Project Title:	Baltic+ BalticAIMS
Document Title:	Service Utility Report
Version:	1.2 Public version
Author(s) and affiliation(s):	Susanne Thulin, Petra Philipson, BG Jenni Attila, Sampsa Koponen, SYKE Carole Lebreton, Kerstin Stelzer, Carsten Brockmann, BC
Version history:	1.0 4.11.2022 Draft for ESA review at SOR 1.1 31.3.2023 Version for ESA review at FR 1.2 21.4.2023 Public version
Distribution:	ESA, Project team, public

Contents

Abstract

This document 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.

Ideally, the BalticAIMS products and services should be of high utility and have a significant impact on the work towards the HELCOM and Baltic Sea nations long term ultimate goal "Baltic Sea in good ecological state". This utility report will not assess the success of the developed service against this high-level goal but will focus on the data and products, which have the potential to complement existing monitoring programs and fill data and knowledge gaps. However, this goal is worth bearing in mind as one of the basic reasons why the project developments were initiated in the first place.

A draft version was presented and approved at the Service Operations Review (SOR) on Nov 10, 2022. This final version has been prepared for the Final Review meeting that will be held in April 2023. The document was sent to a majority of the BalticAIMS users and stakeholders for feedback before submission and the responses were positive with approval from the users that responded. No suggestions for further additions or revisions were received.

Glossary

BA	*BalticAIMS*
CDOM	*Coloured Dissolved Organic Matter*
CHL/Chl a	*Chlorophyll a*
CLMS	*Copernicus Land Monitoring Service*
CMEMS	*Copernicus Marine Environment Monitoring Service*
EEZ	*Exclusive Economic Zone*
EO	*Earth Observation*
HELCOM	*Helsinki Commission*
JNB	*Jupyter Notebooks*
MSFD	*Marine Strategy Framework Directive*
MSP	*Maritime Spatial Planning*
OGC	*Open Geospatial Consortium*
PLC	*Pollution Load Compilation*
RGB	*Red, Green, Blue*
SST	*Sea Surface Temperature*
VHR	*Very High Resolution*
WCS	*Web Coverage Service*
WFD	*Water Framework Directive*
WMS	*Web Map Service*
WMTS	*Web Map Tile Service*

1 Introduction

The objective of WP5 is to document and review stakeholders' feedback on the utility, performance level and impact of the EO-based information and services delivered, and to assess the level of uptake on the stakeholder side. The feedback is collected through internally arranged BalticAIMS user meetings or by participation and presentations at externally organized stakeholder workshops.

During 2021-22, several meetings were attended or arranged with the main stakeholder and user groups within HELCOM, as well as with other national authorities in Sweden, Germany and Finland. Some users were already involved in the early User requirements consolidation phase (WP1, D1.1 and D1.2) and Use case developments (see WP2, D2.1-D2.3) and some have mainly participated in later service demonstrations (See D4.1). While the first round of meetings was focused on user requirements and needs, the second round, which started late spring 2022, was focused on the BalticAIMS services, data access and products. Results of discussions and comments received at the BalticAIMS Workshop in January 2023 are included in Chapter 3. Feedback on all aspects of the developed service was collected during the meetings. This report is mainly focused on the feedback related to the provided data products and information. The feedback related to technical aspects and service tools are addressed in D4.1.

The stakeholder feedback received are together with known gaps and bottlenecks relating to uptake and use of EO data used to elaborate the ideas for future developments in Ch. 4 Roadmap.

2 Service utility assessment

As mentioned in the introduction, the BalticAIMS services and products have been demonstrated to several users and stakeholders from different organizations. Besides presenting BalticAIMS applications and showing examples of the collected and produced EO products, additional data (GIS, model and in situ) from various sources have been included in the service demonstrations to further emphasize the complementarity and utility of the EO data. Users have also been shown how to access and visualize the data and products in different ways, for example via the BalticAIMS Viewer or by integrating the information into their legacy systems using different OGC web map services. For further details on the feedback related to different frontends and tools see BalticAIMS deliverables D3.2 and D4.1. This deliverable (D5.1) is focused on the feedback related to data products and information (i.e. spatial and temporal resolution and thematic content) and reviews the link between requirements, developments, and utility with elaborations on performance and impact of the delivered information, including short and long term impact and future needs (chapter 4 Roadmap).

The following definitions of the concepts “uptake” and “utility” are used in the assessment:

Utility and impact – Degree of usefulness and level of complementarity to existing information or gap filling for non-existing information. (See chapter 2.2.)

Uptake – Actual use of the service and information in the user workflows. In addition to actual user uptake, the potential for future uptake as discussed during demonstrations is also addressed. (See chapter 2.3)

2.1 Participating BalticAIMS users and stakeholders

The consulted users and stakeholders belong to different organizations involved in improving the state of the Baltic Sea. They work at local, national and regional level with a variety of different work tasks related to the overall objectives, as well as specific issues that vary over time and by geographic region. The participating users are listed in Table 1, which includes meeting dates and the BalticAIMS contact partner. In BalticAIMS, five Showcases with a set of linked User stories were defined in the initial stages of the project and some were used in the service demonstrations, targeting each users’ specific interests. The main Showcases and User stories discussed with each user is also listed in Table 1. The Showcases (A-E) and User stories are thoroughly described in D2.1 and D4.1 and listed by title below:

- 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

Table 1 Participating users and stakeholders providing feedback at service assessment meetings and Baltic Workshop (BWS) and links to relevant showcases.

