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Contents

Abstract

This document provides a summary of the work done in the Baltic+ BalticAIMS project and its main results. Please see the deliverables of each WP for further details. Those are available through the web pages of the project (https://www.syke.fi/projects/BalticAIMS) under section Workplan and Deliverables.

Glossary

CDOM	*Coloured Dissolved Organic Matter*
CHL/Chl a	*Chlorophyll a*
CMEMS	*Copernicus Marine Environment Monitoring Service*
EO	*Earth Observation*
GIS	*Geographic Information System*
HELCOM	*Helsinki Commission*
MSFD	*Marine Strategy Framework Directive*
MSP	*Maritime Spatial Planning*
TUR	*Turbidity*
VM	*Virtual Machine*
WFD	*Water Framework Directive*
WP	*Work Package*

1 Introduction

European directives such as the Water Framework Directive (WFD) and Marine Strategy Directive (MSFD) require member states to reach good ecological status in their coastal and inland waters. In the Baltic Sea this goal has not yet been achieved.

Spatial planning is a process that aims for the mitigation of the impacts of human activities and eventual improvement of the state of the environment through coordination and implementation of various practices and policies. Thus, one important action for the improvement of the state of the Baltic Sea is to improve the territorial and maritime spatial planning capabilities of the organizations operating in the area. The goal of the BalticAIMS project was to develop an integrated data approach to obtain a full view of the essential processes of land and coastal water areas by combining various currently available satellite data sources, in situ observations and model predictions about dynamic landcover and water quality characteristics. This goal was reached through the following technical objectives:

- Identify suitable environmental data and GIS materials.
- Integrate, process and store thematic information.
- Create the data access, visualization and analysis systems and tools.

The relevance of the Marine Spatial Planning techniques supported by EO to assess changes in environment due to agriculture, land use, aquaculture and changes in runoff were demonstrated for selected areas in Finland, Sweden, Germany, and Poland (Figure 1).

The work package (WP) structure and logic of the study is shown in Figure 2. See the following chapters for information about the objectives, actions, and results of each work package. Further details are in the deliverables (see Chapter 7) available through the web pages of the project (https://www.syke.fi/projects/BalticAIMS) under section Workplan and Deliverables.

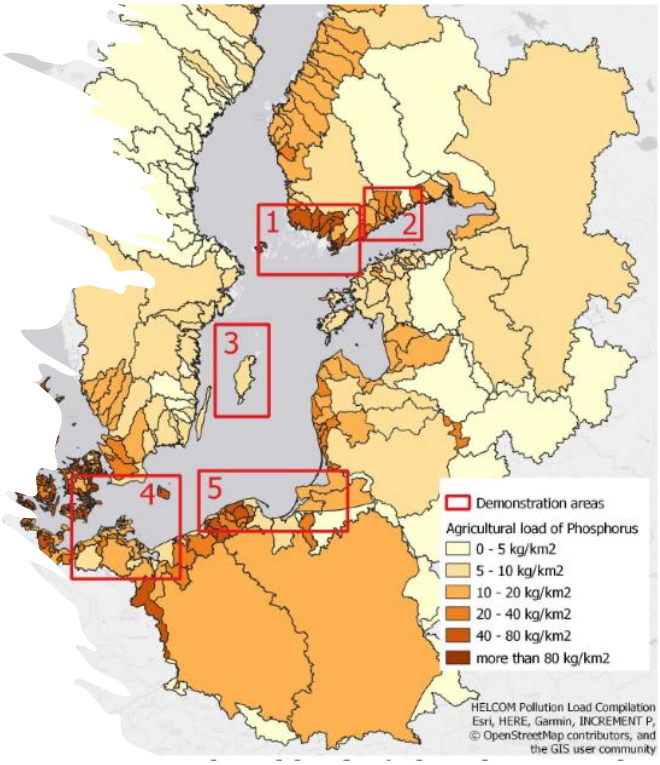

Figure 1. Agricultural load of phosphorus in the drainage basin level in the Baltic Sea and the service demonstration areas of the BalticAIMS project (red rectangles with numbers).

