Suomen ympäristökeskus
Finlands miljöcentral
Finnish Environment Institute

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Author(s) and affiliation(s):	Carole Lebreton, Hannes Neuschmidt, Tejas Morbagal, Carsten Brockmann BC Sampsa Koponen, Vesa Keto, Hanna Alasalmi, Jenni Attila SYKE Petra Philipson, Susanne Thulin BG Juha Karvonen, Patrick Eriksson, Matias Takala, Miriam Kosmale, Kari Luojus FMI
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Content

Abstract

D3.3: Service System Update Report, result of WP 3.3 activities during the BalticAIMS CCN1 project. It builds upon and updates the infrastructure created during the BalticAIMS project with two deliverables (D3.1 and D3.2). During the BalticAIMS CCN1 project, the service system was moved to a new location (from CreoDIAS to DeepESDL) chapter 2.1, a QGIS plugin was developed to facilitate access to the BalticAIMS datasets (chapter 2.2). and the TARKKA+ environment received new updates (chapter 2.3). In BalticAIMS CCN1 a new service has also been added to provide sea ice detection products using the ICEYE data (chapter 3).

D3.1	Service Chain Verification Report (SVR)
D3.2	System and Service Chain Readiness Report (SRR)

Glossary

CCN	Contract Change Notice
DeepESDL	ESA's Deep Earth System Data Laboratory
FTIA	Finnish Transports Infrastructure Agency
IdP	Central Identity Provider
MSP	Maritime Spatial Planning
RRD	Rapid Response Desk
SRR	System and Service Chain Readiness Report
SVR	Service Chain Verification Report

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1 Introduction

1.1 Purpose and scope

Work Package 3 of the 1st phase of the BalticAIMS project (active in 2021-2023) delivered the following reports (links to the public versions included):

- D3.1 Service Chain Verification Report (SVR)
- D3.2 System and Service Chain Readiness Report (SRR)

Together they describe the system setup, configuration and installation status, and how the system is used, how to add data and how to access it from clients.

The purpose of this *Service System Update Report* is to document the modifications made to the system during the 1st half (= by Month 9) of the extension phase of the project (CCN1, active in 2024-2026). Additionally, the report includes a description of the ICEYE data flow and processing systems which were not part of the original project.

This document will be followed by D4.2: *Service Operations and Service Chain Performance Report Update*, (due in Month 15 of the project), which will provide detailed descriptions of the use of the systems including the data added to support the use cases and user stories.

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

1.2 Document overview

After this formal introduction:

section 2	provides a description of the modifications done for the original backend and the user interfaces of the MSP and aquatic environment monitoring themes of the project
section 3	provides a description of the data flow and service systems developed for ICEYE data

2 Marine spatial planning and environmental monitoring theme

2.1 Backend systems

In the previous phase of the BalticAIMS project, the system backend was hosted on the CREODIAS infrastructure, utilizing a single dedicated virtual server managed and monitored by the project team.

As the first major activity under the current Contract Change Notice (CCN), the BalticAIMS services were successfully migrated to the DeepESDL infrastructure (https://www.earthsystemdatalab.net/). Deep Earth System Data Laboratory is a platform providing analysis-ready data cube in a powerful, virtual laboratory to the Earth Science research community. DeepESDL offers a full suite of services to facilitate data exploitation, share data and source code, and publish results. The migration of BalticAIMS backend services to DeepESDL offers several operational advantages, including access to the latest stable versions of key components such as xcube, GeoDB, and JupyterHub, as well as continuous support from the DeepESDL team, who ensure the platform's operational readiness.

The following components of the BalticAIMS system have been migrated to DeepESDL:

1. **Existing datacubes**

   All relevant datacubes previously stored on CREODIAS object storage have been successfully transferred to AWS S3 buckets hosted within the DeepESDL environment, ensuring data continuity and improved accessibility.

