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# Content

**Abstract**

This document is a description of the assessed utility and impact of the developed BalticAIMS information service products. It is based on the contents D5.1 User Service Utility Report, a deliverable of the initial BalticAIMS project that has been updated with findings from the further developments in the extension phase of the project (CCN-1, active in 2024-2026).

Many of the details come from interviews and meetings with the main stakeholder and user groups within HELCOM, as well as, with national authorities and users in Sweden, Germany, Lithuania and Finland. Specific feedback related to the tasks undertaken by Finnish Meteorological Institute (FMI) with an objective to further develop and provide a demonstration of a sea ice monitoring service based on the use of ICEYE SAR data has also been included.

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 does not assess the success of the developed service against this high-level goal but focuses 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.

The roadmap provides both short and long-term steps toward a sustainable EO based service for the Baltic Sea.

This version has been prepared for public release after the Final Review meeting held on 29th of April 2026.

**Glossary**

| | |
|---|---|
| *BA* | *BalticAIMS* |
| *CCM* | *Copernicus Contributing Mission* |
| *CCN* | *Contract Change Notification* |
| *CDOM* | *Coloured Dissolved Organic Matter* |
| *CHL/Chl a* | *Chlorophyll a* |
| *CLMS* | *Copernicus Land Monitoring Service* |
| *CMEMS* | *Copernicus Marine Environment Monitoring Service* |
| *DeepESDL* | *ESA's Deep Earth System Data Laboratory* |
| *EEZ* | *Exclusive Economic Zone* |
| *EO* | *Earth Observation* |
| *FTIA* | *Finnish Transport Infrastructure Agency* |
| *HELCOM* | *Helsinki Commission* |
| *IdP* | *Central Identity Provider* |
| *IICWG* | *International Ice Charting Working Group* |
| *JNB* | *Jupyter Notebooks* |
| *MSFD* | *Marine Strategy Framework Directive* |
| *MSP* | *Maritime Spatial Planning* |
| *OGC* | *Open Geospatial Consortium* |
| *PLC* | *Pollution Load Compilation* |
| *RGB* | *Red, Green, Blue* |
| *RRD* | *Rapid Response Desk* |
| *SAR* | *Synthetic Aperture Radar* |
| *SMA* | *Swedish Maritime Administration* |
| *SRR* | *System and Service Chain Readiness Report* |
| *SST* | *Sea Surface Temperature* |
| *SVR* | *Service Chain Verification Report* |
| *VHR* | *Very High Resolution* |
| *VTS* | *Vessel Traffic System* |
| *WCS* | *Web Coverage Service* |
| *WFD* | *Water Framework Directive* |
| *WMS* | *Web Map Service* |
| *WMTS* | *Web Map Tile Service* |

# 1 Introduction

## 1.1 Purpose and scope

Work Package 5 of the 1st phase of the BalticAIMS project (active in 2021-2023) delivered the following report:

- D5.1 Service Utility Report

It described the assessed utility and impact of the developed BalticAIMS information service products 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 purpose of ***D5.2 Service Utility Report Update*** is to also document the results of the extension phase of the project (CCN-1, active in 2024-2026), including the extension by FMI of a service on operational sea ice monitoring for the shipping industry based on ICEYE SAR satellite imagery which was not part of the original project. After discussions with the project team and ESA at the SOR, it was decided to merge D5.1 and the additional findings from the CCN-1 into one document to ensure the review of all feedback related to the BalticAIMS service is summarized in one document.

The objective of WP5 in CCN-1 is to document and review stakeholders' additional feedback on the utility, performance level and impact of the EO-based information and services delivered, and if possible, to assess the level of uptake on the stakeholder side. The feedback has been collected through internally arranged BalticAIMS user meetings or through participation and presentations at externally organized stakeholder workshops and meetings as well as through direct email communication with stakeholders.

The following tasks were undertaken as part of WP5 of the extension phase:

- WP 5.2 Service assessment update
    - Review users/stakeholder issues associated with each user story/use case explored in WP4
    - Collate feedback from presentations and meetings on the extended service
    - Find stakeholders willing to make supporting statements for continued services
- WP5.3 Service implementation
    - Explore the possibilities for a long-term operational EO-based Baltic service and suggest implementation actions and solutions.
      Review developments and potential for inclusion/use of BA service in other platforms/projects
    - Generate and publish BalticAIMS Service PowerPoint presentations on project web site

The BalticAIMS CCN-1 did not contain a specific task for identifying user requirements as these had been highlighted in the feedback from the initial project phase and partly served to develop the new use cases.

Several on-line meetings were attended and arranged with additional stakeholders and user groups during the CCN-1 (2024-2026). These included HELCOM expert groups, German research institutes, Lithuanian government authorities, and a French local stakeholder as well as several organizations involved in operational sea ice monitoring for the Baltic Sea winter navigation. Feedback relating to the presentations of the BalticAIMS use cases was sought as to whether such examples could be interesting and add leverage to user workflows. In addition, representatives from Lithuanian EPA and Finnish Environmental experts, and HELCOM secretariat participated in CCN-1 meetings PM3 and SOR respectively.

This report is focused on the feedback related to the products and information provided. The feedback related to technical aspects and service tools is described in D4.2. The BalticAIMS CCN-1 did not contain a specific task for identifying user requirements as these had been highlighted in the feedback from the initial project phase and partly served to develop the new use cases.

The stakeholder feedback received are together with known gaps and bottlenecks relating to uptake and use of EO data used to elaborate updated ideas for future developments in Ch. 0 Roadmap.

All documents will be publicly available at the project website after they have been accepted by ESA: https://www.syke.fi/en/projects/balticaims.