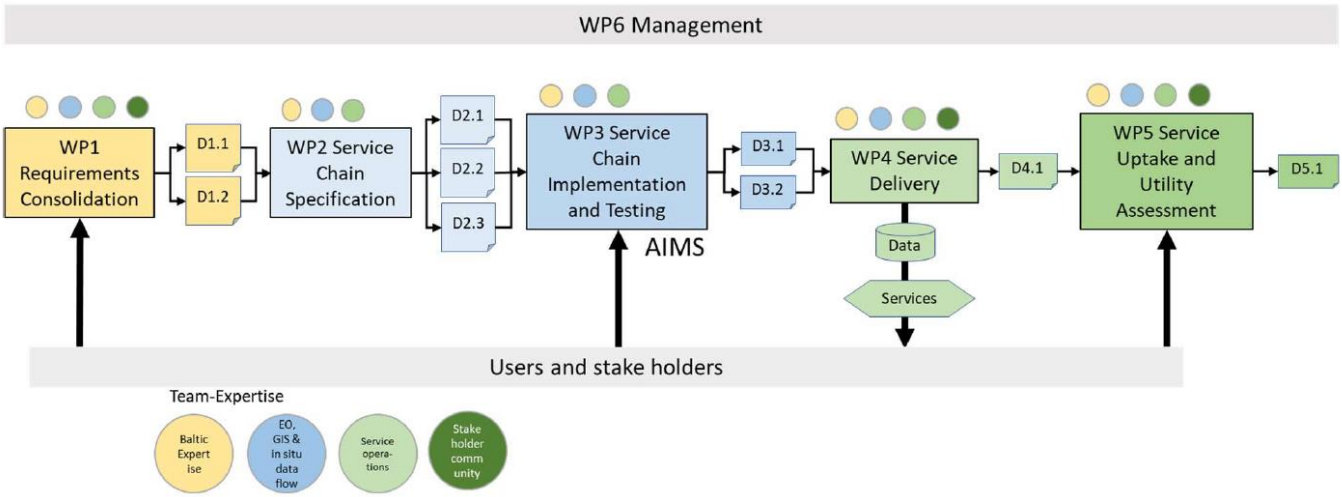

Figure 2. Work logic of the Baltic+ BalticAIMS–project. The deliverables mentioned in the figure are listed in Chapter 7 and described in the WP chapters.

2 WP1 Requirements Consolidation

2.1 Objectives

The main objectives and tasks of the WP were:

- Perform user analysis by:
  - Conducting interviews with the stakeholders and users, as well as with the coordinators of the ESA Baltic+ R&D projects and other relevant Baltic projects.
  - Reviewing relevant documents to collect user requirements information on the target user segments, including their:
    - data handling and analysis systems, and working practices
    - operating practices and information collection activities
    - Define use cases for which data access and processing performance are required
    - Define requirements and implementation approaches for information analysis and fusion.
- Perform requirement definition by:
  - Determining information requirements, associated information delivery performance requirements and system interface features for each of the use segments identified.
  - Determining the functional specifications of the main elements of an EO based information service delivery chain.

2.2 Main results

The results are described in detail in two deliverables:

D1.1 User Segmentation and Operational Practices Review describes the stakeholders and users relevant for terrestrial and maritime spatial planning (MSP and integrated coastal zone management work) and operating within the demonstration areas of the BalticAIMS project. There are many organizations at different levels (regional, national and local) that participate in MSP and environmental monitoring work in various parts of the Baltic. At the regional level HELCOM and its various working and expert groups (e.g. Agri and Pressures) coordinate the effort between the nine member states. The requirements of various EU directives related to the quality of the coastal waters, such as WFD, MSFD, ND, BD, MSPD are relevant at this level. HELCOM also maintains and develops tools for handling and visualizing spatial datasets (e.g. HELCOM BASEMAPS).