2. **JupyterLab service**

   DeepESDL provides a fully operational JupyterLab environment tailored to the BalticAIMS project. In addition to serving as a development and analysis platform through Jupyter Notebooks, the environment offers several enhanced features:

   - **Dedicated object storage** for user data
   - **Isolated user workspaces** with persistent volumes
   - **Shared team storage** to facilitate collaboration
   - **Conda-store UI** for managing custom environments
   - **Integrated visualization tools**, including xcube viewer, directly accessible within the JupyterLab interface

3. **User management**

   User authentication in DeepESDL is managed through a combination of **GitHub authentication** and **Keycloak**, which serves as the central identity provider (IdP). This hybrid setup enables flexible user onboarding while maintaining centralized role-based access control.

   - **Authentication**: Users log in using their GitHub accounts, authenticated via OAuth2/OIDC through Keycloak.
   - **Authorization**: Role and group assignments within Keycloak determine user access to services and datasets (e.g., JupyterLab environments, GeoDB, xcube viewer).
   - **Environment Provisioning**: On first login, users are provided with isolated compute environments in Kubernetes, with persistent storage and access to shared resources based on their assigned roles.

   This approach ensures secure, scalable, and manageable user access across the BalticAIMS system components hosted on the DeepESDL platform.

4. xcube server and viewer

A dedicated xcube server and viewer instance (Figure 1) have been deployed specifically for the BalticAIMS project. It allows users to explore and visualize the data cubes generated throughout the project lifecycle in an interactive, browser-based interface. The deployment is regularly upgraded with the latest xcube releases. Furthermore, the deployment is maintained in alignment with upstream development and undergoes regular upgrades to incorporate the latest stable releases of xcube. This ensures continued compatibility, performance improvements, and access to new features as they become available, thereby supporting long-term operational reliability and scientific relevance.

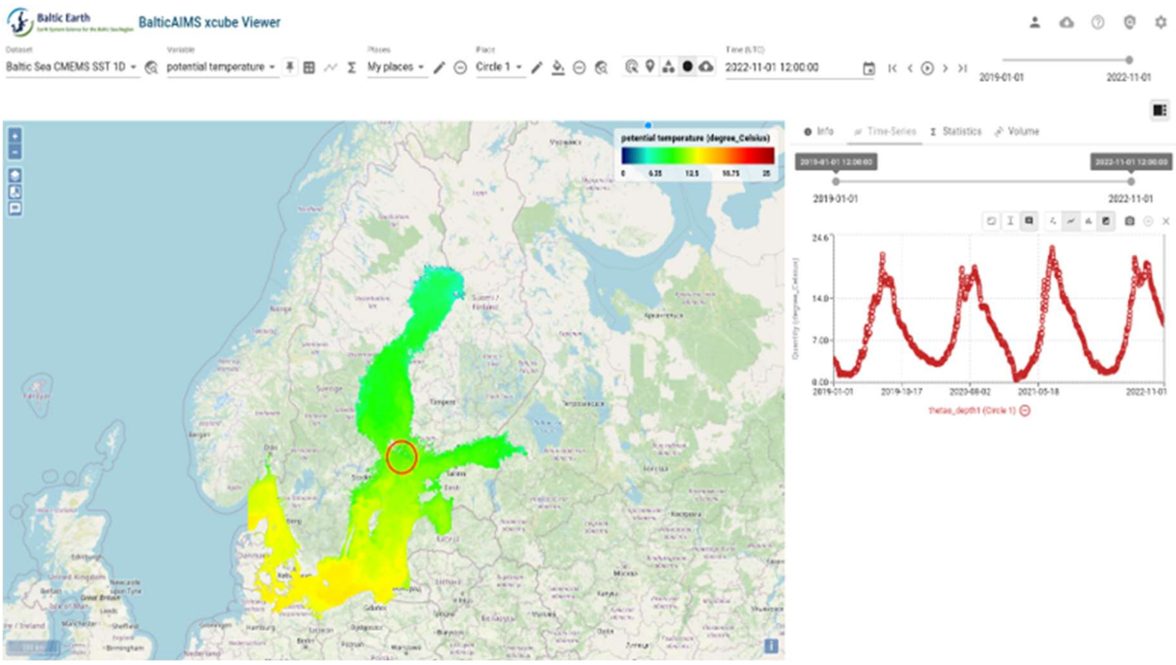


Figure 1. BalticAIMS xcube viewer.