Country	User organization	Type of users	Meetings	BalticAIMS partner	Showcases A-E, User stories, e.g. A1 if relevant
FI	Regional Centre of South-West Finland (VARELY)	National	2023-01-19 (BWS)	SYKE	B, C
FI	Regional Centre of Uudenmaa (UUDELY)	National	2022-08-29, 2023-01-19 (BWS)	SYKE	C
FI	Ministry of Environment	National	2023-01-19 (BWS)	SYKE	B, C
FI	City of Helsinki	Local	2023-01-19 (BWS)	SYKE	C, E
FI	Regional councils	National	2023-01-19 (BWS), 2023-02-02	SYKE	C
FI	Finnish marine management planning coordinator	National	2023-01-19 (BWS)	SYKE	All
FI	Finnish Environment Institute (SYKE)	National	2023-01-19 (BWS)	SYKE	All
GE	German Environment Agency (UBA)	National	2022-07-14	BC	B2
SE	Swedish Agency for Marine and Water Management (SwAM)	National	2022-09-06, 2023-01-19 (BWS)	BG	A1
SE	County Administrative Board of Gotland, Region Gotland, Uppsala University – Campus Gotland	Local	2022-06-22	BG	A1, B3
SE	Swedish Meteorological and Hydrological Institute (SMHI)	National	Contact persons have moved on, no meeting planned	BG	A, B
HELCOM secretariat	Special advisor with expertise on MSP and persons from other groups	Regional	2023-02-27	SYKE	
HELCOM group	Agri	Regional	close contact, but no actual meeting to date	SYKE	B

HELCOM group	VASAB MSP	Regional	VASAB MSP WG meeting on 2022-10-06	BC, SYKE	A
HELCOM group	Pressures	Regional	same stakeholder group as PLC-8, no separate meeting planned	BG, SYKE	B2
HELCOM group	PLC-8	Regional	PLC-8 subgroup meeting on 2022-09-16, 2023-01-19 (BWS)	BC, SYKE	B2
HELCOM expert group	EG Eutro (In-eutrophication group)	Regional	2023-01-19 (BWS)	SYKE	All

2.2 User uptake of service

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. During meetings and demonstrations, the team has endeavored to be proactive in promoting users to test and use the services and products, initially with a focus on the user's main tasks and interest, but also to consider other applications and possibilities.

In general, two types of user uptake exist:

* Case 1 – User is actually using the service frontends to view, access and analyze data, e.g. TARKKA has many users within the Finnish environmental authorities.

* Case 2 – User provides feedback in connection to demonstrations. This is the main source of feedback.

The objective of the project has been to demonstrate the possibilities with EO based products and information and the BalticAIMS service including its technical solutions. Full scale implementation and establishment of operational services can take many years and could hence only be done in a limited experimental way during the lifetime of the current project. To reach an operational service level in the future we need to continue the discussions with each user regarding long-term prospects of user needs and systems and very specific details on products and value-added information. Ch. 4 Roadmap elaborates on what is needed for an actual implementation in the users system and tools.

2.3 Service utility and impact assessment

The BalticAIMS service provides access to analysis ready data from different data sources at different resolutions. To truly assess the utility and impact of the EO based data and information a significantly higher degree of user involvement and actual implementation in the user workflows would be required. As stated above, full scale implementation and operation can take many years. BalticAIMS has significantly contributed to the demonstration of data access and products, but full impact can only be reached when specific data is processed to a higher information level, specifically adapted to the user/usage and the application. However, from partner experiences dealing with EO utility for a long time as well as earlier EO based monitoring assignments and from the feedback received from the participating stakeholders we can elaborate on the potential utility and impact for the Baltic Sea users that are involved with planning and environmental monitoring.

2.3.1 Product information aspects

This section is focused on feedback related to the EO based products listed in Table 2, which are provided by the BalticAIMS service**.** All products were included in the BA datacubes and accessible to Users via the BA viewer, WMTS services and/or TARKKA+. The product generation is described in deliverable D2.3.

The assessment of the products mainly relates 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)

Table 2 EO based products included in the BalticAIMS service.

Parameter	Spatial resolution	Spatial extent	Temporal aggregation[1]	Temporal extent
S2 images used for RGB	100 m	Finnish Cube Gotland Cube Mecklenburg-Vorpommern Cube	daily	2020-2022
Turbidity	60 m	Finnish Cube Gotland Cube	daily	2016-2021
	100 m	Finnish Cube Gotland Cube Mecklenburg-Vorpommern Cube	monthly, daily	2020-2022
	100 m	Baltic Sea, Kattegatt	daily	2020-2022
Sea Surface Temperature	100 m	Finnish Cube	daily	2018-2022
	1 km	Finnish Cube Gotland Cube	daily	2017-2021
	2 km	Baltic Sea, Kattegatt	daily	2019-2022
Chlorophyll-a	100 m	Finnish Cube Gotland Cube Mecklenburg-Vorpommern Cube	monthly, daily	2020-2022
	100 m	Baltic Sea, Kattegatt	daily	2020-2022
Suspended particulate matter	100 m	Finnish Cube Gotland Cube Mecklenburg-Vorpommern Cube	monthly, daily	2020-2022
	100 m	Baltic Sea, Kattegatt	daily	2020-2022
Algae (cyanobacteria)	300 m	Finnish Cube Gotland Cube	daily	2016-2021
	60 m	Finnish Cube Gotland Cube	daily	2017-2021
Corine land cover national	100 m	Finnish Cube Gotland Cube Mecklenburg-Vorpommern Cube	~every six years	1990, 2000, 2006, 2018
Corine land cover national	20 m	Finnish Cube	~every six years	2000, 2006, 2012, 2018

Dedicated access to RGBs and EO based raster products that are relevant for spatial planning and monitoring of coastal land and waters of the Baltic Sea is seen as a substantial improvement compared to accessing these products from European general repositories (e.g. Copernicus CMEMS, CLMS). Users have expressed that it is too difficult to navigate to different sources and to determine what data and products might be useful for their needs and to fully understand the properties and quality of the products. In addition, downloading and organization of data and products for daily use are not easy tasks for most users in local, national and regional organizations. It has also been stated that the data must be possible to import and include in the users existing system in quick and simple ways to increase the usage of EO products at all levels, for example via API or different web mapping services.

Many local users find VHR airborne orthophotos useful for their daily work and have access to such data via their organization's GIS system. However, the temporal resolution of these photos is usually very low, e.g. every other year and usually from the same time period, e.g. spring or early summer. High resolution Sentinel-2 based RGBs can serve as a valuable complement to gain better knowledge about seasonal variation despite its slightly lower

[1] Temporal aggregation relates to the time steps present in each cube. However, due to the nature of sensors and overpass repeat cycle, not all regions in a cube are always covered for each of the time steps.

spatial resolution. The EO data can also be made available near-real-time, which adds a new dimension to the usefulness and potential applications. This has been brought up by several users many times and especially in relation to monitoring of near coastal waters and the situation and impact of algal blooms or dredging activities. Animation of raster layers in time steps has also received very positive feedback. However, any such implementation should be direct without requiring user download and attribution of each layer time step by the users themselves. Finally, the relatively large spatial coverage of the EO data adds a valuable overview component compared to other data sources.