# 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, e.g. via the BalticAIMS Viewer, Tarkka or by integrating the information into their legacy systems using different OGC web map services.

In addition to the assessment of service utility relating to the baseline project the utility of seven new use cases in the extension were assessed. These are described in the deliverable D4.2, BalticAIMS_Report_D4.2_Service_Operations_and_Service_Chain_Performance_Report_Update_V1.1.pdf

This report includes some feedback from stakeholder meeting participating in the original project that are still relevant and in addition it includes feedback from new stakeholder meeting during the CCN-1 that relate to the new use cases. It is focused on the feedback related to data products and information (i.e. spatial and temporal resolution and thematic content) as well as some aspects of service implementation. It reviews links 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 0 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.

**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.

## 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 levels 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 base line project and used in the service demonstrations, targeting each user’s specific interests. These were further expanded in the extension phase of the project to include also Showcase F Operational ICEYE for FMI sea ice service.

The main Showcases and User stories discussed with each user are referenced in Table 1 in the last column with the users/stakeholders. The Showcases (A-F) and User stories are thoroughly described in documents D4.1 (original project) and D4.2 (CCN-1) and the user stories for the latter are listed below by title for reference under the six themes to provide basis for some of the feedback described in section 2.2.

- A: Provide EO based information to be used in user legacy systems for spatial planning
  - Material to support the review of MSP Plans and for Syke & Finland: Regional Councils (RC) updating MSP plans.
- B: Monitor the effects of nutrient flow from the drainage basin to the coastal waters
  - B4: River load monitoring in Finland
  - B5: Eutrophication issues in Curonian lagoon
  - B6: Seine River expansion
- C: Monitoring the impacts of coastal activities
  - C2: Water quality coastal Finland
  - C3: HELCOM dredging & dumping
- D: Combination of Coastal Zone mapping and CMEMS coastal water quality material
- E: Monitoring of temperature anomalies
  - E3: Detection of marine heatwaves
- F: Operational ICEYE for FMI sea ice service

**Table 1. Participating users and stakeholders providing feedback at service assessment meetings, Baltic Workshop (BWS), external meetings and links to relevant showcases. The meetings undertaken with user organisations as part of the CCN-1 are in bold.**

| 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,<br>2023-01-19 (BWS) | SYKE | C |
| **FI** | Ministry of Environment | National | 2023-01-19 (BWS),<br>**2025-09-18** | 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 |
| **FI** | **Finnish Environmental experts involved in river load monitoring and eutrophication** | **National** | **2025-11-10 (PM3)** | **SYKE** | **B4** |
| **FI** | **Winter Navigation unit and icebreaker masters** | **National** | **2025-05-20, online workshop** | **FMI** | F |
| **FI** | **Winter Navigation authorities (FTIA and SMA), Icebreakers, Ice services, pilotage and VTS centers monitoring vessel traffic in the Baltic Sea** | **Finnish, Swedish and Norwegian national** | **2025-09-22to26, presentation to the 26th meeting of the International Ice Charting Working Group (IICWG)** | **FMI** | F |
| **FR** | **Seine River Estuary – Ifremer, LandSeaLot project** | **Local** | **2026-03-02**<br>**2026-04-10** | **BC** | **B6** |
| **GE** | German Environment Agency (UBA) | National | 2022-07-14 | BC | B2 |
| **GE** | **German Federal Waterways Engineering and Research Institute (BAW)** | **National** | **2026-03-23** | **BC** | **C3** |

| Country | User organization | Type of users | Meetings | BalticAIMS partner | Showcases A-E, User stories, e.g. A1 if relevant |
|---|---|---|---|---|---|
| **GE** | **German Federal Institute of Hydrology (BfG)** | **National** | **2026-03-23** | **BC** | **C3** |
| **LI** | **Environmental Protection Agency** | **National** | **2025-11-10 (PM3)** | **Klaipeda University** | **B5** |
| **LI** | **Ministry of Environment** | **National** | **2025-07-24** | **Klaipeda University** | **A1, B5** |
| **SE** | Swedish Agency for Marine and Water Management (SwAM) | National | 2022-09-06,<br>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 people have moved on, no further meeting planned | BG | A, B |
| **HELCOM secretariat** | Special advisor with expertise on MSP and persons from other groups | Regional | 2023-02-27,<br>**2026-03-27, SOR** | SYKE | A |
| **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 |

| Country | User organization | Type of users | Meetings | BalticAIMS partner | Showcases A-E, User stories, e.g. A1 if relevant |
|---|---|---|---|---|---|
| **HELCOM expert group** | EG Eutro (eutrophication) | Regional | 2023-01-19 (BWS) | SYKE | All |
| **HELCOM expert group** | **EG DreDS (Expert Group on dredging/depositing operations at sea)** | **Regional** | **2026-02-23** | **SYKE** | **C3** |
| **HELCOM and others** | **Regional and national organisations interested in detection of marine heatwaves (coop w LandSeaLot)** | **Regional** | **HELCOM: Through email and 2026-03-27** | **All** | **E3** |
| **HELCOM Secreteriat** | **Maps and Data Services (MADS)** | **Regional** | **2025-09-11 2026-04-27** | **All** | **Service implementation** |
| **Europe** | **European Space Agency (ESA), sand extraction** | **Regional** | **2025-01-29** | **All** | **C** |

## 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 use the BalticAIMS services and products, initially with a focus on the user's main tasks and interests, 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. Chapter 4 Roadmap will elaborate on what is now seen as essential both in the short-term and long-term to capitalize on the BalticAIMS developments.

Users and stakeholders have provided different levels of feedback related to the different themes addressed in CCN-1. These include Use for Marine Spatial planning in general with some specifics from the Finnish MSP coordination theme, River load monitoring, Eutrophication of the Curonian lagoon, Monitoring of sediment loads in the river Seine, Marine heatwaves as well as a final subsection on feedback from use of ICEYE data in FMI ice charting services.