5. GeoDB service

A dedicated **GeoDB subscription** has been established to manage and store vector and feature data relevant to BalticAIMS. This service is seamlessly integrated with the JupyterLab environment (Figure 2) and accessible through authorized user roles. This migration improves the system’s maintainability, scalability, and long-term sustainability by leveraging an established infrastructure and dedicated operational support.

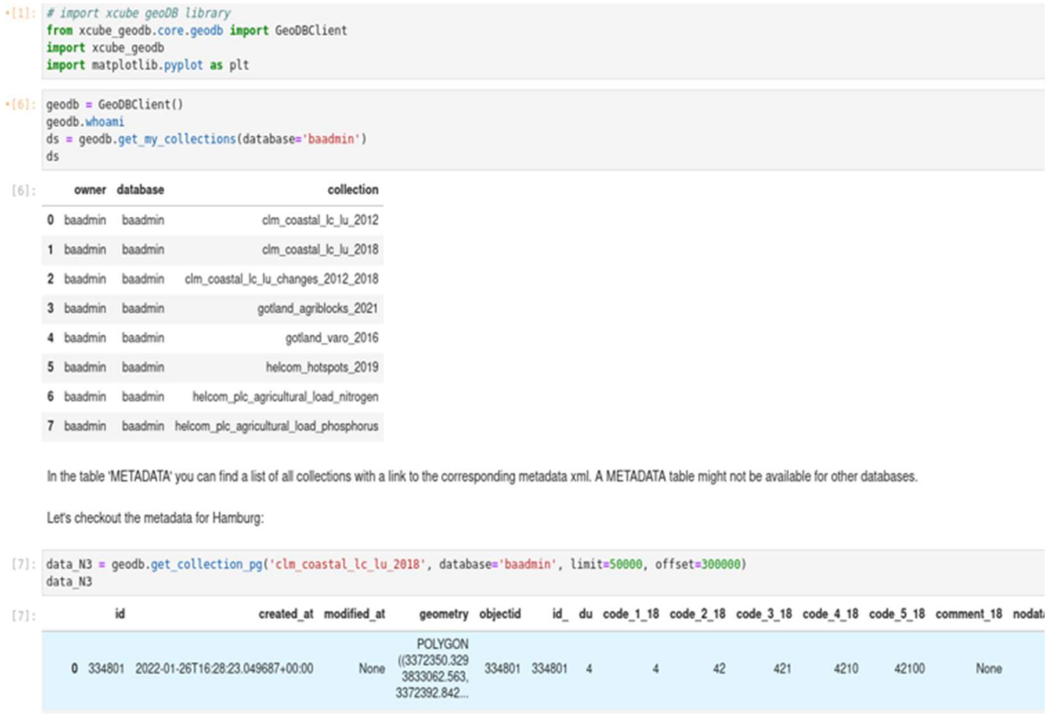


Figure 2. Example of the seamless integration of the BalticAIMS GeoDB in the demo jupyter notebooks.

2.2 QGIS user interface

QGIS is a free and open-source geographic information system (GIS) software used for visualizing and editing geospatial data in a variety of raster and vector formats. QGIS provides a Python plugin infrastructure that can be used to add additional processing functionality or control and extend the graphical user interface. The QGIS documentation page provides a User Guide for general usage of QGIS and a Plugin Development Guide for developing Python plugins.