At national level the practices and legislation related to terrestrial and maritime spatial planning vary. However, there typically is one central agency, who is responsible for the overall coordination of the work in the country and provides the main tools that are used.

Local actors are often responsible for implementing the MSP work and directive monitoring in their area using the methods and tools provided by national level organizations.

In addition, D1.1 describes the working practices, such as operating practices, information collection activities and data handling and analysis systems of the main stakeholders. Examples of these include e.g. the HELCOM Map and Data Service (HELCOM MADS) which contains the geospatial data relevant for HELCOM work and HELCOM BASEMAPS, which is a map service to access Baltic Sea maritime spatial planning (MSP) relevant data from the original source where it is stored. National systems include

- TARKKA (Finland), which is a free and open service that provides various EO, in situ and GIS materials and the
- Symphony (Sweden), which is a model-based assessment method with the objective to show at a general level how the distribution of the cumulative environmental impact from human activities varies across areas and how planning can affect the distribution.
- GeoSeaPortal (Germany), which is an information platform providing all relevant information for North Sea and Baltic Sea

D1.2 User Requirements Specification (URS) describes the user requirements for the BalticAIMS information service. The user requirements are based on interviews of the main stakeholder and user groups listed in D1.1. The description includes the determination of information requirements, associated information delivery performance requirements and system interface features for each of the use segments identified. Based on the analysis the following Showcases were defined:

A: Provide EO based information to be used in user legacy systems for spatial planning
B: Monitor the effects of nutrient flow from the drainage basin to the coastal waters
C: Monitoring the impacts of coastal activities
D: Combination of Coastal Zone mapping and CMEMS coastal water quality material
E: Monitoring of temperature anomalies

For each the main information needs (water quality parameters, GIS materials etc.), tools (functionalities that the users need) and user groups are described. In addition, the requirements and implementation approaches for information analysis and fusion are described.

3 WP 2 Service Chain Specification

3.1 Objectives

The main objectives of the WP were:

- Determine functional specifications of the main elements of the EO-based information service delivery chains.
- Develop a strategy for accessing all required data.

3.2 Main results

The results are described in detail in the following three deliverables:

D2.1 Service Portfolio Definition describes the specifications of the BalticAIMS service chain. This includes a portfolio of services that the users will be able utilize once the system is operational. In D2.1 the showcases introduced in D1.2 are described in more detail. Showcase A concentrates on providing EO based information to be used in user legacy systems (mainly GIS) while the other 4 demonstrate the generation of use of EO based materials for specific purposes. Each showcase includes one or more user stories and describes the required data, tools and functionalities.

D2.2 Data and Platform Provisioning Plan describes the datasets, system structures, interfaces and deployment strategies required to implement the user service portfolio defined in D2.1 while **D2.3 Service Delivery Chain Specification** provides a comprehensive technical description of the end-to-end data acquisition, processing, analysis, delivery, and integration. Topics covered in D2.3 also include Data ingestion and conversion, Data processing, and Data services and user data access.

Implementing the specified services requires both backend (data processing and provision) system and frontend (user interface) systems. The main principles and functionalities are described in D2.2 and D2.3 and the main elements of the overall system are shown in Figure 3. The system utilizes various data interfaces (WMS, WCS and WFS) to facilitate efficient access to data for all user interfaces. These interfaces include TARKKA, XCube viewer, GIS applications (QGIS, ArcGIS) and Jupyter notebooks. Examples of the EO data included in the system are shown Table 1.