### 2.2.1 Use for Marine Spatial Planning

All the Baltic countries had adopted Marine Spatial Plans (MSPs) by 2022. The plans for continuation to make updates (second cycles) and plans for implementation vary between countries. For example, in Sweden the government is still to adopt a proposed amendment to address the need for increased electricity production and the next round for 2030 has not yet started. In Lithuania, responsibility for Maritime Spatial Planning (MSP) is shared among several governmental institutions (e.g., Ministry of Environment, Ministry of Transport and Communications, Ministry of Energy, Ministry of Agriculture, Ministry of the Interior, Ministry of National Defence and they are responsible for different aspects of marine governance, including environmental protection, maritime transport and infrastructure development, and spatial planning and regional policy. Effective MSP implementation therefore requires strong coordination across sectors and institutions, particularly in the context of increasing pressures from infrastructure development and environmental management needs.

In Germany, marine spatial planning for the EEZ is the responsibility of the federal government, implemented through the Federal Ministry for Housing, Urban Development and Building with support from the Federal Maritime and Hydrographic Agency. The current national maritime spatial plan for the North Sea and Baltic Sea EEZ entered into force on 1 September 2021. It coordinates shipping, offshore wind, cables, pipelines, fisheries, research, and defence, while also trying to reduce conflicts and protect marine ecological functions. The responsibility for the 12nm zone is with the individual Bundesländer (Mecklenburg Vorpommern, Schleswig-Holstein, Niedersachsen). Thus, the responsibilities are spread among different administrations. Plans shall be reviewed every 5 years.

BalticAIMS presented the services to the Finnish MSP coordination team on Sep 18, 2025. They were mostly interested in long-term time series which allow the used to see what has been happening and where things might be going. Monitoring areas (e.g. water bodies) was more interesting than rasters. ArcGIS is the main tool, but QGIS is in use also and there was interest in test the plug-in.

Different feedback from contacts with Baltic MSP coordination teams are echoed in the key takeaway messages from a Workshop "Marine Data for Maritime Spatial Planning (MSP)" held in Brussels on March 31, 2026[1], organized by Mercator Ocean International, (MOi)[2], implementer of the Copernicus Marine Service.
One of these were:

> "*Policy Evolution and the "Ocean Act": A major focus was the transition toward a unified "European Ocean Pact" to break down policy silos between sectors like fisheries, energy, and tourism. A key milestone discussed was the upcoming "Ocean Act" (planned for 2026), which aims to modernize the MSP Directive and strengthen cross-sectoral coordination."*

Another takeaway message relevant to the objective of BalticAIMS to facilitate easy access to marine EO data for users in the Baltic region was:

> *"Data Accessibility vs. Volume: Experts noted that while the volume of marine data is vast, the "greatest challenge" remains its accessibility and the "last mile" of making it directly usable for planners and policymakers."*

### 2.2.2 River load monitoring in Finland

Use of Tarkka for monitoring river loads was demonstrated to stakeholders at PM3. They commented that the methods and results are very interesting. The selection of the River Vantaanjoki is good due to its relevance for other projects. The innermost bays are important, and the project is requested to continue working towards providing EO estimates also from those. Halikonlahti Bay is another supersite, and it would be good to include that in future analyses. The catchment of the Archipelago Sea in South-West coast of Finland is the last HELCOM hotspot remaining in Finland and focus on that area is needed. In that area clay soils dominate, and the largest part of riverine phosphorus load is bound to clay particles. Remote sensing could be used in finding the most critical areas in regard to leaching of suspended solids and phosphorus. On the other hand, in peat dominated nitrogen rich catchments in Central and Northern Finland remote sensing could be used to find hotspot areas of humic substances leaching. HELCOM is planning a renewal of hotspot areas which may lead to new areas being defined.

### 2.2.3 Use for Eutrophication issues in the Curonian lagoon

The Curonian Lagoon is shared by Lithuania and the Russian Federation, representing the largest coastal lagoon in Europe. The lagoon is a transitional water body between the south-eastern Baltic Sea and the watershed of the Nemunas River, which is one of the largest river systems in the south-eastern Baltic Sea and contributes most of the water, sediment, and nutrient loads to the Curonian Lagoon. The Nemunas River is one of the four most important rivers in the Baltic Sea region and the main freshwater input, discharging nutrient-rich waters in the central part of the lagoon. The Nemunas river and the Curonian Lagoon are considered as active HELCOM hotspots (see MADS, https://maps.helcom.fi/website/mapservice/). Intensive management of aquatic environments is required, particularly with regard to nutrient concentrations and loadings, which play a key role in eutrophication processes. In this context, Earth Observation (EO)–based data products provide valuable support by enabling consistent, large-scale, and frequent monitoring. For this reason, biogeochemical products from the Copernicus Marine Environment Monitoring Service (CMEMS) were evaluated for their applicability.
A takeaway message from a meeting with the Lithuanian Environmental Protection Agency was *"A comparison between in situ measurements and CMEMS-derived data showed good to moderate agreement, with $R^2$ of 0.56 for $PO_4$, 0.46 for $NO_3$, and 0.41 for $NH_4$, with evident underestimation in spring and summer. These results indicate that, while the CMEMS products show potential, regional tuning and calibration are necessary before their operational use and integration into the service."*
The hypertrophic state and recurring harmful algal blooms were primarily driven by intensive external nutrient loading throughout the twentieth century. In response, a range of restoration measures have been implemented, with a strong focus on improving overall water quality. These efforts have included significant upgrades to wastewater treatment infrastructure, leading to a substantial reduction in point-source pollution. In parallel, nutrient inputs from the Nemunas River watershed have been reduced through decreased fertilizer use in agriculture and stricter controls on industrial discharges.
Together, these measures have contributed to lowering nutrient loads entering the system, although the long-term recovery of the ecosystem remains a gradual and ongoing process and therefore requires comprehensive data sets