Access to/use of EO based point or region-based information and time series data from user selected stations and areas has been assessed by users to be very useful as increased knowledge about seasonal and interannual variation is important for several applications. For most applications and locations such data provide a strong complement to the spatially and temporally sparsely available data from other sources. The higher temporal resolution provided by EO can also add value to the few field-based observations as it helps the user to better understand under what conditions the single sample was taken. Extracted time series data is also perceived as easy to incorporate and use in the user's daily workflow and easy to compare to data from other sources. The BalticAIMS viewer includes functionality for data extraction and download based on the users own point or region definition. As the BA service also includes access to data via OGC interfaces, it is important that GIS users can view and extract image data time series and values for their locations of interest in their GIS software. This is currently only possible for layers served with an OGC WMS with a time dimension and not yet possible for OGC WMTS layers, but this is a core component for the further technical developments in the planned extension of the BalticAIMS service (see Section 4.1).

When it comes to **thematic content,** especially chlorophyll a, cyanobacteria abundance, turbidity and sea surface temperature products are mentioned by many users to have large potential for aspects related to human impact on the environment and for many applications as summarized below:

Chlorophyll a is an important parameter related to estimation of phytoplankton biomass and an indicator for trophic status. Nitrogen and phosphorus are usually the most important indicators to describe the trophic state, but these substances cannot be directly estimated by EO. However, the amounts are crucial for plant growth and an overload can cause a massive development of phytoplankton and potentially toxic blooms by **cyanobacteria**. Phytoplankton are of fundamental importance to aquatic ecosystems. They are the primary producers of organic matter and produce oxygen in the process of photosynthesis. They act as food for animals and excrete dissolved organic matter, which is a resource of energy and nutrients for microbes. However, the breakdown of algae requires oxygen, and the result can be oxygen-free water and bottoms if these blooms continue to be large and frequent. Chl a is used in the Water Framework Directive (WFD) as one of the main parameters of the biological quality factor phytoplankton. Chl a is also an important parameter for the assessment of the environmental conditions within the Marine Strategy Framework Directive in relation to e.g. Descriptor 5: Human-induced eutrophication. And finally, Chl a has been used in several HELCOM eutrophication assessments since the agreement of the Baltic Sea Action Plan, to follow-up on the status of eutrophication of the Baltic Sea.

Turbidity is a common water quality parameter and a measure of the amount of particles in the water. These particles can originate from sediment loading in coastal areas where the surrounding agricultural practices result in excessive soil erosion. The suspended particles will affect the transparency of the water and therefore the transmission of sunlight through the water. Poor transparency can result in low plant productivity. Particle transport from nearby soil is also linked to increasing levels of phosphorus, especially during high rainfall. In addition to erosion, high turbidity levels can be a result of resuspension. The most common effect of dredging activities is resuspension of sediments into the water column. These particles scatter light and are thus readily visible in true color satellite images and turbidity products. Based on EO data it is possible to estimate the area covered by the turbid water and the level of turbidity and thus analyze the effects of the activity in the coastal environment, which makes it an attractive parameter for many applications.

Sea Surface Temperature is an important ecological parameter as all aquatic organisms depend on a certain temperature range for optimal growth and health. In addition, temperature affects many other parameters in the water, including the amount of dissolved oxygen available, the types of plants and animals present, and the susceptibility of organisms to parasites, pollutants, and disease. Causes of water temperature changes include weather conditions, climate change, and discharges to the water from urban sources or groundwater inflows. It

can be measured with high accuracy and can thus be used as an indicator of long-term climate change and to track short-term heat wave events. Given the high temporal resolution of the data, water circulation, upwelling patterns, outflows from land and industrial activities can be identified and monitored with high precision. Together with Chl a, SST is also an important parameter for the carbon cycle and especially the estimation of the air-sea flux of carbon dioxide.

In addition to these main water quality products, and deriving from needs of MSP, data on underwater noise, detection of boats and vessels including oil spills and false alarm detection and identification of surfactants caused by pigments has been mentioned as products of interest by the different users.

BA is complementing the water parameters with those describing land surface properties, such as land cover / land use, or information of land-water interface, such as nutrients input from rivers. This makes it easy for users to find all required data for their analysis in one single place.

The **spatial coverage, and spatial and temporal resolution** of EO based products are in general an improvement compared to data based on any other technique. The frequent cloud coverage over Baltic Sea means that the full capabilities of the satellites are not possible to utilize, but there is still a multifold increase of complementary data at most locations. The stated need for temporal resolution ranges from current phenomena (daily data) to long term averages (seasonal or annual averages). In addition, daily products can be aggregated and interpolated both in space and time for better visualization and improved usefulness. For many needs on national and regional level, 300-1000 meters resolution is sufficient to support many applications. However, due to the scattered nature of the Baltic Sea coastline higher resolution, i.e., 10-100 meters spatial resolution, correspond better to most local requirements, which means that the current products do not fulfill all users' needs and all applications. It has been stated that, for a Baltic wide service 100 meters resolution might cover most of the user needs, if provided as close to the shoreline as possible. Such products would contribute to Water Framework Directive (WFD) assessments in most water bodies, and to the Marine Strategy Framework Directive (MSFD) targets and Marine Spatial Planning (MSP) activities within each country's Exclusive Economic Zone (EEZ). There is also a stated need for products with higher spatial (<10 meters) resolution, but then from a small scale and local perspective. Some user quotes:

"The spatial coverage of the products needs to be extended to also include the western coast of Finland (up to the Bay of Bothnia) as dredging and deposition related to establishment of wind parks will take place there in the future." – Finnish user

"For some regional assessments monthly or seasonally aggregated chlorophyll-a products would be preferred even if also higher temporal resolution is welcome." – German user

"Daily chlorophyll-a and turbidity products for comparison with local user data for evaluation of mitigations measures aimed at reducing land pollution impact on coastal waters but also effects of dredging and upwellings are desirable." – Swedish User

Within the present service, the EO products have been provided and demonstrated in different **formats** using the generated datacubes as backend and then made accessible to Users via the BalticAIMS Viewer, WCS and WMTS services and/or TARKKA+. This setup has received positive feedback and offers easy access to the EO based products for users at different skill levels and without the need for advanced GIS software. **The quality and other limitations** of the products are important information and should be provided with each product, together with a description of how the quality assessment was performed and what/if other data sources were used for the assessment.