The BalticAIMS QGIS plugin enables QGIS users to visualize and analyze the spatiotemporal data cubes located in S3 storage from the QGIS environment that they are familiar with. The plugin itself provides "actions", which are menu entries under the "Plugins" main menu, that let users select data to load into QGIS. Figure 3 shows the Plugin menu and the actions added by the BalticAIMS plugin. The data of one variable is represented as a Raster Layer in the same way e.g. a GeoTIFF file would be, enabling users to analyze it with standard QGIS functions. The functionality of the plugin encompasses loading data from S3 and annotating it with the correct metadata to integrate with built-in QGIS features. Data analysis is left to built-in tools and other plugins.

Unlike a traditional raster data set which represents a physical quantity for a single time frame, data cubes often represent data for many time steps in a time series. The plugin represents time series data as a single raster layer with one band per time step. The concept of a "variable" in a data cube is represented as a Layer in QGIS whereas the "band" concept is used to represent time steps. With this mapping, datasets with dense time series can be represented without overcrowding the Layers Panel. However, it is important to keep these concepts separated to avoid confusion between "band" and "variable".

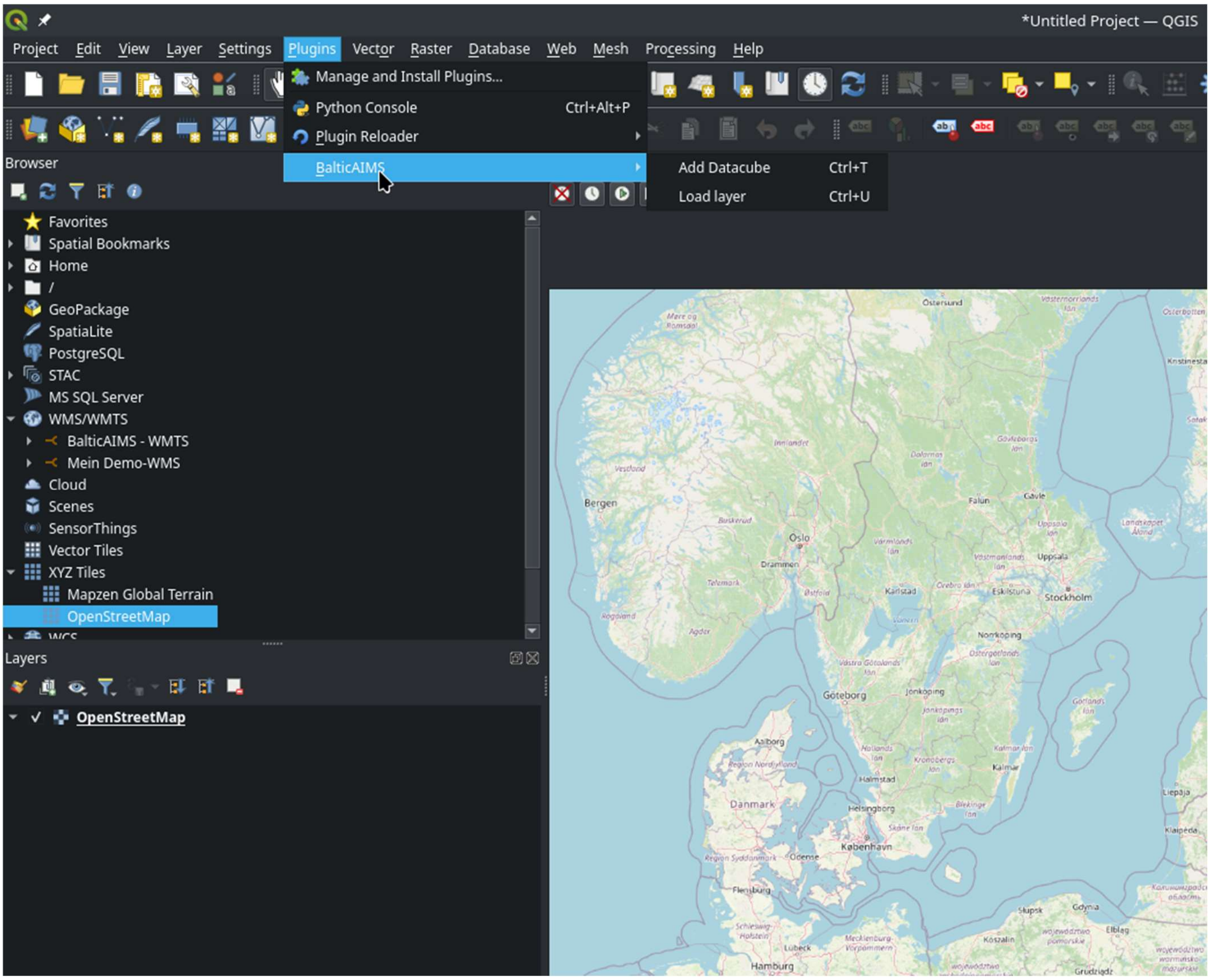


Figure 3. The plugin provides two actions in the Plugin menu: Add Datacube and Load layer.

2.2.1 Loading Data

The plugin loads data in two steps, which are shown as an action each, in the main menu. On a higher level, BalticAIMS provides data cubes in an S3 bucket. The plugin adds an action “Add Datacube” listing the available cubes and allows the user to add one to the selection of open cubes. At this first stage, no data is downloaded yet; the action merely makes the plugin aware of the metadata of the cube of interest. Figure 4 (left) shows the data cube selection popup.

The second action, “Load layer”, allows users to select any variable from the data cubes previously opened using “Add Datacube” to download and visualize. (Figure 4 right). After the download is complete, the newly created layer appears in the Layers Panel.

