-4, NFR-5, NFR-6, NFR-7, NFR-8, NFR-9, NFR-10, NFR-11, NFR-12, NFR-13, NFR-14	N/A
2	Vulnerability	Assessment of vulnerability			N/A
3	Risk	Integration of hazard, exposure and vulnerability to quantify risk			N/A

6.1.4 Hardware specifications

- Intel i7 CPU (or better)
- 16MB RAM
- 50GB Storage

6.1.5 Software specifications

- Python 3.5 and above

6.2 EO and spatial data platform

The EO and spatial data platform represents a single-access interface for the visualization and data access of projects' added-value information regarding EO and spatial data (**Figure 8**). More precisely, it offers a graphical user interface following UX/UI principles designed for non-expert users as well as technical access by APIs for developers and the two OCEANIDS platforms Multi-hazard Risk Assessment Platform and the Decision Support Platform (O-DSP).

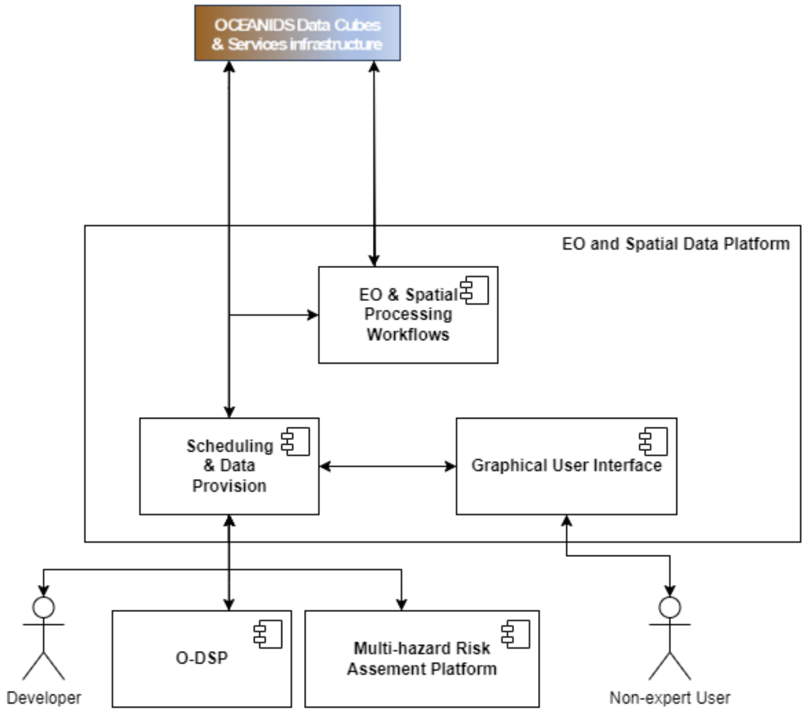

Figure 8: High-Level Workflow of the EO and spatial data platform.

The provision of data is managed by a Scheduling & Data Provision component, which further encompasses the EO & Spatial Data Processing Workflows, if specific datasets will be requested on demand, or requested on a period schedule.

The platform offers stakeholder-oriented data products, which are derived by the data utilisation from the OCEANIDS Data Cubes and Services Infrastructure. Hence, it offers widely used and open-access EO data repositories including exploiting the operational infrastructure, data and services of the Climate Data Store, whose assets have not yet sufficiently been capitalized from current initiatives.

6.2.1 Role in the project

Along with the Multi-hazard risk assessment platform and the Decision Support Platform, the EO and spatial data platform is one of the three main components of the developed Multi-level governance platform for coastal regions. OCEANIDS envisions its EO and spatial data platform as the central gateway for accessing, visualizing, and extracting the project's added-value information. The platform will serve as a pivotal tool for decision-making support in climate change management across OCEANIDS' platforms.