[1] Minutes of the Marine Data for Maritime Spatial Planning Workshop
[2] https://www.mercator-ocean.eu/

and information on the status. Another takeaway message from the meetings with Lithuanian stakeholders and representatives from the Ministry of Environment was: *"EO-based information supports improved coordination across countries and facilitates more effective implementation of eutrophication mitigation measures. Its application is particularly beneficial in complex transboundary environments, where traditional monitoring alone is insufficient to ensure timely and comprehensive assessment."*

### 2.2.4 Use for Seine River monitoring

The project team presented the xcube viewer and HR-OC processing done in 20 m resolution (instead of the nominal 100 m) to researchers from Ifremer[3] who are monitoring the Seine River. The stakeholders noted the usefulness of the product and commented how well the EO results were able to represent the actual characteristics of the river and its estuary. They were interested in receiving additional EO based materials from the area as well as modelled data. Ifremer is currently working on finalizing their models and would like to integrate them in the viewer as well. Further, in-situ data from permanent measurement stations along the river could be integrated and visualized together with the EO and modelled data in dedicated time series plots. BC will continue the collaboration within the context of the HEU LandSeaLot project[4].

### 2.2.5 Heatwave tool, dredging, sand extraction

A new tool has been developed that visualizes Marine Heatwaves (MHW) in the Baltic Sea. The data sources are L4 gap-filled EO SST products provided by the Copernicus Marine Service**Virhe. Viitteen lähdettä ei löytynyt.**. The products are used for the generation of temperature climatology, which includes values for each day of the year and covers the Baltic Sea with 2 km resolution. The Marine Heatwaves are detected for a selected year by comparing temperature values with the climatology. The user can draw a yearly Heatwave graph for a selected point or area of interest. There are two demonstration years implemented (2018, 2024) and the service is publicly available (https://mhw.viewer.brockmann-consult.de/).
The tool is based on the xcube viewer and uses chartlets (https://github.com/bcdev/chartlets) software framework. Chartlets is a software framework that allows extension of the xcube viewer by server-side UI contributions and has been developed by Brockmann Consult.
The MHW tool is still under development. The work is performed in cooperation with the EU LandSeaLot project. The MHW Tool has been demonstrated to HELCOM and SMHI (partner within LandSeaLot). Both expressed interest in the tool and discussed potential applications. We were also contacted by BSH who want to get a demonstration of the tool which might be integrated in one of their projects.

For dredging activities, a meeting was held with BfG and BAW (Germany) who also work with the topic. The results from satellite data (for now only RGB visual investigation) where compared to model output for the dedicated days that dredging activities could be seen in the images. The overall agreement was good, and it is now investigated how close in time the data need to be acquired to monitor the effects of dredging. BAW is very interested in using the data for their model evaluation, though the model resolution is much less than the 10m Sentinel-2 spatial resolution.

Feedback from the demonstration of the usefulness of EO products (RGBs and turbidity) to monitor dredging activities (an example from the Gdynia Bay) to the HELCOM expert group (EG DreDS) included noting that time series can support monitoring of legal dredging activities relating to extent and locations. Such products can also help to determine activities outside recommended/regulated dredging times (e.g. May-October) as well as detecting illegal dredging although availability of automated and validated methods would be needed to support operationalisation. In addition, it was pointed out that both spatial and temporal components are important and should be considered in relation to dredging, e.g. where, how many, how often (cumulative effects), as such knowledge can affect the view on new or extended dredging permits.

Sand extraction was identified as a potential topic at the beginning of the CCN-1 and a meeting was held with an ESA representative. The effects of sand extraction from an EO point of view are very similar to those from dredging. A separate user story was not developed, however the dredging case shows how this application can work, e.g. for detection of illegal sand extraction.

[3] https://www.ifremer.fr/en
[4] https://landsealot.eu/

### 2.2.6 Use of ICEYE data in FMI ice charting services

FMI extended a service on operational sea ice monitoring for the Baltic Sea winter navigation based on ICEYE SAR satellite imagery. With its high spatial resolution and multi-temporal images, ICEYE data allows for better monitoring of sea ice drifts and classification of sea ice, which is important for sea ice navigation and other offshore operations in and on ice. The ICEYE service extension is focusing on the Baltic Sea area and data provision to the winter navigation operation is ensured through IBNet, which is the official situational awareness portal for the Swedish and Finnish winter navigation. The user consortium includes Winter Navigation authorities (FTIA and SMA), Icebreakers, Ice services as well as essential parts of the pilotage and VTS centers, who monitor vessel traffic in the Baltic Sea.

The ice monitoring service based on ICEYE data is developed in close collaboration with users from Finnish icebreakers. On May 20th, 2025, an online workshop with representatives from the Winter Navigation unit as well as icebreaker masters was held to present the new ICEYE capabilities in sea ice charting. Additionally, the service had been presented at the 26th meeting of the International Ice Charting Working Group (IICWG) meeting held in Tromsø, Norway hosted by the Met Norway Ice Service, September 22-26, 2025.The ICEYE development was introduced to the operational ice service personnel with some interesting discussions with the researchers and ice analysts. It was found that the major advantage of ICEYE for ice analysts is the good temporal coverage of certain AOI: ICEYE can cover the same area with a temporal gap of only some hours and unlike the operational C-band instruments only able to capture morning and evening imagery, ICEYE data covers the different times of day.