We have demonstrated examples of an integrated data approach to the users that support analysis and visualization of land-sea interactions. To be useful for additional user applications related to, for example MSP activities and WFD reporting, the BalticAIMS services and products might need an **additional value adding step** such as specific spatial and temporal aggregation over predefined locations and water bodies. And even if the products are available in standard formats there might be a need for additional conversion for ease of access and direct use in user systems and tools. As this step is very user and application specific it has not been implemented and tested within the present service.

Access to ancillary products and user data (vector) together with EO-based products is central to most applications and was therefore important to demonstrate within BalticAIMS. Ancillary products have been provided as user point data and via the BalticAIMS GeoDB. The following layers were included in the service based on requirements solicited from users in the early stages of the project:

- HELCOM PLC agricultural load of total phosphorous
- HELCOM PLC agricultural load of total nitrogen
- HELCOM Hotspots 2019
- Swedish subset of coastal subcatchments (VARO 2016)
- Swedish subset of agricultural blocks (2021)
- CLM coastal LC LU and LC LU changes (2012, 2018)

Comparisons with EO based products in different user presentations have highlighted the coarse nature of the HELCOM PLC layers and users have emphasized that to monitor and plan for coastal activities and measures much finer resolution of this type of data is needed. The user data in the form of Swedish coastal subcatchments that include both land and coastal waters and agricultural blocks facilitated for users to be able to view the EO-based products in better context, which is necessary for further analysis of land-sea interactions. To be able to access user data attributes are seen as desirable and hence the possibility to access the EO-based products in QGIS and ArcGIS/ArcMap are deemed essential.

2.3.2 Service implementation aspects

TARKKA+ and the BalticAIMS service and products have presently been developed and implemented externally from the user's systems, but still provide the opportunity to access, import and test products of interest. As mentioned above, additional value adding steps such as specific spatial and temporal aggregation over predefined locations and water bodies and fine tuning of products and information would probably be necessary before finally applicable to a specific user, tool and application. As this step is very specific it has not been implemented and tested within the present service. Instead, the show cases and user stories have demonstrated the potential of the information as a preview of what can be done in a subsequent step.

In addition, major revisions and assessments related to for example MSP and WFD are coming up in several countries within the next few years. While not occurring during the BalticAIMS main project, the present service provides an opportunity that can be utilized by different national authorities during the revision and support their understanding and assessment of EO potential for these applications. By extending BalticAIMS, we can also continue to promote the use of EO data for several applications and extend the showcases to support these activities. For example, in Sweden, activities to update the Marine Spatial Plans have recently started and will continue into 2024. The main tool for MSP in Sweden is part of their own system/platform called Symphony. As described in D1.1 (Ch 3.3), Symphony is primarily used at a national level, but the plan is to make it available to local authorities in the future. The use or integration of BalticAIMS products, which provide better spatial and temporal resolution, has potential to improve the MSP process and information base, but has currently not been thoroughly assessed in terms of actual implementation. EO support within the MSP revision is one of the service extension ideas proposed for the continuation of BalticAIMS.

3 Stakeholder workshop

A stakeholder Baltic workshop was held on January 19, 2023, as part of the Finnish Satellite Workshop 2023, between January 18-20, 2023, at Aalto University, in Espoo close to Helsinki, Finland. Feedback from the stakeholders was solicited both from discussions connected to the team presentations and directly when interacting with stakeholders during the practical demonstrations and is summarized below.

Participants were invited both from the group of BalticAIMS users (in advance) and from those attending the Finnish Satellite Workshop (on the day). It was possible to attend both in person and on-line. All users participating in the project and attending earlier meetings and presentations were invited by the BalticAIMS partners to the workshop. The participants represented several different stakeholder groups:

- ELY-centers (joint regional offices of three ministries), Uusimaa, Varsinais-Suomi, Kaakkois-Suomi, Finland
- Regional councils (Kymenlaakso), Finland
- Finnish Ministry of the Environment
- Finnish Environment Institute (Syke), people from various units
- City of Helsinki, and ForumVirium
- SwAM Swedish Agency for the marine environment.
- Members of HELCOM groups State and Conservation, Eutrophication (EG-EUTRO), PLC-8

The workshop agenda included the following presentations by different team members:

- Introduction and objectives of the day, Gordon Campbell (ESA) and Sampsa Koponen (SYKE)
- BalticAIMS Systems, Kerstin Stelzer (Brockmann Consult)
- Presentations of Baltic Sea application examples:
    - Monitoring the impact of agriculture on eutrophication of coastal waters, Petra Philipson (Brockmann Geomatics)
    - Nutrients and Water Quality and Dredging, Kerstin Stelzer (Brockmann Consult)
    - Human impacts at the coast of Finland, Jenni Attila (Syke)
- The parallel project lead by Tartu University was also presented and their results and services demonstrated. New remote sensing products for understanding nutrient fluxes from land to sea, Martin Ligi (University of Tartu)
- Roadmap, Petra Philipson (Brockmann Geomatics)
- Discussion, recommendations, conclusions
- Hands-on demonstrations (in the room + online)

In the last part of the workshop practical demonstrations on how to access BalticAIMS data and products through different interfaces were carried out both in the room and on-line. Actual hands-on was also offered at the venue. The interfaces demonstrated included TARKKA+, BalticAIMS Viewer and QGIS.

The following seed questions were provided in connection to the presentations:

- What are the ongoing and near future projects and activities that we could collaborate with or should be aware about?
- Are the developed tools suitable for future challenges and how should they be developed further?
- Which data or materials are the most interesting or useful when we plan larger scale provision in the future?
- What information needs does MSP have in the future and what is the schedule for them?