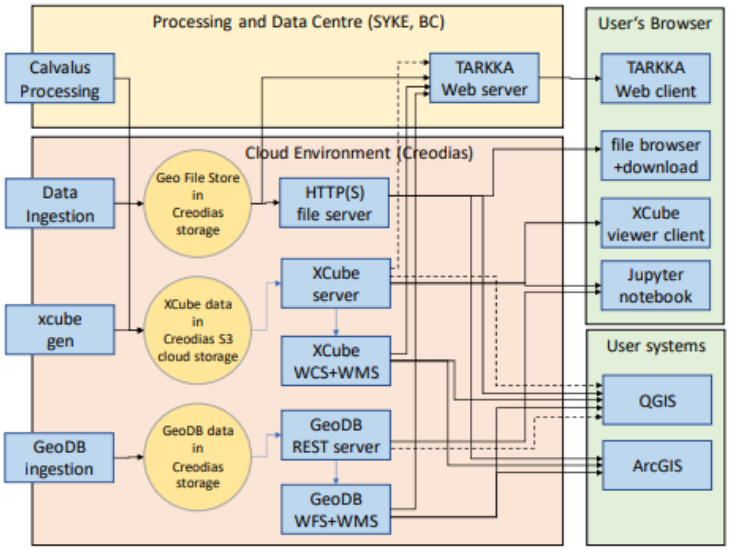

Figure 3. BalticAIMS system elements

Table 1. Time series EO raster datasets for BalticAIMS

Variables and source	Representation	Extent, resolution	Showcases
HR-OC TUR, CHL, SPM	data cube daily, monthly averages	Baltic Sea 100m	A1, B, C, D2, E2
HR-OC RGB	data cube daily, monthly	Baltic Sea 100m	A, D
SYKE HR+MR WQ (tur, cdom, sdt, algae)	data cube temp. aggreg. TBD	Northern Baltic Sea 60m, 300m	A, B, C
SYKE HR+MR SST	data cube daily	Baltic Sea 100m, 1km	A1, C, E1, E2
SYKE data fusion gap-filled SST	data cube daily	Finland 100m	E
CMEMS SST	date cube daily	Baltic Sea 2km	A, E
SentinelHub RGB (MSI, OLI, OLCI)	WMS on-the-fly retrieval used with TARKKA	global 10m, 15m(?), 300m	A, B, C, D, E

4 WP 3 Service Chain Implementation and Testing

4.1 Objectives

The main objectives of the WP were to:

- Perform overall system setup and configuration within CREODIAS cloud infrastructure
- Perform system verification by testing data ingestion and access

4.2 Main results

The results are described in detail in the following two deliverables:

D3.1 Service Chain Verification Report (SVR) describes how the BalticAIMS services specified in WP2 are verified and provides instructions how to add data to the system and how to use the interfaces and data from the various (user) clients. **D3.2 System and Service Chain Readiness Report (SRR)** in turn describes in detail the system setup and configuration of BalticAIMS services and describes the installation status reached.

As planned the backend infrastructure was set up in Virtual Machines (VM) operating in CREODIAS. Raster time series data were ingested and stored in Xcube and made available to user interfaces (Viewer, TARKKA and GIS) via OGC WMS and WCS. Feature data (GIS data) were inserted into GeoDB and served to user applications via OGC WFS. Unstructured or simple file data were stored in a structured geo file store and served via HTTP for download or direct access by user GIS applications. Jupyter Notebooks were also provided as example on how to reach and work with the data made available, as can be seen in Figure 4.

The first versions of the data and user interfaces were made available for user organizations in April 2022.

