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Contents

Abstract

This deliverable describes the user requirements for the BalticAIMS information service. The user requirements are based on interviews of the main stakeholder and user groups in HELCOM, Sweden, Germany and Finland. The description includes the determination of information requirements, associated information delivery performance requirements and system interface features for each of the use segments identified. In addition, the requirements and implementation approaches for information analysis and fusion are described.

Glossary

CDOM	Coloured Dissolved Organic Matter
Chl a	Chlorophyll a
CMEMS	Copernicus Marine Environment Monitoring Service
EO	Earth Observation
HELCOM	Helsinki Commission
ICES	International Council for the Exploration of the Sea
LEP	Landesraumentwicklungsprogramm (spatial planning programme)
LSTM	Land Surface Temperature Mission
MERIS	Medium Resolution Imaging Spectrometer
MSP	Maritime Spatial Planning
TSM	Total Suspended Matter

1 Introduction

The objective of this document is to specify the user requirements for the BalticAIMS information service. This includes the determination of information requirements, associated information delivery performance requirements and system interface features for each of the use segments identified. User requirements were collected by interviewing the main stakeholder and user groups in HELCOM, Sweden, Germany and Finland, and reviewing relevant documents and websites. The persons interviewed represent experts in agricultural/land use impacts on coastal waters or coastal activity in national maritime spatial planning, monitoring and marine management and relevant HELCM group chairs and co-chairs.

Based on the user and stakeholder interviews, we identified five showcases to demonstrate most of the relevant combinations of EO materials and user interest related GIS and model material. These will constitute the contents of the BalticAIMS demo area material and will be available for the users and stakeholders to evaluate during the service provision (WP4, starting in spring 2022). In addition, we have defined data access and processing performance requirements and the requirements and implementation approaches for information analysis and fusion for these showcases.

See D1.1 User Segmentation and Operational Practices Review for background information and more details about the users and their working practices related to terrestrial and maritime spatial planning. Together these two documents are used as input in the follow-up WP2 Service Chain Specification and its deliverables.

2 Information requirements

2.1 Summary of main information requirements

The user interviews provided good insight for the current state of the user and stakeholder plans for forthcoming actions in land-sea interactions and terrestrial and maritime spatial planning. It provided not only good background for the service provision phase, but also lots of new and inspiring ideas on how EO datasets can be taken in use in various practical cases related to management and planning of coastal water and land areas. Furthermore, the overall conclusion from the user interviews is that the initial plans about the service provision made in the tendering phase were pointing to the right direction. For example, there are users who want to integrate the information provided by the BalticAIMS system to their own information systems and users that prefer to utilize a web map interface based on e.g. TARKKA interface or other similar services.

Much of the requirements and wishes by the users and stakeholders can be accomplished by either providing existing EO material and combinations of current material and other information sources, like GIS, information in databases and summaries made from them. As an example, currently lacking information related to the water quality in coastal waters, its changes and land-sea interactions can be further derived from spatial and temporal variations and combinations of EO turbidity, Chl-a and temperature. In spatial planning work, much of the information gaps in current working practices can be identified even with a selection of individual representative RGB-images for each relevant season. As an example, human impacts nearby cities are manifold, but identifiable in combinations of RGB and GIS material relevant for the plans.

Despite of the long-term work related to pressures and determination of drainage basing to coastal water quality, the current material of human impact and in particular nutrient loading (both internal and external) still has gaps. EO datasets can increase the existing information in the long perspective. This applies to some part of the human pressures and drainage basin related (agricultural) pressures to the coastal waters. As a long-term plan, many of the summary materials now combined from point sources and are combined as Baltic Sea wide summaries for HELCOM, can benefit from spatially and temporally comprehensive material. Some of these Baltic-wide requests are more long-term development but may well be demonstrated in BalticAIMS demo areas that are very representative for this purpose.

The users and stakeholders interviewed so far consist on two types of users: some have already been utilizing EO data and thus have a clear picture about the possibilities offered by EO for their future work. The other group has not utilized EO datasets and is not yet able to specify requirements in detail. However, both user groups are highly motivated and devoted to follow the progress of BalticAIMS during the project. There is a clear tendency in users' increasing ability to utilize new types of data sources. This is related to the ongoing digitalization and its possibilities. E.g., many of the experts are already accustomed to utilizing open data sources provided by other national and international organizations through OGC services. This makes it very straightforward to start utilizing EO data layers that are available in machine readable and easily accessible sites.