Vessels can directly access all relevant information on their ship bridge with IBNet, which supports captains and personnel in charge of vessel assistance in ice. As this system is an established well known Nautic portal, easy access to that data is ensured. Besides general nautical charts and weather information, interactive map access, this service includes various satellite-based information on ice conditions. By embedding the new ICEYE-based sea ice products into the system, the usability and quality of the new service features could be tested and assessed by the relevant stakeholders. Furthermore, ICEYE images were embedded and tested through including them in the manual ice charting analysis in the Finnish Ice Service's ice charting software Vanadis.

## 2.3 Service utility and impact assessment

The BalticAIMS service is open and provides entry 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 and could hence only be done in a limited experimental way during the lifetime of the current project. 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 adopted 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.

In implementing ICEYE imagery to the winter navigation operation, users emphasized the advantage of the IBNet ICEYE interface in offering tailored waypoints to single vessels and updating these based on fresh imagery. These sea ice images are useful to identify moving ice floes and open water areas during winter conditions. The high spatial resolution of ICEYE data significantly improves the existing ice charting datasets and maximizes the information content. To achieve the full capability of those datasets, noise reduction in the images is important for the users. Images with good contrast balance are easier to interpret, and ice ridges can be identified. In general, the gray-scale image shows the most important information and should work as the primal information source. Nevertheless, users mentioned some specific desired features of the system’s ice chart representation, such as customized color coding. Certain forms of ice could be assigned dedicated colours, such as areas of deformed ice, single heavy floes, and ridges. Since the project development focused on new products on ice classification and ice drift, it addresses these user requests and offers a real added value in sea ice monitoring and the shipping industry.

According to user feedback within those two workshops, there is currently no urgent need for ice chart predictions or forecast systems. To facilitate ICEYE data for an operational service on sea ice information, emphasis should be put on a flexible data order mechanism and stable data interfaces to ensure an operationally functioning provision of sea ice imagery and to minimize undesired delays in delivery. This way, the strength of the large ICEYE constellation would provide effective gap filling for time windows when other SAR imagery, like Sentinel-1, are not available.

Overall stakeholders from the navigation industry appreciated the new developments on high-resolution ice monitoring. Due to less stable winter conditions, changing climate in the Nordics and its effects on winter navigation, there is an increasing need for detailed and tailored information on sea ice conditions.

### 2.3.1 Product information aspects

This section is focused on feedback related to the updated EO based products listed in Table 2, which are provided by the BalticAIMS service**.** All products were included in the BA data cubes and accessible to Users via the BA viewer, OGC web services and/or Tarkka. The product generation is described in deliverable D2.3 of the baseline project. A special focus during CCN-1 was put on the development of a QGIS plug-in that enables the integration of data cubes (zarr files) into QGIS.

The table below provides an overview of the **extension of the data sets we performed during CCN-1.** Additional data cubes include the entire Baltic Sea (2 km coastal), the German Bight and the River Seine, as well as extension of time series to cover recent years and addition of some daily/5-daily temporal aggregation.

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. Data cubes added and temporal extents that have changed during CCN-1 are highlighted in bold.**

| Parameter | Spatial resolution | Spatial extent | Temporal aggregation[5] | Temporal extent |
|---|---|---|---|---|
| **S2 images used for RGB** | 100 m | Finnish Cube<br>Gotland Cube<br>Mecklenburg-Vorpommern Cube<br>**Baltic Sea Cube incl. Kattegatt** | daily<br>daily<br><br><br>**daily** | 2020-**2024**<br>2020-2022<br><br><br>**2020-2025** |
| **Turbidity** | 60 m | Finnish Cube<br>Gotland Cube | daily | 2016-2021 |
| | 100 m | Finnish Cube<br>Gotland Cube<br>Mecklenburg-Vorpommern Cube | monthly, daily | 2020-2022 |
| | 100 m | **Baltic Sea Cube incl. Kattegatt** | daily | **2020-2025** |

[5] 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.

| Parameter | Spatial resolution | Spatial extent | Temporal aggregation[5] | Temporal extent |
|---|---|---|---|---|
| | 20 m | **Seine, France**<br>**German Bight** | **daily**<br>**daily (for each overflight)** | **2021-2022**<br>**2015-2023** |
| **Sea Surface Temperature** | 100 m | Finnish Cube | daily | 2018-2022 |
| | 1 km | Finnish Cube<br>Gotland Cube | daily | 2017-2021 |
| | 2 km | Baltic Sea Cube incl. Kattegatt | daily | 2019-2022 |
| **Chlorophyll-a** | 100 m | Finnish Cube<br>Gotland Cube<br>Mecklenburg-Vorpommern Cube | monthly, daily | 2020-2022 |
| | 100 m | **Baltic Sea, incl. Kattegatt** | **daily, 5-daily** | **2020-2025, 2021-07-2021-09** |
| | 20 m | **German Bight** | **daily (for each overflight)** | **2015-2023** |
| **Suspended particulate matter** | 100 m | Finnish Cube<br>Gotland Cube<br>Mecklenburg-Vorpommern Cube | monthly, daily | 2020-2022 |
| | 20 m | **Seine, France**<br>**German Bight** | **daily, 5-daily**<br>**daily (for each overflight)** | **2021-2022**<br>**2015-2023** |
| | 100 m | Baltic Sea Cube incl. Kattegatt | daily | 2020-2022 |
| **Algae index (cyanobacteria)** | 300 m | Finnish Cube<br>Gotland Cube | daily | **2020-2024** |
| | 60 m | Finnish Cube<br>Gotland Cube | daily | **2018-2024**<br>2017-**2024** |
| **Corine land cover national** | 100 m | Finnish Cube<br>Gotland Cube<br>Mecklenburg-Vorpommern Cube | ~every six years | 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 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 at local, national and regional organizations. It has also been stated that the data must be possible to import and include in the users' existing systems to increase the usage of EO products at all levels, for example via API or different web mapping services.
The CMEMS coastal products (HR OC) are showing some striping effects, especially in the chlorophyll products. An update end of 2025 improved the products, but not all striping effects are solved. There will be another product update in 2026, and a new chlorophyll algorithm based on ML will be implemented further reducing the striping.