The platform will complement existing applications and data repositories like Copernicus Services and DIAS, amplifying its functionalities and fostering cross-referential feedback loops with technical partners to innovate and produce new EO products effectively. Through iterative processing workflows, the platform will recurrently generate fresh insights and information, utilising widely accessible EO data repositories and capitalizing on the operational infrastructure, data, and services offered by the Climate Data Store. This integration aims to maximize the utilisation of assets that have yet to be fully capitalized on by current initiatives. Ultimately, the outputs generated by the EO and spatial data platform will feed into the O-DSP platform, ensuring a seamless flow of information and enhancing the overall effectiveness of OCEANIDS' initiatives in climate change management, mitigation, and adaptation actions.

6.2.2 Hardware specifications

- Intel i7 CPU (or better)
- 16MB RAM
- 50GB Storage

6.2.3 Software specifications

- Python 3.10 and above
- JavaScript ES6
- SQL/NoSQL database

6.3 O-DSP (OCEANIDS Decision Support Platform)

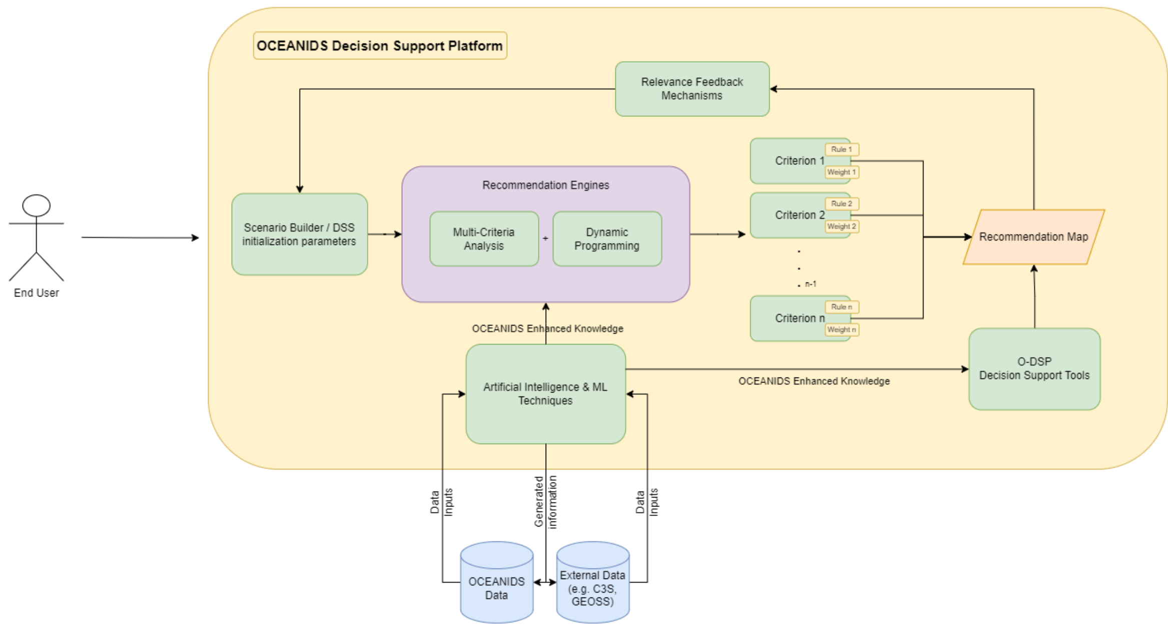

Figure 9. Workflow of the O-DSP

6.3.1 Role in the project

The OCEANIDS Decision Support Platform (O-DSP), will be designed to support operational optimization for climate impacts, data, and knowledge in coastal regions, particularly for port cities and local municipalities (**Figure 9**). The OCEANIDS Decision Support Platform (O-DSP) shall secure ports, port cities, regional, and local authorities' operational optimization on climate impacts, data, and knowledge. More specifically, the work conducted will include:

1. **Integration of Climate Data:** O-DSP aims to provide better access to climate data, including openly available data in the C3S Climate Data Store and other initiatives like GEOSS. It will combine this data with locally sourced information to offer climate change services that are relevant to users.
2. **Interconnected Building Components:** The platform's building components will follow a methodological approach, ensuring that each component interacts with inputs from other OCEANIDS platforms. The overall design will adhere to a UML (Unified Modeling Language) framework, promoting interoperability with other tools and components.
3. **Design Emphasis:** Special attention will be given to the computational execution time, precision/recall values for assessment, and security and privacy trust issues within the platform's architecture.
4. **Integration with the Climate Data Store:** O-DSP is intended to be integrated into the operational infrastructure and services of the Climate Data Store, enhancing its capabilities, in collaboration with T3.5 and the CREODIAS Platform.
5. Relevance Feedback Mechanisms: The platform will support relevance feedback mechanisms that can automatically update the system's response to user preferences. This includes the development of (i) Recommendation engines, (ii) Decision Support Tools, and (iii) Relevance Feedback mechanisms.
6. Recommendation Engines: Multi-criteria analysis and dynamic programming methods will be utilised for recommendation engines, allowing for the development of reliable recommendation maps.
7. Decision Support Tools: O-DSP will integrate Artificial Intelligence (AI) tools, including deep Machine Learning algorithms, to process large and diverse datasets, extracting semantic entities and information.
8. Enhanced Climate Data Services: The platform will support and maintain local quality-controlled climate data services, enhancing the overall climate services provided by the European Union's Climate Data Store.

6.3.2 O-DSP (OCEANIDS Decision Support Platform)

Table 9. O-DSP and O-DSS provided values

Module Name	Description	Input Parameters	Output Parameters	Dependencies
O-DSP	OCEANIDS Decision Support Platform	Risk assessment Platform	End-users	Decision Support System
O-DSS	OCEANIDS Decision Support System	Risk assessment Platform, EO Platform	JSON files, Maps, Report	Risk assessment methodology, Required Data collection

6.3.3 O-DSP specifications

Table 10. O-DSP and O-DSS

ID	Short Title	Description	Related FR(s)	Related NFR(s)	Related Material/Sources
1	O-DSP	OCEANIDS Decision Support Platform	FR-1, FR-2, FR-3, FR-5, FR-6, FR-9, FR-10, FR-12, FR-13, FR-14, FR-16	NFR-1, NFR-2, NFR-4, NFR-5, NFR-6, NFR-7, NFR-8, NFR-9, NFR-10, NFR-11, NFR-12, NFR-13, NFR-14	N/A N/A N/A
2	O-DSS	OCEANIDS Decision Support System	FR-7, FR-8, FR-9, FR-10, FR-11, FR-12, FR-13, FR-14	NFR-2, NFR-4, NFR-5, NFR-6, NFR-7, NFR-8, NFR-9, NFR-10, NFR-11, NFR-12, NFR-13, NFR-14	N/A

6.3.4 Hardware specifications

- Intel i7 CPU (or better)
- 16MB RAM
- 50GB Storage

6.3.5 Software specifications

- Python 3.10 and above
- JavaScript ES6
- SQL/NoSQL database

7 Conclusions

This document represents the deliverable "D1.4 Report on technical requirements for the core technology modules" for the OCEANIDS project. This deliverable is connected to Task 1.2: "Data management plan (DMP)" of Work Package (WP) 1 "Project Management", led by Geosystems Hellas (GSH). This report outlines the essential technical and end-user requirements for the development and implementation of the core technology modules, especially the technologies developed under WP3. Meeting these requirements is crucial to ensure the success and reliability of these technologies as the project moves forward, as well as in combination with the requirements gathered from WP2 and MS1. The main focus of this deliverable was to provide a complete preliminary overview of the main modules and workflows developed under WP3 and the requirements from a technical perspective, but not exclusively limited to that. It is essential to maintain an integrated approach considering that the core technology modules created under WP3 will be ultimately integrated into the platforms generated under WP4. Therefore, this report also documented and gave an introduction and description of WP4 platforms.

As the OCEANIDS project is currently in its first stages of implementation it was considered essential to first identify the synergies among the technological modules, and by having this information available then each partner to introduce and identify preliminary requirements for the core technology modules and platforms, included in the afore-mentioned sections. It is essential to use this deliverable as a first step in identifying each Task's responsibilities and creating the first workflow depicting the synergies that shall be established among WP3 and WP4, once the insightful information from WP2 is available and ready to use.

8 References

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