For the users who are not yet familiar with EO data, it is often not very straightforward to accurately define in advance what EO based material they would like to see and utilize in their forthcoming work. Thus, it will be necessary to iteratively go through the details of the specific user requirements during the service specification and implementation phases (WP2 and WP3). This concerns for example the complementary GIS-material and layers included in the final datasets of each showcase determined in WP1. We also foresee that the service delivery phase (WP4) will require interactive sessions for analysis and iterative processing of EO and GIS data combinations together with users.

We defined five showcases through which the possibilities provided by the BalticAIMS service will be demonstrated. In this document the requirements of the showcases are presented at a broader level. It is necessary to further define the technical requirements together with the users in WP2 and WP3 of the project.

The user interviews were made with respect to the two main use cases: agriculture and coastal activity mapping. Altogether, about 20 interviews with a more that 35 experts and stakeholders were conducted. The main information needs are summarized in Table 1. Within both themes, interesting new ideas were raised up. The

stakeholder and user requirements for the two use cases have clear synergies, and some of the EO materials (Table 2) suit well for the purposes of both use cases. However, there are some clear differences that may be practical to demonstrate as their own cases during the service delivery.

2.1.1 Information needs for Use case 1: Agriculture and land use practices

Summary of information requirement from users dealing with follow-up of agricultural practices and land-sea interaction projects:

- Many information requirements are related to creating linkages with existing information on nutrient flows to coastal waters and its changes both in seasonal and interannual scales.
- It is relevant to
    - define natural background levels to be used in different assessments and action plans.
    - separate human impact and natural background raised up in many interviews.
- Linking land-use changes and changes in coastal water quality are of high interest and results related to these can be taken in use in user and stakeholder work.
- Linking wetland and wet forest restoration efforts to retention of water on land and thereby reducing run-off and limiting pollution, by assessing soil moisture and vegetation changes.
- The recent summary report from HELCOM pressures—group (https://helcom.fi/helcom-at-work/groups/pressure/) highlights well the importance of the demonstration areas chosen in BalticAIMS and a suggestion was made to make a demonstration of comparing the output summaries of the report (statistics) to the coastal water quality.
- Turbidity, algae blooms, temperature, and transparency of the water are useful and linked with ongoing actions related to nutrient load and land use practices in the demo sites 1, 2& 5.
- Spatio-temporal changes both in turbidity, algae and temperature are relevant.
- Intercomparisons between the years and areas are vital.
- Interlinkages between the nutrients and EO observations of turbidity.
- Hotspot on cyanobacteria blooms, nutrients and long-term monitoring of these (seasonal, annual and permanent changes towards better or worse)
- Typical areas with annual algae blooms would be beneficial to identify (this applies to the demonstration area located in the archipelago (at least test area 2), which contains semi-enclosed areas, where riverine nutrient (and other) loading typically remains. The area also has other human impact in various levels, such as aquaculture
- Long term aspects:
    - Identification of natural phenomena from human impacts in land-sea interactions is not doable in short-term project. Demonstrations on the correspondence between nutrients and coastal turbidity & Chl-a are doable.
    - Identification/separation of resuspension from riverine impact areas.
    - Identification of upwelling, as it brings nutrients to the surface waters (internal loading).

2.1.2 Information needs for use case 2: Coastal activity mapping

For the coastal activity mapping, a lot is interlinked with maritime spatial planning and marine management. Depending on the national organization, high-resolution satellite material is of great interest. Although some of the national MSP plans can be done in generalized level, input material in high spatial resolution is beneficial during the planning phase. This is highlighted in the forthcoming years, when the recently released plans are followed. This applies also for marine management in general.

- In many of the interviews, the importance of linking existing GIS and other material to EO observations of seasonal chances of turbidity, temperature was highlighted.
- A lot can be achieved by demonstrating the spatio-temporal changes both in turbidity, algae and temperature.
- Intercomparisons between the years and coastal areas are vital for marine management and spatial planning.