Some of these questions were commented on by the participants and further discussed during the meeting and summarized together with other feedback below. Some statements are already covered in Ch. 2.3 Service utility and impact assessment above but repeated here for completeness. The feedback can be divided into different categories:

- General comments
- Datasets needed and requirements for these (e.g. resolution, spatial coverage) and use/usefulness of current products for marine spatial planning and monitoring

- Tools and interfaces
- Ideas for expansion and continuation of the service

In **general**, the participants found the BalticAIMS work inspiring, especially as the project has worked closely with users. Exploring the possible relationship between EO products and nutrients is of large interest, including statistical relationships as nutrients come from different sources, not only river outflow but also from bottom resuspension. In addition, the relationship to pressures was highlighted as important. There were also comments from Finnish regional centers that they should use EO data and products more in their work as they have plenty of material available through for example TARKKA.

When it comes to **datasets and products** several participants mentioned that products identifying pressures, both on land and at sea, are of great interest, including location of human based pressures, e.g. dredging, smaller fishing vessels and wind power parks. Finer resolution datasets (both temporal and spatial) are useful and appreciated for validation of indicators, for improving modelling and are also needed for the updates of marine strategies. Any eutrophication assessment needs chlorophyll-a indicators and, in addition, Secchi Depth and identification of resuspension and upwelling areas were mentioned as interesting.

Comments regarding **the tools and interfaces** shown included the need for both straight forward and simple to use tools such as the xCube Viewer and TARKKA and for tools that fulfill many contrasting requirements and provide answers to a range of questions (QGIS/ArcGIS and Jupyter Notebooks). Both types have pros and cons and address different user groups. To have the alternative data access solutions as provided by BalticAIMS is considered very good. It was stressed that uploading of user vector data should be seen as a base requirement also for interfaces and service tools like the xCube Viewer and TARKKA.

Ideas for **continuation of the service** included expansion to full coverage of the Baltic Sea for some products but also focus on specific “hotspots” (location and specific themes) in selected parts of the Baltic. An extension of the test area to longer stretches of the coast could also be highly relevant. However, it was stressed that small-scale and large-scale information are equally important and that providing products of intermediate scale that do not fulfill any user needs is of no use.

Thoughts on collaboration with ongoing or near future projects included highlighting of the availability of funding from the Digital Earth program and the need to develop a Baltic Digital Twin (model of the Baltic Sea). However, ESA pointed out that such developments need products and tools on high readiness level to be readily implementable, which require the BalticAIMS concept to be further developed and expanded (Future EO program has been trying to support such developments).

4 Roadmap

The main focus of this section is to elaborate and discuss how the developed tools and service infrastructure can continue to serve the diverse Baltic Sea user community and be further developed and adopted to meet as many regional needs as possible. The content is based on feedback received from stakeholders together with known gaps and bottlenecks relating to uptake and use of EO data. The main questions are:

- What does the process look like to reach a sustained service and who would be the best coordinating organization for such an initiative?
- Since funding would be required to generate and maintain a service, what could such a funding solution, potentially shared by all Baltic Sea countries, look like?

The responsibilities and information need of the different organizations acting in the Baltic Sea region vary and are partly overlapping. In addition, the capabilities of the stakeholders in relation to how they can and prefer to access EO based products are driven by the user organizations and traditions and the types of applications the users are engaged in. Providing products and information in standardized and accepted formats should cover most organizations' needs and capabilities.

The foreseen development needs and actions are different from a short-term and a long-term perspective and are addressed in separate sections below. Short-term developments, as described in Ch. 4.1, are important to ensure continued user access to the developed EO products and services. Long-term actions, addressed in Ch. 4.2, is to ensure that the developments and results of the BalticAIMS project are appropriately utilized and reaching operational status. This includes securing funding as well as determining a suitable future data host and service platform.

4.1 Short-term needs for BalticAIMS service continuation

The generated data cubes and implemented service provision architecture, including user interfaces and backend systems, will be kept up and running for the total length of the now planned ESA funded extension of BalticAIMS. This will support continued discussions of data needs and best solutions for the diverse user community. Ideas are presently collected and described in a document that will serve as a basis for the planned project extension, which is expected to prolong the current project with 18 months. The proposed project continuation encompasses both thematic and geographical, as well as technical developments as indicated below:

Service expansion and generalization

The performed stakeholder meetings and demonstrations of the BalticAIMS project have shown that it is desirable to expand the service provision in various ways:

- Additional user stories to promote the use of EO data for several applications, for example exploring the use and integration of BalticAIMS products to improve the national MSP processes, tools and information base.
- Additional data products and longer time series, for example evaluation and generation of a Baltic wide Chl a product for MSFD, HELCOM and research applications.
- Additional demo areas, for example selected HELCOM 'hotspot' areas, but also including development and testing of high-resolution products (Sentinel-2) covering the whole Baltic Sea area.

Further technical developments

The list below includes examples of technical developments that were identified during the service demonstration phase that would improve the service delivery:

- QGIS plug-in and ArcGIS support: the already implemented OGC interfaces (WCS, WMTS) is limited due to their generic nature. Additional interfaces (e.g. WMS with a time dimension) would overcome these limitations, increase the data utility and significantly improve the user experience and user acceptance.
- Ready to use Jupyter Notebooks (JNB) for user specified functionality needs.
- EO processing and analysis on the generated data cubes: currently the data cubes within BalticAIMS are containers for preprocessed data, and further developments can provide the users with the opportunity to not only analyse, but also modify the data.

In summary, the proposed new developments will improve the present BalticAIMS service functionality, extend the spatial coverage, and include additional show cases for discussing future opportunities and solutions with relevant stakeholders.

4.2 Long-term needs for sustainable services

As stated earlier, the specification of the long-term needs should ensure that the developments and results of the BalticAIMS project are appropriately utilized, reaching operational status and support as many different needs and user organizations as possible.

The following user groups have been assessed with respect to potential future needs:

- HELCOM and its working groups, e.g. AGRI, VASAB-MSP, State and Conservation, Pressure (PLC) and different data and expert groups
- National monitoring authorities
- National councils and MSP authorities
- Local authorities

4.2.1 HELCOM and other Baltic Sea regional stakeholders

HELCOM plays an important role in the Baltic Sea region, being the main organization that joins efforts and actions by all the member states. The needs encompass data and information scaling from the whole Baltic Sea region to more local sites such as HELCOM hotspots, which correspond to identified pollution sites around the Baltic Sea. A natural development could therefore be to incorporate the developed services in the HELCOM framework and activities. This option should be further discussed and elaborated with different HELCOM representatives during the extended project.