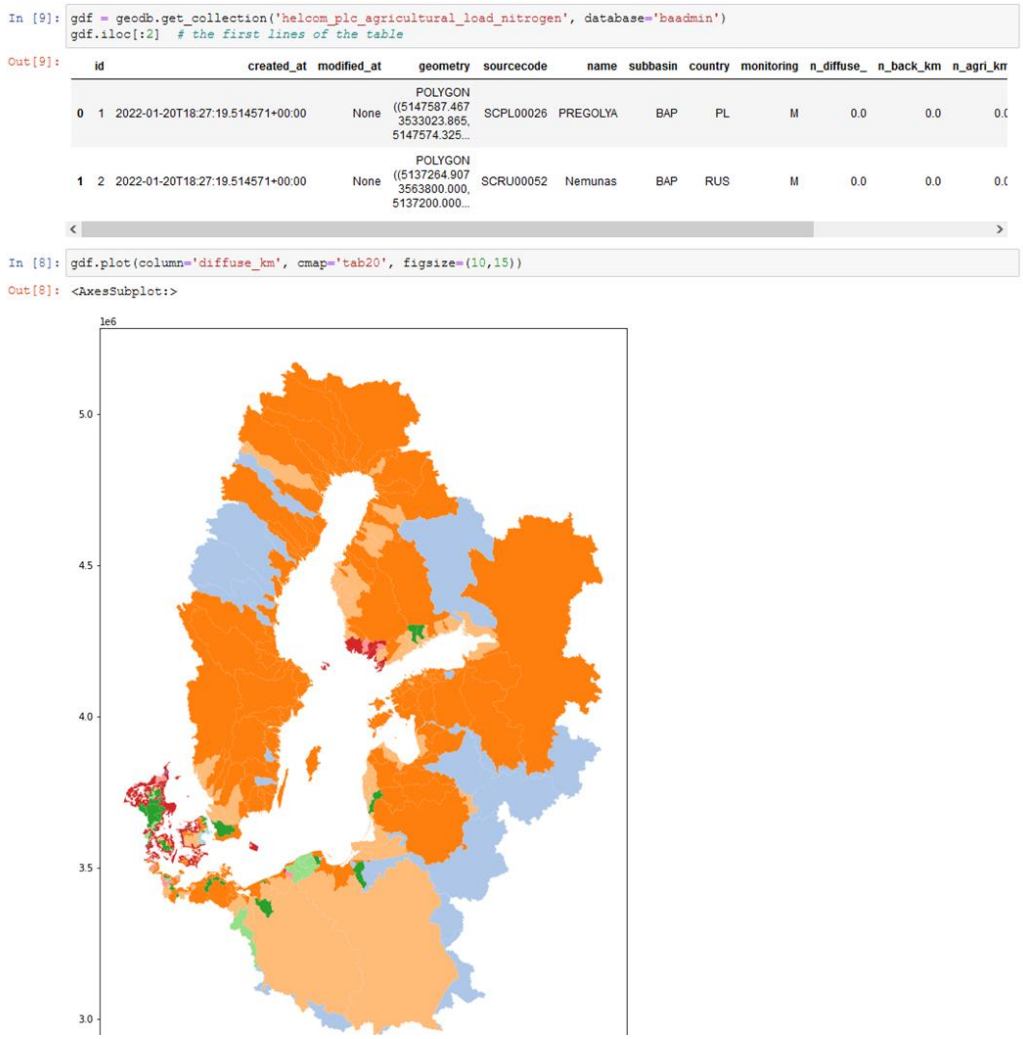

Figure 4. Example notebook to read and display nitrogen agricultural loads from geodb.

5 WP 4 Service Delivery

5.1 Objectives

The main objectives of the WP were:

- Deliver EO-based information services and support consistent with specifications in Deliverables D2.1 (Service Portfolio Definition), D2.3 (EO Service Delivery Chain Specification) and D3.2 (System and Service Chain Readiness Review).
- Review the performance of each element of the service chain and assess deviations from planned performance levels and elaborate appropriate mitigation measures.

5.2 Main results

The results are described in detail in the following deliverable:

D4.1 Service Operations and Service Chain Performance Report describes EO-based information services delivered during WP4 of the BalticAIMS project and provides a performance review of each element of the service chain by assessing deviations from planned performance levels and elaborating appropriate mitigation measures.