- Seasonal changes in coastal activity and how to make the coastal plans taking the seasonality into account are important for at least part of the demo areas. At present, especially wintertime has poor information cover. Here EO can be of great help in many practical ways.
- A good catalogue of non-cloudy RGB images is already helpful

Further user requirements are related to transport, shipping, human leisure activities nearby large cities (small sized boats, their influence on coastal turbidity) would be practical to demonstrate. This can be done by linking available GIS material and EO datasets.

In coastal environmental monitoring, an interesting idea came up in the subject of identification of e.g. 'flada' areas and separating those fladas that already have human impact from those still in natural conditions. Only a limited amount of information is available about this topic and it is relevant for planning of areas that need further protection.

The possibility to monitor effects on seabed has been discussed for Gotland, e.g. reed extents and eel grass abundance, as well as local non-profit initiatives for restoration of shallow bays and inlets. Presently, there is now possibility to monitor the success/failure of such activities.

The availability of high-resolution temperatures raised a lot of discussions with interesting collaboration opportunities for the future use of EO material. As for example separation of small upwellings, sources of ground water to surface waters and separating human impact on water temperature, other temperature related phenomena (the areas, where groundwater and surface water are mixing which shows as colder temperature in surface waters).

For the northernmost demonstration areas, ice cover during wintertime is relevant in coastal activity. These are related to leisure activities i.e. tour skating and just walking/skiing on ice during wintertime. Furthermore, ice cover is important for evaluating the living conditions of certain habitants (e.g. nesting on seals).

Table 1. Summary of main information requirements.

Use case	User & Stakeholder group	Main information requirements/relevant cases to demonstrate within BalticAIMS	Interfaces now in use /(requirements)
Agriculture	HELCOM AGRI	Drainage basin and land use (agriculture) linkages to coastal water quality land-based nutrient pollution and internal loading identification of point sources of nutrient input to coastal waters	HELCOM MADS, experts use GIS-tools (ArcMap)
	HELCOM Pressures	Human impacts and *in long term*: Relative distribution of nutrient (total nitrogen/phosphorous) concentration, Productive surface waters (Chl-a map) Input of anthropogenic heat For this group, it will be interesting to see combinations of EO information and HELCOM-pressure-related material	HELCOM MADS, experts use GIS-tools (ArcMap)
	National level	Nutrients, land use and its changes drainage basin linkages to coastal water quality, eutrophication, riverine impact areas (annual, seasonal), algae blooms, hot spot areas for effective water protection measures Input of anthropogenic heat	FIN: TARKKA, ArcMap,
	HELCOM VASAB-MSP	Material determining human impact to coastal waters and following the recently finished MSP The plans and their level of details vary in Baltic countries, but main information requirements are: - determining and following the human impact and activities in the marine waters and planning how to minimize human impact. Combinations of EO information and HELCOM MSP-GIS layer material Areas needing more protection or reservations in human activities are relevant and, at present, sometimes made with lacking information.	HELCOM BASEMAPS
Coastal activity mapping	MSP National coordinator and experts	Material determining human impact to coastal waters is relevant. Spatial data is often missing and EO material can provide lots of new input for planning and follow-up work. Use of EO datasets to follow the recently finished MSP plans. Listed in detail in Table 2.	ArcMap for planning Other MSP interfaces: e.g. Symphony (SWE), Mosaic-tool, marinefinland.fi, maritime spatial planning (FI)
	National regional authorities: Coastal monitoring and status assessment	Monitoring requirements necessitate to follow eutrophication and human impact with a set of parameters. (FI) already use EO data (TARKKA and STATUS interfaces) along with other monitoring data sources.	
	Municipal level use	High resolution data is relevant. Human impact in areas that typically have multi-use, like transport to harbors, dredging and dumping of dredging materials, leisure activities (boats), human impact on water temperature Areas requiring nature protection or restrictions in human activities (marine vulnerable species) Seasonal aspects (winter: ice, spring melting time riverine nutrients, summer: leisure activities and cyanobacteria). Listed in detail in Table 2.	(FI) already use a lot TARKKA service, other material in ArcGIS/QGIS

Table 2. Summary of main requirements for information that can be generated from EO data and their links to user needs. X indicates that the material and request related to it is relevant.