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

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 the 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 provides 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 user's 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 data time series and values for their locations of interest in their GIS software. This was only possible for layers served with an OGC WMS with a time dimension and not yet possible for OGC WMTS layers. Therefore, a dedicated QGIS plugin was developed to integrated data cubes (zarr files). This enables the users to work with the real data and perform the analyses together with their own data layers.

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 well as the usefulness of the ice products. These are 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 colour 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 analyse the effects of the activity in the coastal environment, which makes it an attractive parameter for many applications. Analysis of detailed structures are of interest in respect to dredging or sand extraction.

**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. Further, marine heatwaves are subject of several investigations concerning the ecological effects and in terms of climate change.

**Sea Ice** products such as segmentation, degree of deformation, sea ice thickness and sea ice drift are important for the ice charting and icebreaker organisations. However, no additional parameters from the ICEYE data than the basic backscatter image have yet been implemented in the operational process. In order to convey classification and segmentation products to the end users' desktops, further refinement and specification is required.

In addition to the 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.

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, corresponds better to most local requirements, which means that the current products do not fulfil all users' needs and all applications. It has been stated that, for a Baltic wide service 100 meters resolution might cover a majority 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, 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.

*"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*

*"This is exactly what we are looking for" – related to the heatwave tool by a HELCOM colleague*

Within the present service, the EO products have been provided and demonstrated in different **formats** using the generated data cubes as backend and then made accessible to Users via the BalticAIMS Viewer, OGC 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. **Quality and other limitations** of the products are important information and should be provided for 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 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 monitoring and planning for coastal activities and mitigation 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 BalticAIMS EO-based products in QGIS and ArcGIS/ArcMap are deemed essential.

### 2.3.2 Service implementation aspects

The possibilities for a long-term operational EO-based Baltic service were assessed by discussing with several stable organisations and initiatives such as HELCOM, BalticEarth and Syke (Tarkka). In addition, activities and results of other projects and initiatives involved in providing EO based information were explored, e.g. EO-BALP[6], the EO Baltic platform for governmental services in the three Baltic countries, i.e., Latvia, Estonia and Lithuania (2023-2025). The goal of the EO –BALP project was to demonstrate the practical use of satellite data in six different domains (e.g., Agricultural and Land, Forest, Infrastructure and settlement, Water quality and Maritime monitoring) using a cloud service to allow for efficient data access and processing.

Tarkka and the BalticAIMS service and products have presently been developed and implemented external to 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, and their tools and applications. 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 future development steps.

In addition, major revisions and assessments related to, for example MSPD and WFD are coming up in several countries within the next few years. While not occurring during the BalticAIMS 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.

The use or integration of BalticAIMS products, which provide better spatial and temporal resolution than is currently in use, there is potential to improve the MSP process and information base, but this has currently not been thoroughly assessed in terms of actual implementation.

There may be additional platforms that perhaps could be considered to inform or facilitate access to the BalticAIMS service and products. As outlined in the workshop in Brussles on March 31, 2026 – Marine data for MSP mentioned in section 2.2.1, there are now a number of platforms that aim to provide information products and tools for MSP activities, such as EDITO[7], EMODnet[8] as well as Copernicus Marine Services[9] including Ocean

[6] EO-BALP – https://www.baltsat.lv/products/eo-balp/
[7] EDITO – https://www.mercator-ocean.eu/ocean-intelligence/the-digital-twin-of-the-ocean/the-european-digital-twin-of-the-ocean/ and EDITO Lab https://datalab.dive.edito.eu/
[8] EMODnet – https://emodnet.ec.europa.eu/en
[9] https://marine.copernicus.eu/

Monitoring indicators (OMIs). Another example shown was PlanBleu[10], whose mission is to be a Mediterranean cooperation area for sustainable development and includes the facility to link project results to their platform.

The ordering process of ICEYE imagery is the same as for the other Copernicus Contributing Missions (CCM's), except that the scenes can only be ordered up to 2 weeks in advance, so orders must be made more frequently. First, an order form is filled in the order management system and afterwards the ordering process continues in an email chain. Based on a tasking feasibility check sent as an email attachment, the suitable scenes are chosen and then ordered by replying to the email, and later the availability and possible cancellations of the scenes are also communicated in the same email chain. From ICEYE, the tasking feasibility is usually received rather quickly. The process has been generally working well, and filling out the order form is easy. Still there have been some issues with the order form parameters and contents of the kml-format feasibility overviews, but the user support desk has been able to help with these. Ultimately, choosing which scenes to order is the most time-consuming part of the ordering process, and the time spent on this could be reduced by developing scripts that combine and visualize data in the feasibility reports from different CCM's, however this is made more challenging by the non-uniform structure of the data files.

[10] PlanBleu – https://planbleu.org/en/

# 3 Outreach activities

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 online. 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 including Finnish ELY-centers, regional councils, Ministry of the Environment and City of Helsinki as well as the Swedish Agency for the Marine environment (SwAM) and members of HELCOM groups (State and Conservation, EG-EUTRO and PLC-8). The workshop agenda included presentations by different BalticAIMS team members covering the BalticAIMS system, application examples and the Roadmap. 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 online. Actual hands-on was also offered at the venue. The interfaces demonstrated included Tarkka, BalticAIMS Viewer and QGIS.
The feedback from the workshop 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 fulfil 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. Having 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 fulfil any user needs is of no use. Parts of this have been addressed by the CCN-1 work.