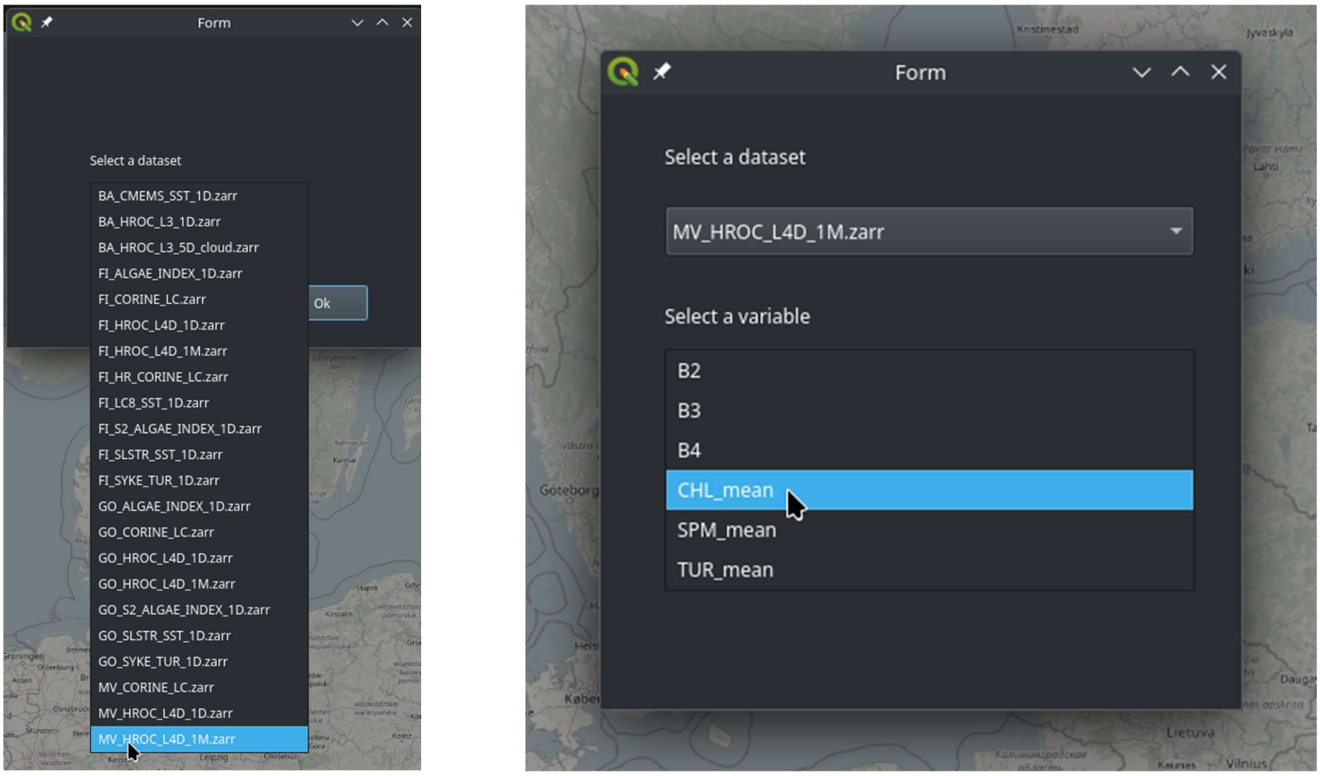