	Spatio-temporal annual changes (seasonal& annual)	**Permanent changes**	**Human impacts identified (natural variation excluded)**	**Natural phenomena**	**Coastal high-resolution needs HRC**	**Baltic Sea wide requirements as summaries (HELCOM)**
Turbidity	x	x	• Dredging & dumping • Trawling/fishing • Marine traffic/shipping on regular routes • Leisure boating • Stormwater • Lime extraction	• Resuspension • Riverine impact areas (high peaks and annual median)	High need for human impacts and natural phenomena in national regional authorities and municipals.	• New index for resuspension areas • Riverine input information in various seasons and annually
Chl-a	x	Eutrophication	• Leisure boating • Wastewater effluents • Agriculture		High need in national regional authorities and municipals	• Chl-a indicator • Disturbance layer 6 development related to it
CDOM	x	Climate change, brownification	x	x	Could be user more, important to separate CDOM and turbidity well in coastal processes	DOC/CDOM, brownification
Water color/(RGB)	x	x		x	Daily RGB is used already a lot. As a combination to other data, can assist in monitoring and spatial planning	
Algae blooms	x	Eutrophication	Identification of typical bloom areas caused by land use influence on coastal waters		Need for these by national regional authorities and municipals during summertime and in long perspective	• Cyanobacteria bloom indicator & development related to it
Temperature	x	Climate change, human activities	Input of heat (caused by human activities)	Upwelling, annual/periodical upwelling index maps	Many interesting coastal uses: upwelling, spatial distribution of temperature is important, ground water sources under seafloor	• update/input for the input of heat-layer • upwelling index
Sea ice	x	x	x	x	x	
Land use		x			x	
Coastal Zone mapping?		x			x	
Flada-areas		x	With and without human impact	x	x	
Soil moisture	x	x	Restoration of wetlands for water retention			

3 Showcases based on user requirements

On the higher level the use cases of the project are:

- Use case 1. Agriculture and land use practices
- Use case 2. Coastal activity mapping

For service development purposes, it is convenient to define additional use cases that have a more focused scope. We call these '**showcases'** in order not to confuse them with use cases listed above. Below we present five such showcases by describing their purpose, what kind of information they require, how the information can be displayed and analyzed and who the main users are. Showcases B and D are built bearing in mind the Use case 1 (Agriculture and land use practices). Showcases A, C and E serve mainly Use case 2 (Coastal Activity Mapping).

For users who are not yet accustomed to EO data, it is often not very straightforward to accurately define in advance what EO based material they would like to see and utilize in their forthcoming work. Thus, it will be necessary to iteratively define the details of the specific user requirements during the service specification and implementation phases (WP2 and WP3). This concerns for example the complementary GIS-material and layers included in the final datasets of each showcase. In addition, the spatial resolution of some of the EO material may change during the process. As a first estimate, we will use the highest available resolution provided by the instruments, but a coarser resolution may be necessary due to performance or other issues. We also foresee that the service delivery phase (WP4) will require interactive sessions for analysis and iterative processing of EO and GIS data combinations together with users.

Showcase A: Provide EO based information to be used in user legacy systems for spatial planning

Most of the terrestrial and maritime spatial planning work is done in GIS systems (e.g. ArcMap). The planners are accustomed in reading materials from data interfaces to their GIS-projects. Thus, this is a suitable way for them to integrate EO materials to their working practices. The EO based information provided by BalticAIMS helps e.g. to continue the actual planning work and monitor the impacts of the recently released plans. For this, the demonstration phase of this project is timely, as the next planning phase will start in 2022. Therefore, the users are interested in demonstration material related to the following parameters:

- Turbidity and its seasonal changes
- Chl-a and its seasonal changes
- Algae blooms (summerly period)
- Temperature

Within this showcase the users are mostly interested in seasonal or even longer-term information, which requires data to be aggregated over time.

The users interested in this showcase are the MSP planners in all countries with demo areas. In addition to planners, national coordinators and managers of environmental monitoring data are interested in this dataset. Also, HELCOM groups and data manager can familiarize themselves to the possibilities of including EO datasets in the future as Baltic Sea wide material of input data source to Baltic Sea wide combinations on human impacted areas.