Instead of organizing a second workshop during the CCN-1 to demonstrate results it was decided to create PowerPoint presentations to inform users and demonstrate the further development of the BalticAIMS extension. These will be available on the BA website, https://www.syke.fi/en/projects/balticaims, after the conclusion of CCN-1. These will be advertised to Users and stakeholders so they can view these on their own and contact us if/when needed.

# 4 Roadmap

The purpose of this roadmap is to outline the steps that allow the developed tools and service infrastructure to continue to serve the diverse Baltic Sea MSP and water quality monitoring community in a sustainable manner. The roadmap is an updated version of the one provided in D5.1 factoring in the technical developments performed during the extension and changes that have taken place in other services, common European research infrastructures, organizations and policies relevant for BalticAIMS services since the end of the baseline project in 2023. Since the extension phase of BalticAIMS was able to solve many of the remaining technical issues (see D4.2) and the basic service elements are ready for scaled-up service operations the main questions still 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?

As before, we provide below both short-term and long-term steps and perspectives. Short-term developments are important to ensure continued user access to the developed EO products and services. Long-term actions ensure that the developments and results of the BalticAIMS project are appropriately utilized and reach operational status. This includes securing funding as well as determining suitable host platform(s) for the data and services.

The ICEYE SAR based sea ice monitoring topic is not part of the long-term roadmap as the service chain from satellite acquisition to the desktop of the user is already established. However, the technical data access issues described earlier remain to be solved and there are ideas for further improvement of the data processing (chapter 4.4). Automated ICEYE data products could be included in the Copernicus Marine Service sea ice products. Also, there are plans to integrate the automated Copernicus Marine Service products in the ice charting process such that the ice analysts can use the automated analysis as a starting point of the analysis.

## 4.1 Short-term needs for BalticAIMS service continuation

Service upkeep

The obvious first step is to keep the current services running so that the users do not experience a gap in service availability. This requires funding for the servers hosting the data cubes and xcube viewer and occasional service maintenance (security updates etc.). This service as it is deployed on EarthCode/DeepESDL and an operator from BC, requires about 750 - 1000 € per month (JupyterHub not included but offered on request and extra funded). Tarkka is being developed in other projects and will remain online. However, additional funding for the BalticAIMS topics would allow further development based on user needs described below.

Service expansion and generalization

While the service systems are considered ready for a scale-up further technical system improvements and development of additional thematic use cases and user stories are useful for attracting additional users. Discussions with stakeholders have led to previously unknown needs (e.g. the Marine Heatwave topic by HELCOM), or collaboration between projects (e.g. the Seine River topic with the LandSeaLot project).

The current modular service architecture allows additional datasets to be conveniently added to the data systems although effort is needed to convert the data into a format suitable for ingestion into the cube or other systems. Sometimes (e.g. the Marine Heatwave case) the development of an additional user interface is required.

Current unimplemented ideas include:

- Generation of a Marine Heatwave pressure map requested by HELCOM. This would involve processing of climatology data to find locations and spatial and temporal extent of heatwaves within a time period of interest and compiling a map about the results.
- Adding in situ and model data to xcube viewer for the Seine River user story.
- Support for dumping model validation by providing EO data with 20 m resolution.
- Improve and expand the river load monitoring use case
- Improved connection to EMODnet, possibly bi-directional.

Joint ESA-EC Earth System Science Initiative – EC LandSeaLot project

The Join ESA-EC Earth System Science initiative is a strategic partnership between ESA and DG-RTD fostering an ambitious European and international scientific collaboration between ESA's FutureEO / Earth Action and EC Horizon Europe. In January 2026, as part of the EC LandSeaLot (LSL) project, an ESA-LSL workshop took place in the context of this initiative. The BalticAIMS project was among the projects from ESA's Ocean Science Cluster. BalticAIMS has already started a small collaboration on the Seine estuary, which is one of the LSL Integration Labs.

A continuation and expansion of the initial collaboration was considered very valuable. As already mentioned in the previous paragraph, at least adding additional data to the BalticAIMS system is needed, but possibilities to address real science questions in the Seine and other LSL Integration Labs would be feasible.

Further technical developments

The following technical developments would further improve the services:

- Improving the FAIR-ness of the data. This requires effort to make the datasets (and services) Findable (metadata available in suitable repositories), Accessible, Interoperable and Reusable.
- Further automation of data ingestion from various sources.
- Operationalisation of QGIS plug-in (easier install).
- 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 pre-processed data, and further developments can provide the users with the opportunity to not only analyse but also to modify the data.

In summary, the current services can remain online with small amount of funding (X € per year). The funding required for further service development and eventual up-scaling varies depending on the number of development cases and is more difficult to estimate accurately.

## 4.2 Long-term needs for sustainable services

Since the main technical roadblocks have been solved, and service upscaling is possible the remaining questions are related to the organization structure and funding base of the services. The service upscaling can start slowly, but should eventually provide useful information for a wide user base including the following organizations:

- **HELCOM** and its working groups, e.g. AGRI, VASAB-MSP, State and Conservation, Pressure (PLC) and different data and expert groups (e.g. Dredging, Eutrophication).
- **National monitoring authorities** are performing monitoring and management activities in the context of European directives (MSP, MSFD, WFD, etc.), regional obligations (e.g. providing data for HELCOM HOLAS assessments) and national legislation (e.g. managing and using data collected through statutory monitoring by industry).
- **National councils and MSP authorities** concentrate on the planning activities and monitoring the effects of human activities on the aquatic environment.
- **Local authorities,** e.g. in coastal cities, manage and monitor the status of their coastal areas and participate in planning activities. The scope of their information needs is typically limited to the immediate area but can require higher resolution than available through free and open satellite data sources.