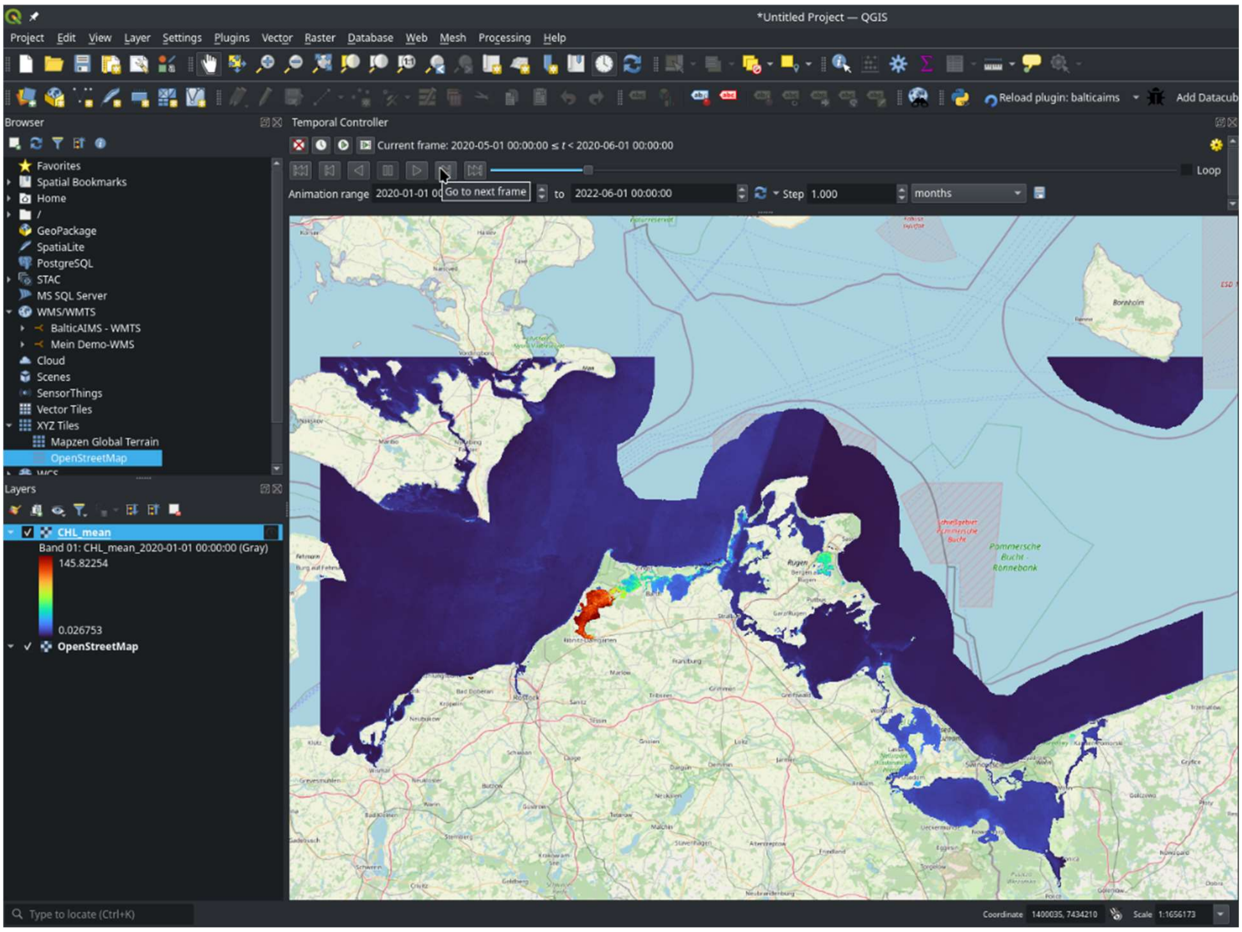