Showcase B: Monitor the effects of nutrient flow from the drainage basin to the coastal waters

The effects of nutrient flow from the drainage basin to the coastal waters cause visible changes in water quality through turbidity and algal growth (eutrophication). Users interested in this showcase want to visualize and combine the following information layers:

- Agriculture production data
- Land cover data

- In situ sensor data of water quality in streams
- Coastal water quality data (turbidity, Chl-a)
    - Daily products and longer-term aggregates
    - Time series analyses
    - River impact areas

By analyzing the combined information the users can estimate e.g. the effectiveness of agriculture management practices and find correlations between agriculture production and the status of coastal waters.

The demonstration service will be provided through TARKKA, but the data will also be available through OGC interfaces.

The users interested in this showcase are HELCOM AGRI- and Pressures-groups, regional environmental authorities (ELY Centers FI, County Board SE), UBA (GE) and on a local level, Blue Centre Gotland that presently targets land to sea transport of nutrients, in collaboration with farmers, and is planning for a network of in situ sensors to measure different water quality parameters in streams.

Showcase C: Monitoring the impacts of coastal activities

Coastal cities are hubs for human activities. Dredging, coastal construction, shipping and other activities cause local and often transient changes to water quality which are easily visible from space. Combined, these changes can have long term impacts in the coastal ecosystems. In this showcase we utilize the TARKKA interface for service demonstration and allow the users to visualize and combine GIS and EO material. Users are interested in the following information:

- True color (RGB) images
- Turbidity (daily products and aggregates)
- Temperature
- Human activity information (GIS data)
- Sea ice extent information

We will also demonstrate the estimation of the number of leisure boats in a limited number of scenes.

With this showcase the users gain more information about the status of the coastal environment and the effects of human activities on it. The users interested in this showcase are e.g. the municipalities of Helsinki (FI) and Visby (SE), MSP-planners in LEP M-V(GE), regional environmental authorities (ELY Centers FI) and developers of the MSP tool Symphony at SwAM (SE). HELCOM VASAB-MSP in the long run.

Showcase D: Combination of Coastal Zone mapping and CMEMS coastal water quality material

The Copernicus Services provide a large variety of products. Users often find it hard to find the relevant information for their applications. Therefore, dedicated collections of service products are needed.

This showcase is a demonstration of harmonized material that exists from all demonstration areas and gives examples for the users on material available beyond Baltic Sea. As e.g. the Coastal zone material consists of 70 layers, only relevant ones are chosen. The selection of the relevant layers will be done in co-operation with part of the users and land use experts.

The information layers are even more valuable for the users if they are combined with GIS material available from other sources, such as HELCOM maps and databases. A showcase demonstrating the combination of available datasets in the view of coastal zone mapping is therefore of high interest by the users.

The users interested in this showcase consist of most user group interviewed and do not need to be specified at this point of the project.

Showcase E: **Monitoring of temperature anomalies**

Temperature anomalies are caused by natural phenomena such as upwellings where cold and nutrient rich water from deeper layers is brought to surface by wind action, and human (industrial) activities such as the condensation waters of power plants which increases the local water temperature. Both can affect the local environment. Upwellings can lead to increased algal growth while warm water from a power plant may affect the species composition in the area. Users have expressed interest in the spatial information of temperature for monitoring such effects.

Monitoring temperatures near the coast requires measurements with good spatial resolution. Landsat-8 currently provides thermal images with 100 m resolution. The availability of data will be doubled once Landsat-9 is launched later in 2021. ESA and European space industry are constructing the Sentinel Land Surface Temperature Mission (LSTM) which will provide even better resolution, but the launch will be after 2028. Continuous in situ measurements can complement the satellite data by providing data during cloudy days and days without satellite overpasses and provide calibration data if needed. The combination of punctual, temporally high resolution in-situ data with spatial information about phenomena is of high interest.

This showcase will utilize the TARKKA system for service provision (the data will also be available through OGC interfaces). The products will include:

- High resolution temperature maps where the effects of anthropogenic heat sources and location of coastal ground water areas can be estimated
- Coarse resolution temperature maps for more frequent estimates
- Locations of upwelling areas (Baltic Sea upwelling index)

Data fusion techniques will be demonstrated to combine the EO and in situ data into a spatially and temporally extensive information. This use case would serve as basis for future input towards HELCOM ‘input of heat’-layer in Baltic Sea.