Currently there is a HELCOM web page that lists "databases" with links to different services. However, to ensure user access and knowledge of the existence of an EO based service in the long term, any products and services need to be reachable from different points of access and need to be clearly advertised by HELCOM. The HELCOM Map and Data Service (MADS) could also serve as a potential repository for long-term access to EO products. Currently the data and information provided does not include any EO-based datasets or products, which means that this may not be the place where users would seek this type of information.

Another opportunity to explore during the extended project is the results of the HELCOM project, Baltic Data Flows[2], (2020-2023). Baltic Data Flows is "*co-financed by the Connecting Europe Facility of the European Union, and seeks to enhance the sharing and harmonization of data on marine environment originating from existing sea monitoring programmes, and to move towards service-based data sharing*." In particular the project aims to make open and harmonized datasets accessible and discoverable in the European Data Portal (EDP). The BalticAIMS team has been in contact with HELCOM VASAB-MSP working group representatives and members during the project.

In addition, several Baltic R&D projects exist and could make use of EO based products and information. One example being the PASPS project that aims to support the objectives assigned in the PA (Policy Area) Spatial Planning of the EU Regional Strategy for the Baltic Sea Region (EUSBSR) Action Plan. This project is co-led by VASAB and HELCOM (special advisor active also in PLC-8 and eMSP). Another example is the project HELCOM BLUES, a Baltic-wide effort to help attain Good Environmental Status (GES) through development of new measures to address pressures and improve monitoring of biodiversity, litter and underwater noise.

Baltic Earth (www.baltic-earth.eu/) is a regional organization that aims to "achieve an improved Earth System understanding of the Baltic Sea region as the basis for science-based management in the face of climatic, environmental and human impact in the region." It operates through "Grand Challenges" by organizing joint research efforts, workshops, conferences and capacity building events to tackle them. One of these challenges is "Land-Sea biogeochemical linkages in the Baltic Sea region", which is linked to the objectives of BalticAIMS while the anthropogenic changes and anthropogenic impacts on the Baltic Sea region are overarching topics to be kept in mind in all activities. Baltic Earth does not host data systems and as such is not directly linked to the data

[2] https://balticdataflows.helcom.fi/

provision aspects of BalticAIMS. However, it provides important links to the scientific community and other stakeholders and thus is important to involve in future activities.

In the Roadmap of the ESA Baltic+ SeaLaBio project (https://www.syke.fi/projects/BalticSeaLaBio), a vision for the Baltic Sea called **the LEGO Baltic Sea Initiative** was presented (LEGO stands for Leveraged use of Earth and Ground Observations). When deliberating an extension of the BalticAIMS services in the long term it is indeed pertinent to reiterate the ideas behind the LEGO Baltic Sea Initiative and highlight the need for a "LEGO" based approach where appropriate "building blocks" of EO, in situ and model data, methods for predictions and scenario development including guidance, are easily accessible to users of all types and levels from a stable platform that is continuously supported by a panel of experts (see Appendix).

4.2.2 National

National long-term needs for EO based products and time series information are dominated by the processes of different European Directives, regional assessments and plans, and their rounds and cycles. These include:

- New MSP rounds (schedules vary by country) – how are the MSP processes continuing in different countries and what data layers would be useful for the work?
- New HELCOM assessment rounds (HOLAS IV, 2021-2026) - how are the HELCOM processes continuing and what data layers would be useful for the work?
- New MSFD rounds (6-year cycles, 3rd cycle of implementation will start in 2024) - how are the MSFD processes continuing and what data layers would be useful for the work (parameters related to eutrophication (chl-a, algae blooms, transparency))?
- New WFD rounds (6-year cycles, 2025) - how are the WFD processes continuing in different countries and what data layers would be useful for the work (focus is on chl-a, nutrients and secchi depth/transparency) in the Baltic Sea, also CDOM or water colour can serve as complementary parameters for water types)?

Some of these assessments might not be in focus in terms of Baltic regional needs and data provision, but rather applications that need to be further developed within each nation.

In Finland, TARKKA has many national users working with both environmental monitoring and MSP within the Finnish environmental authorities. TARKKA has been in place since 2017 and is already an established part of the workflow in Finland, which makes user uptake easier. In addition, TARKKA+, an updated version is soon to be fully implemented. In addition to TARKKA and TARKKA+, a practical tool to advance the use of EO datasets is the national database STATUS. EO data can be read to other interfaces from the database, which enables the distribution of EO data to user legacy systems. Like TARKKA, this national database serves as one example for users, how future EO data in datacubes can be used as input data in their systems.

4.2.3 Local

In the context of management, monitoring and planning of the coastal zone, local users are a very important group and from this perspective *local* is a sub-national level represented by for example regional councils and ELY centers in Finland and County Boards and regional water authorities in Sweden. At the truly local level users employed by local councils include city councils that have responsibilities for collecting data and some coastal planning.

These local authorities use various data sources and information products (mainly national, regional and local) in their daily work. The use of pan-European data or HELCOM-Baltic Sea regional data is limited. They have participated in the project providing very valuable information regarding requirements in the first stages (WP1-2) as well as feedback on the utility and usefulness of the developed services (WP4) and products (WP5). Some Finnish local users express a notion that they "should" use more EO-data in their daily work, and they also admit that they do have access to a large range of products via TARKKA.

Many local users find VHR airborne orthophotos useful for their daily work. The temporal resolution of these photos is usually very low, for example every other year. High resolution Sentinel-2 based RGBs can serve as a valuable complement to gain better knowledge about seasonal variation despite its slightly lower spatial resolution.

The Swedish local users would like to see EO products with higher spatial and temporal resolution to be available for the coastal waters as this is where their main responsibilities lay when it comes to planning and monitoring.

The needs also include the use of consistent information products to support collaboration between national and local authorities with responsibilities for reporting to national authorities and that have statutory planning responsibilities including monitoring of impacts.