Figure 4. Plugin Pop-up windows to select a data cube (left) and a variable from the data cube (right). The data cube list contains all the cubes found on https://xcube.balticaims.eu/api/datasets.

2.2.2 Integration with QGIS' analysis tools

As mentioned above, the individual time steps in a time series data cube are represented by bands in a raster layer. The plugin annotates each band with the start and end date of that time step to integrated with the built-in Temporal Controller, shown in Figure 5 (top), allowing users to step through the time series and create animations without requiring any manual modification of time annotations.

The raster layers loaded by the plugin support the Identify Features Tool. When this tool is selected, a user can click on a location on the map canvas and receive a list of the pixel values of each layer and each band at that location. Because time steps are represented as bands in the data cube representation provided by the plugin, the tool shows values for each time step at the selected location. The Identify Results panel is shown on the right in Figure 6.



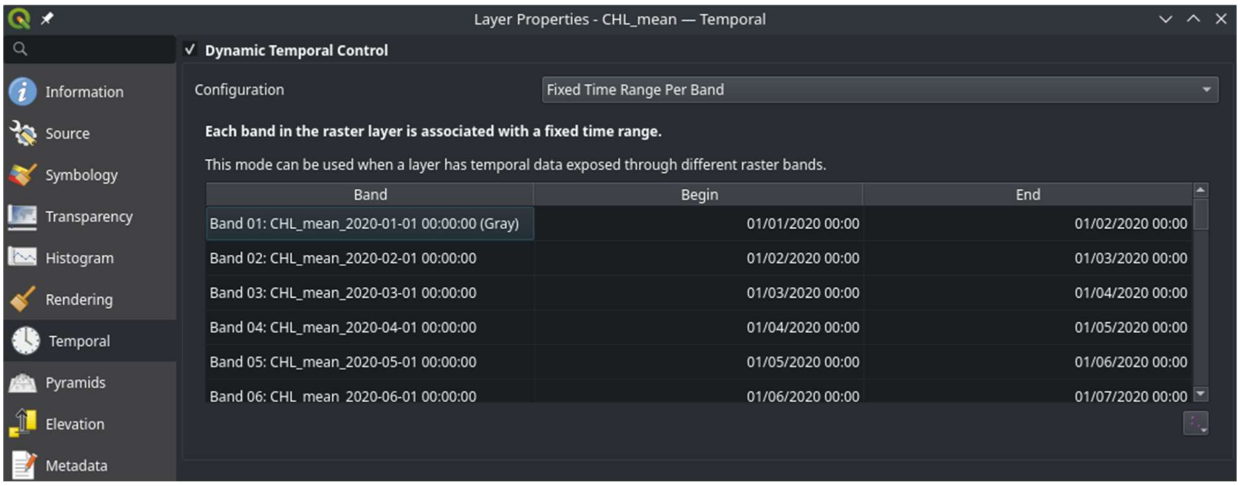


Figure 5. Temporal control integration of a data set. The build in temporal controller can be used to step through the time series of a data set (top). Each band, representing a time step, is annotated with the time frame metadata (bottom).