From May 2022 onwards EO, model, GIS and in situ dataset required by the user stories were added to the backend systems and visualized in the user interfaces. To facilitate user interaction the team prepared and presented demonstrations for the user community to get comments about the services and feedback for improvements. By the delivery of D4.1 in Nov 2022, the user stories shown in Table 2 were implemented. The objective was to implement at least one user story per show case, and this was exceeded.

The service performance review showed that for the most part the systems worked as expected. The tools developed or extended during BalticAIMS generally fit well with user expectations, notably regarding ease of use (simple point and click of the BalticAIMS viewers, easy WFS/WMTS/WCS connections with QGIS). One major problem was identified: ArcMAP WMTS compatibility with the xcube datasets was missing, which prevented efficient use of this data interface. This has been communicated to ESRI and is to be resolved by them for ArcGIS Pro and ArcMap.

Table 2. Showcases and their user stories (the ones implemented are underlined)

Show case	User Stories
A: Provide EO based information to be used in user legacy systems for spatial planning	
	A1: Material to support the review of MSP Plans
	A2: Human impact
	A3: Hotspots
B: Monitor the effects of nutrient flow from the drainage basin to the coastal waters	
	B1: Impact of agriculture
	B2: PLC subgroup
	B3: Monitoring of nutrient reduction measure
C: Monitoring the impacts of coastal activities	
	C1: Dredging Helsinki
	C2: Water quality coastal Finland
	C3: HELCOM dredging & dumping
	C4: HELCOM human pressures
D: Combination of Coastal Zone mapping and CMEMS coastal water quality material	
	D1: Wind park
	D2: Aquaculture footprint
	D3: Coastal land use
E: Monitoring of temperature anomalies → upwelling & input of heat	
	E1: Helsinki city coastal water temperature
	E2: Climate change

6 WP 5 Service Uptake and Utility Assessment

6.1 Objectives

The main objective of the WP was:

- Perform service assessment by
  - Reviewing uptake, utility and impact of EO-based information services for the participating users and stakeholders
  - Organizing and actively participating to the Stakeholder workshop for users and stakeholders to solicit their feedback and preferred way forward.

6.2 Main results

The results are described in detail in the following deliverable:

D5.1 Service Utility Report is a description of the assessed utility and impact of the developed BalticAIMS information service products. It is based on interviews and meetings with the main stakeholder and user groups within HELCOM, as well as, with other national authorities and users in Sweden, Germany and Finland. The document also includes a Roadmap that presents ideas for future developments and expansion of the service, and further uptake.

The results relate to user uptake and assessment of the service utility and impact with specific focus on product information and service implementation aspects.

The participating users and stakeholders have very different experience levels of EO data, ranging from no earlier experience to already having used it in existing monitoring programs and ecological assessments. In general, two types of user uptake of the BalticAIMS service were identified; the user is actually using the service, as exemplified by TARKKA users within the Finnish environmental authorities, or the case where the service and the products have been demonstrated in user meetings. The latter is the main source of feedback.

The BalticAIMS service provides access to analysis ready data from different data sources at different resolutions. The assessment of the products mainly related to:

- Access to/use of RGBs and EO based raster products
- Access to/use of EO based point or region wise information and time series products
- Thematic content, resolutions, format and quality of the products
- Provision of value-added information in application-oriented formats
- Access to ancillary products (e.g. user data) together with EO based products
- Quality/usefulness of ancillary products (e.g. user data)

Feedback on service implementation aspects highlighted needs for additional value adding steps such as specific spatial and temporal aggregation over predefined locations and water bodies and fine tuning of products and information. However, the feedback from users show that they find both service and products highly relevant and very interesting and that the BalticAIMS show cases and user stories have demonstrated the potential of the information for such subsequent steps. In addition, major revisions and assessments related to for example MSP and WFD are coming up in several countries within the next few years presenting opportunities for further streamlining of products and services.