Based on the experiences in the service delivery phase (WP4) we could further conclude that it is very important for users to access the BalticAIMS system and products through their own interfaces without having to refer to organizational support or use of additional platforms. The exception to this is TARKKA which is already widely used by Finnish users, and which will be provided and further developed by SYKE also in the future.

4.2.4 Opening up the Sentinel Expansion Missions for the Baltic Region

The raster products included in the BA datacube are largely derived from the Sentinels, either by facilitating the Copernicus Services, or by directly taking raw data from the Sentinel satellites and applying algorithms optimized for the Baltic Region. Currently, the Sentinel fleet includes 5 missions with 10 satellites in space, delivering optical medium and high spatial resolution data, thermal data, and measurements from active and passive microwave instruments.

In the second half of the 2020's this fleet will be complemented by the so-called Sentinel Expansion Missions, or Sentinel 6 – 10, which follow the same principles as the first set of Sentinel satellites in terms of operational reliability and long-term commitment. The expansion missions will provide useful complementation data for the Baltic Region. The BA System, and the experts maintaining it, would be ideally placed to bridge the gap between the satellite measurements and information, tailored to the needs of Baltic Region stakeholders and made available through interfaces these users will be used to.

- **CHIME**: Copernicus Hyperspectral Imaging Mission for the Environment. The CHIME mission would carry a unique visible to shortwave infrared spectrometer to provide routine hyperspectral observations to support new and enhanced services for sustainable agricultural and biodiversity management, as well as soil property characterization. The mission would complement Copernicus Sentinel-2 for applications such as land-cover mapping.
    - Baltic Region benefit: Improved water quality parameters, including better CDOM retrieval, differentiation of phytoplankton function types (PFTs), better detection of cyanobacteria and other species; better delineation of crop types and other agriculture areas impacting nutrient balance and carbon budgets
- **CIMR**: Copernicus Imaging Microwave Radiometer. The CIMR mission would carry a wide-swath conically-scanning multi-frequency microwave radiometer to provide observations of sea-surface temperature, sea-ice concentration and sea-surface salinity. Uniquely, it would also observe a wide range of other sea-ice parameters. CIMR responds to high-priority requirements from key Arctic user communities.
    - Baltic Region benefit: improved measurements of physical quantities of the Baltic Sea
- **CO2M**: Copernicus Anthropogenic Carbon Dioxide Monitoring. The CO2M mission would carry a near-infrared and shortwave-infrared spectrometer to measure atmospheric carbon dioxide produced by human activity. These measurements would reduce current uncertainties in estimates of emissions of carbon dioxide from the combustion of fossil fuel at national and regional scales. This would provide the EU with a unique and independent source of information to assess the effectiveness of policy measures, and to track their impact towards decarbonising Europe and meeting national emission reduction targets.
    - Baltic Region benefit: contributing air quality information, currently not covered in BA
- **CRISTAL**: Copernicus Polar Ice and Snow Topography Altimeter. CRISTAL would carry a dual-frequency radar altimeter and microwave radiometer to measure and monitor sea-ice thickness and overlying snow depth. It would also measure and monitor changes in the height of ice sheets and glaciers around the world. Measurements of sea-ice thickness would support maritime operations in polar oceans and would in the longer-term help in the planning of activities in the polar regions. Since inter-annual sea-ice variability is sensitive to climate change, the mission would contribute to a better understanding of climate processes.
    - Baltic Region benefit: snow and sea ice information data layers in BA data cubes
- **LSTM**: Copernicus Land Surface Temperature Monitoring. The LSTM mission would carry a high spatial-temporal resolution thermal infrared sensor to provide observations of land-surface temperature. The mission

responds to priority requirements of the agricultural user community for improving sustainable agricultural productivity at field-scale in a world of increasing water scarcity and variability. Land-surface temperature measurements and derived evapotranspiration are key variables to understand and respond to climate variability, manage water resources for agricultural production, predict droughts and address land degradation, natural hazards such as fires and volcanoes, coastal and inland water management as well as urban heat island issues.

  - Baltic Region benefit: currently high-resolution temperature comes from Landsat with overall limited temporal revisit and limited accuracy for water applications. Land and water data layers in the BA datacube would be significantly improved.

- **ROSE-L**: Copernicus L-band Synthetic Aperture Radar. ROSE-L would carry an L-band SAR. Since the longer L-band signal can penetrate through many natural materials such as vegetation, dry snow and ice, the mission would provide additional information that cannot be gathered by the Copernicus Sentinel-1 C-band radar mission. It would be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security. In addition, the mission would contribute to the monitoring of polar ice sheets and ice caps, sea-ice extent in the polar region, and of seasonal snow.
  - Baltic Region benefit: Snow and sea ice mapping, land cover and forest mapping with significantly improved quality.

Appendix – A vision for the Baltic Sea – the LEGO Baltic Sea Initiative (from SeaLaBio Roadmap)

From the SeaLaBio Scientific Roadmap, Ch 6, A vision for the Baltic Sea – the LEGO Baltic Sea Initiative[3]:

The vision of HELCOM, as presented in the Baltic Sea Action Plan, is "*a healthy Baltic Sea environment, with diverse biological components functioning in balance, resulting in good environmental/ecological status and supporting a wide range of sustainable human economic and social activities*". To reach this vision a joint effort by many actors is required and a need for environmental data that can support the work by a large variety of decision makers, experts, research groups, businesses, national/regional/local stakeholders and administrators. Several initiatives and R&D projects are already running so there is plenty of momentum and energy around, which if appropriately harnessed and streamed has great potential to push things forward. Hence, there is a need to build a holistic approach to studying, monitoring and managing of the Baltic Sea. Continued and new ESA initiatives can support linking of all stages, of the work of remote sensing experts, biogeochemical modelers and experimentalists (in situ observations), and generate synergy.

EO based environmental information should be an increasingly important source of information to support these efforts and it should be easily available for relevant work, projects and initiatives, also those not directly supported by EO experts.