In Finland many national and local authorities are already using Tarkka. One of the main reasons for this is that it is free to use (Syke takes care of the upkeep and development costs through projects and government funding). A common obstacle, at all these levels, for the continued use of service systems which are not funded by public sources is the availability of funding in the current economic situation. System development work can typically take place only through external (project based) funding. There is often cost-saving collaboration between the different stakeholder levels when it comes to collection and use of in situ data. Costs related to the servers hosting the data and services are small compared to the personnel costs required for handling the data for ingestion and development of user tools so the aim should be to ensure similar use of EO based materials as cost efficiency can be maintained by maximizing the use of the same datasets for many purposes. Differences in user requirements may affect the service provision so it is necessary to harmonize the requirements in consultation with the stakeholders. We do not see this as a big obstacle anymore.

Similarly, it is more cost effective to provide the services through an existing organization structure instead of building a new one. Based on our analysis, the potential host organization should be:

- Interested in finding solutions to a multitude of problems affecting the Baltic Sea
- International in scope, but closely linked to countries surrounding the Baltic Sea
- Capable of handling the coordination required by the service (the technical service provision and development can be outsourced)

Such a central well-connected organization would be ideal for expanded service uptake also by national and local stakeholders, and for expanding the use of the systems beyond the Baltic Sea area.

The only organization with those characteristics operating in the Baltic is HELCOM. It plays an important role as being the organization that joins efforts and actions by all the member states. The needs of HELCOM encompass data and information scaling from full 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. HELCOM operates a Map and Data Service (MADS) which hosts a variety of datasets. Thus, they are already experienced in providing data services.

Theoretically collaboration with EU level services such as Copernicus Marine, EMODnet, EDITO, and JERICO-RI[11] could also be considered. Operational services like Copernicus Marine and EMODnet are essential foundations for MSP and environmental monitoring of the European sea basins. Emerging technologies like the European Digital Twin of the Ocean (EDITO) are likely to be able to provide "what-if" scenario testing for decision support. However, there would be an advantage if the focus is on the Baltic rather than European level to ensure leverage of the specific developments of BalticAIMS.

As a summary we see two options for organizing (and funding) continued services:

- Find a willing host for the services and arrange a public funding source to keep the services free for users. Then launch a large service after upscaling had been performed. HELCOM would be the obvious choice for a service operating in the Baltic Sea. A European level host would be suitable for EU wide services.
- Continue current services through collaboration with other projects and slowly expand the capabilities until a more sustainable solution is found. This is already partly taking place e.g. with the LandSeaLot project. The downside of this option is that the scale of the services would be more limited and at least partly dependent on the interests of the project(s).

## 4.3 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 late 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 are well 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. In fact, BG is coordinating an ESA SUP (Sentinel Users Preparation) project AQUATIME (with Syke and BC among the partners) and BC is coordinating HEATWISE project under the same programme (Syke as a partner). AQUATIME[12] is developing algorithms for CHIME and LSTM to derive novel phytoplankton

[11] Jerico-RI – https://www.jerico-ri.eu/
[12] AQUATIME – https://eo4society.esa.int/projects/aquatime/

information products for improved understanding of aquatic ecosystems and biodiversity while HEATWISE is developing urban products using the same instruments. These projects will end before the launch of the satellites, but they will have contributed important information regarding the potential and limitation of these sensors which will be interesting also to the Baltic stakeholders.

- **CHIME**: Copernicus Hyperspectral Imaging Mission for the Environment (first launch estimated to be in 2028). The CHIME mission carries 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 functional 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 (first launch estimated to be in 2029). The CIMR mission will 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 (first launch estimated to be in 2027). The CO2M mission will 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 (first launch estimated to be in 2027-28). CRISTAL will 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, in the longer term, would 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 (first launch estimated to be in 2028). The LSTM mission will 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 also to 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 (first launch estimated to be in 2028). ROSE-L will 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.

## 4.4 Sea ice monitoring service

For the sea ice monitoring theme, the service has already been established and the purpose of the development done in BalticAIMS was to allow ICEYE data to be added as a new data source. Hence, the is no need for a specific roadmap towards sustained service similarly to the water monitoring theme outlined above. Nevertheless, there are steps that must be done to fully use ICEYE data in an operational service and can be done to further improve the scope and usefulness of the service.

Must be done:

- **Automate the data transfer**: At the time of writing the current access method to data does not support an operational service (see section 2.3.2).
- **Establish a permanent quota for ICEYE data**: ESA had granted BalticAIMS a quota of images to be used for the service and algorithm development steps.

Could be done:

- **Development of an automated machine learning (ML) approach to support the sea ice analysis**
    - The tool would be based on the ML-based Copernicus Marine Service Baltic Sea ice mosaic products providing segment-wise SIC. SIT, and degree of ice deformation information over the whole Baltic Sea based on C- and X-band SAR imagery, microwave radiometry and other available EO data. Part of these products are still under development. After all the products have been integrated into the Copernicus Marine Service the data are used to derive polygons from the data segments. The automatically provided polygons will have ice parameters assigned to each polygon and this information can then be used in the ice service as a starting point for ice chart drawing. This will aid the manual ice charting, and the ice analyst work will be to check, correct and update the automated products.
- **Expansion of the service to other areas**: It is possible to extend the service coverage to other areas where sea ice is present, such as the Arctic Sea. In addition to getting access to more data, this would require the verification of the algorithm (and possible tuning based on the verification results) in the new area.