The users interested in this showcase are e.g. the municipality of Helsinki (FI), regional environmental authorities (ELY Centers FI), Finnish ministry of environment and Blue Centre Gotland. HELCOM VASAB-MSP and pressures-group in the long run.

4 Information delivery, analysis and fusion requirements and implementation approaches

4.1 Information delivery and analysis performance requirements

The main objective of the information delivery and analysis tools is to provide data from various sources (EO, GIS, model and in situ) to the users in a way that allows analyses to be made conveniently. In here "convenient" means the following:

- The user can integrate the provided information in its own systems by a well-defined interface
- It is possible to combine and view together different data and information layers in order to make conclusions required by the analysis
- The user experience is good (the systems are user friendly and react quickly to user commands)

Based on the information requirements defined in Chapters 2 and 3 we will locate or create ourselves the necessary data flows and make them available through standard data interfaces in analysis ready form. In practice – i.e. when the data is not available through interfaces and in order to facilitate good user experience – this often requires data to be collected into a database. In BalticAIMS the raster type data is collected into a data cube, which allows further processing (e.g. temporal and spatial aggregation) to be made in addition to data access. Other types of data (from in situ stations and transects and GIS shape files) are collected into a database (geoDB).

'Good user experience' here means the following:

- Information layers can be found conveniently from a list and metadata descriptions are available
- Information layers open within a few seconds
- Map operations such as zooming and panning are fluent (the data on the user interface updates within a few seconds)
- If the analysis requires computation before the visualization the computation time is minimized, and an estimate of the processing time is given.
- If near-real-time data is required, the delay from the satellite overpass to being available is minimized (delay up to one day)

4.2 System interface features

Two types of user interfaces will be connected to the data interfaces. The TARKKA system of SYKE will be utilized to make publicly available demonstrations of the use cases. For visualization, the user shall be able to e.g. select

- raster layers,
- vector data and
- point based data,
- pan and zoom on a map,
- define temporal extent.

Other interface functionalities include:

- Ability to change
    - the order of selected layers
    - visualization of layers
- Perform spatial statistics for ROIs
- Display several layers at once
- Swiping of layers (e.g. RGB image and turbidity layer, GIS material and EO layers)

The users shall also be able to connect their legacy systems to the data repositories of BalticAIMS. This allows the users to utilize their own tools, routines and data to perform the analysis, now enhanced with additional information

provided by the BalticAIMS system. The interfaces shall be based on the standards defined by OGC and includes functionalities for data and processing WFS (Web Feature Service), WMS (Web Map Service) and Application Programming Interface (API).

4.3 Data fusion requirements and implementation approaches

The users expressed their interest in having analysis ready data from different data sources and from different resolutions. This gap can be filled for smooth integration into models. E.g. the users were keen on seeing examples of data fusion on some of the demonstration areas. There is an existing data fusion model and model outputs in demo areas 1 and 2 that can be used to fulfill these requirements and demonstrate the benefits of this approach for later use in other demo areas also. The BalticAIMS data fusion demo case is based on a system that uses statistical methods (Kalman Filtering) to combine observations of different resolution and accuracy. The data fusion is mostly retrospective: the idea is to find the optimal estimate of the state of the system over the whole-time span of the observations. However, the results could be used to make predictions, too. The Data Fusion System contains two implementations of a Kalman Smoother for state space estimation: (stochastic) Ensemble Kalman Filter (EnKF, Evensen, (2009)) and Error Subspace Transform Kalman Smoother (ESTKS, Nerger et al. (2012), Nerger et al. (2014)). The interpolation model is based solely on empirical information on the natural variability of the parameter being used and auxiliary variables and on the measurement principles and processing of the observations.

Data fusion of chlorophyll a and turbidity observations done with EO, station sampling and on-line fluorometer devices has been successfully demonstrated in the coastal waters of Finland. In BalticAIMS this data fusion methodology will be utilized within the demonstration areas 1 and 2 – where the availability of observational data via stations and ferrybox on-line devises is sufficient to support both the agriculture and coastal human activity themes. In addition, we will create a plan for the utilization of the methodology for the other demonstration areas (e.g. what are the minimum requirements for in situ observations etc.).

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