CMEMS, the Copernicus Marine Environmental Monitoring Service, is currently producing and providing several EO based data sets, which can freely be used to support status and trend assessments and research and development initiatives in the Baltic region and globally. However, the spatial and temporal resolution is limited, and the end user uptake of the data is still relatively low. From Q1 2021 and onwards, CMEMS will provide 100 m (Sentinel-2) daily and monthly coastal water quality products, which should be sufficient for many coastal applications, but they will not be produced for the open Baltic. The SeaLaBio project has contributed with a new atmospheric correction (AC) algorithm and a regional algorithm for estimation of colored dissolved organic matter (CDOM) in the Baltic Sea, to support the overarching carbon cycle analysis and understanding. The Baltic+ AC and additional in-water estimation method have improved CDOM estimation accuracy significantly. After further validation, the CDOM product could be added to a publicly available service portfolio and made accessible to the Baltic user community. However, despite the improved availability and accessibility of data and information, there are still gaps in terms of temporal and spatial resolutions, type of products and, very important, quality of products.

Besides the data limitations, it might also be difficult to find, understand, download and analyse the products for users with no or little experience in EO data. To address this, ESA has initiated activities in the application domains of; "Integrated Maritime and Territorial Spatial Planning" and "Emerging HELCOM Monitoring and Assessment Priorities". These projects aims to identify suitable environmental data (EO, in situ, models) and GIS materials, integrate, process and store thematic information and create the data access, visualization and analysis systems and tools. An information service will be created that provide the relevant EO and non-EO data together through contemporary interactive apps, or by linking the machine-to-machine interfaces to the GIS tools of the user organizations (e.g. HELCOM and national user organisations). It is also envisaged that identified gaps in product availability, in terms of spatial and temporal resolution of publicly available EO products, could be overcome and provided within the framework of these initiatives.

In addition to the EO based services described above, there are other initiatives focused on other types of environmental data. The HELCOM Baltic Data Flows (BDF) project, co-financed by the Connecting Europe Facility of the European Union, seeks to enhance the sharing and harmonisation of data on marine environment originating from existing sea monitoring programmes, and to move towards service-based data sharing. In particular, open datasets will be made available by HELCOM to a wider community, such as European open data ecosystem, researchers, NGOs and private sector, in order to benefit from the availability of harmonised environmental data. The project will run from October 2020 to October 2023 and efforts between BDF and coming ESA initiatives should be coordinated.

The collection of existing data is one thing, but for many applications, including development and quality assessment of existing and new EO products, additional data is needed. More and strategically located samples, especially for some parameters and regions, would be an important contribution to coming developments and assessments. Another added value related to an extended effort to collect appropriate in situ measurements for

[3] See http://eo.ymparisto.fi/data/water/Baltic_SeaLaBio/Deliverables/SeaLaBio_Report_Scientific_Roadmap_v2.1.pdf

validation of EO products is the potential to increase confidence in and acceptance of EO products as appropriate to complement current methods of monitoring of water quality and ecological status.

WHAT CAN ESA SUPPORT WITH A NEW INITIATIVE?

The objective of the current ESA Baltic Regional Initiative is to enhance the use of state-of-the art European satellite missions to support definition and cooperative implementation of regional priorities in the Baltic, in line with national policy objectives in the context of the EU legislation, national legislation as well as the HELCOM framework. We propose to support:

- Definition of parameters and locations for complementary in situ data collection
- Validation of existing open products with publicly available in situ data sets and formulate quality/uncertainty labels for easy access by potential end users
- Further development of EO products that currently have low quality
- Development of new regional products if non-existing
- Review of the temporal and spatial resolutions of provided and developed products
- Production and provision of missing temporal and spatial products
- Discussions and active lobbying to explicitly include EO based environmental data in national and regional guidelines and directives in response to national legislations and European directives
- Devoted training of a critical mass, at all levels, within the Baltic Sea stakeholder group
- Formulation of a recurring revision program to keep products and processes up to date
- And in general, at all stages, to link the efforts by experimentalists, bio-geochemical modelers and the remote sensing community to increase synergy

Despite the many ongoing initiatives discussed above we foresee that there are still missing pieces, i.e. "EO building blocks" to support all R&D needs to fulfill the HELCOM vision. With the list of actions presented above we propose to create the LEGO Baltic Sea Initiative. The LEGO Baltic Sea Initiative stands for the Leveraged use of Earth and Ground Observations for Baltic Sea R&D Initiative. To utilize Earth System Science (ESS), there needs to be possibilities to choose and combine alternative input data, to test different approaches, especially as new findings and knowledge become available. When data from both ground, space and models are collated and combined appropriately, information can be produced that make it possible to take different and new steps to ameliorate undesirable developments, monitor status and trends, and to reach good environmental status. Appropriate "building blocks" of data and information to support different applications and changing end user needs is therefore essential. This is the reason we suggest moving towards a "LEGO" based approach.

In general, products derived from EO data using different methods and algorithms, e.g. for chlorophyll estimation, can be used in models developed for different purposes that produce different output values. No one product or model will satisfy all needs, neither in space nor over time, nor will one solution be accepted by all parts of the Baltic community (political, science, business or the general public), partly because of traditional or institutional barriers. Spatial, temporal and thematic flexibility of information products is needed in combination with guidance sourced from well documented data and data products, and preferably endorsed by an appointed long-term Baltic panel of experts. Work by such a panel could also include establishment of standards (methods and products) and harmonization of metrics to ensure that appropriate comparisons between member states and regions can be done reliably. Consequently, in addition to the actions presented above, the LEGO initiative should bring together experts in monitoring and in situ, EO and modelling, as well as, representatives from e.g. HELCOM working groups and projects, to regularly produce new and revised guidelines to support WFD and MSFD and HELCOM Action Plan revision cycles.

As mentioned above, some areas with missing components could, if filled, greatly advance developments towards the HELCOM vision and global ESS. These include carbon cycling and improved knowledge of the function, structure and health of both ecosystems and socioeconomic sectors. "Building blocks" procured through the LEGO concept could also support the creation of combined bio-geo-chemical models for the Baltic region that takes into account the atmosphere, the terrestrial and marine/freshwater components and utilizes all state of the art remotely sensed products at different spatial and temporal resolutions and in situ data becoming available at a pan-Baltic level as earlier discussed within SeaLaBio. In a broader perspective, outputs from such models could enhance the global carbon budget models and support global monitoring of climate change, adaptation and mitigation efforts.