The project organized a Baltic stakeholder workshop on January 19, 2023 in Espoo, Finland. In this event and in other meetings the provided services were well received, and the user organizations were interested to continue the uptake of the developed services. They also proposed new parameters to be included in the service. For example, eutrophication assessment needs full Baltic coverage chlorophyll-a indicators and Secchi Depth, and areas where resuspension and upwelling take place were mentioned as interesting. For the service to reach its full potential, there is a request for data in certain hotspot areas, in addition to medium and high-resolution products (Sentinel-2) covering the whole Baltic Sea area. The roadmap accounts for these requests and also includes plans for further technical development to improve the service experience and capabilities as well as opportunities for the Baltic region relating to the opening up of the Sentinel Expansion Mission.

7 WP 6 Management

7.1 Objectives

The main objectives of the WP were:

- Manage the administrative, financial, and technical elements of the project including:
  - Organize meetings with ESA and stakeholders
  - Handle milestone payments
  - Quality control and deliver the deliverables and monthly progress reports
  - Create and maintain the project internal online working environment
- Coordinate the promotion of the project
  - Create and update the project website
  - Present the project at conferences and workshops

7.2 Main results

Table 3 shows the planned and actual meeting schedule of the project. In addition to these official review meetings the team held internal planning telecons at least once per month. The deliverables of the project are shown in Table 4 together with their delivery dates. As can be seen the originally planned schedule of the project was realistic with only a small delay at the end of the project. Meetings with stakeholders were organized particularly in the beginning and demonstration phases of the project. See WP1, WP4 and WP5 for more details.

In addition to the user & stakeholder events, the project was presented at the ESA Living Planet Symposium 2022 in Bonn, Germany (May 23, 2022, session E3.04.1).

The webpage of the project (http://www.syke.fi/projects/BalticAIMS) was created soon after the kick-off (publication date March 17, 2021) and maintained throughout the project with news and updates. E.g., all deliverables were made available in the site once approved by ESA.

The project team had regular contact with the parallel project led by TU (Estonia) to collaborate and exchange ideas.

Table 3. Meetings of the project.

Meeting	Planned Date	Actual date
Kick-Off (KO) TC	KO+0	2021-02-23 (KO+0)
Progress Meeting 1 (PM1) TC	KO+2	2021-05-04 (KO+2)
PM2 TC	KO+4	2021-06-23 (KO+4)
Preliminary Design Review (PDR) TC	KO+6	2021-09-23 (KO+7)
PM3 TC	KO+8	2021-11-25 (KO+9)
PM4 TC	KO+10	2022-01-27 (KO+11)
System Readiness Review (SRR) TC	KO+12	2022-03-31 (KO+13)
PM5 TC	KO+14	2022-06-13 (KO+15)
PM6 TC	KO+16	2022-09-13 (KO+18)
Service Operations Review (SOR) TC	KO+18	2022-11-10 (KO+20)
Baltic Workshop, Helsinki, Finland	KO+18	2023-01-19 (KO+22)
PM7 TC	KO+20	2023-02-09 (KO+23)
PM8 TC	KO+22	Was not needed
Final Review (FR), Helsinki, Finland	KO+24	2023-04-19 (KO+26)

Table 4. Deliverables of the project (see Table 3 for the event abbreviations).

Deliverable ID	Title	Review Event	Delivery to ESA (month/year)
D1.1	User Segmentation and Operational Practices Review	PM1	04/2021
D1.2	User Requirements Specification (URS)	PM1	04/2021
D2.1	Service Portfolio Definition	PDR	09/2021
D2.2	Data and Platform Provisioning Plan	PDR	09/2021
D2.3	Service Delivery Chain Specification	PDR	09/2021
D3.1	Service Chain Verification Report (SVR)	SRR	03/2022
D3.2	System and Service Chain Readiness Report (SRR)	SRR	03/2022
D4.1	Service Operations and Service Chain Performance Report	SOR	11/2022
D5.1	Service Utility Report (draft)	SOR	11/2022
D5.1	Service Utility Report (final)	FR	04/2023
	Final Report	FR	04/2023