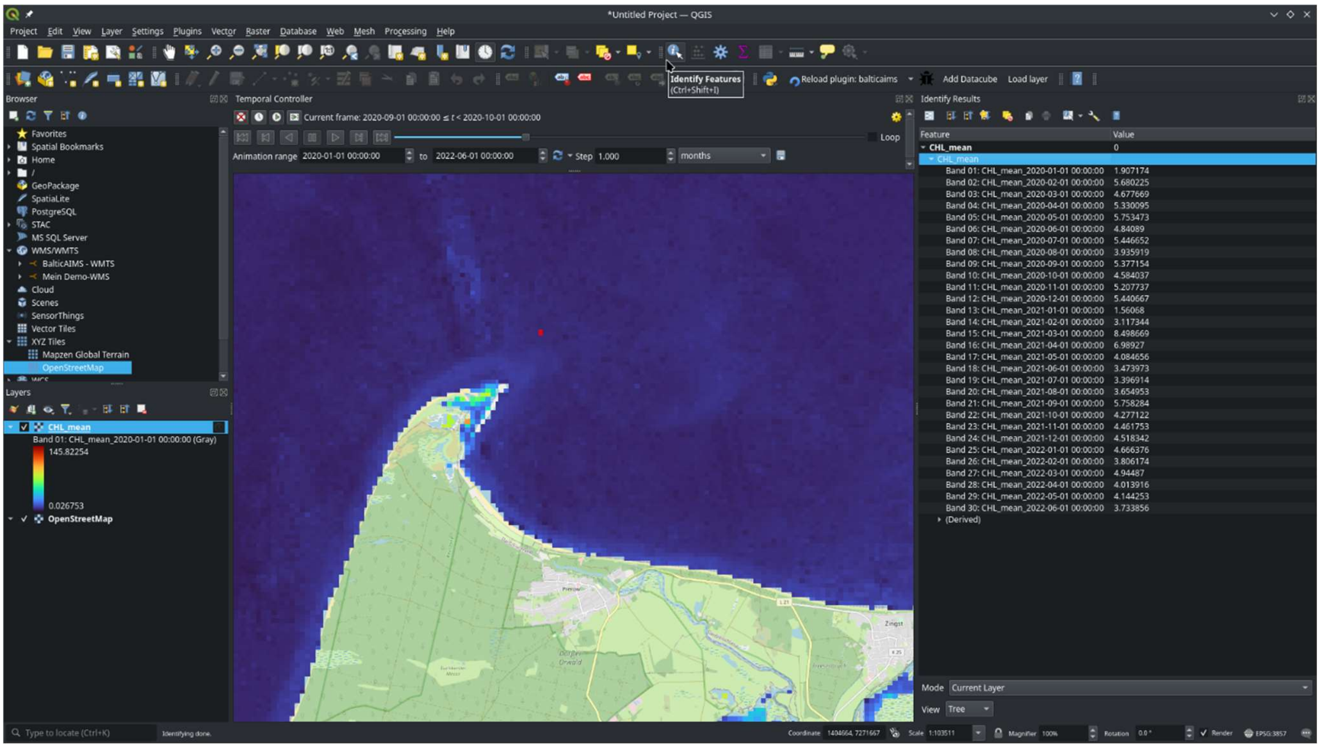


Figure 6. Identify Features. When clicking on the map, the user can see the values for each time step of the time series in the inspect window on the right of the screen.

2.3 Tarkka user interface

Tarkka is an online service provided by Syke for making EO, in situ, citizen observation, model and GIS materials available for various user communities including authorities, companies, media and citizens. Tarkka was originally launched in 2017 and since then it has been continuously developed in several nationally and internationally funded projects, including BalticAIMS. Additional information about Tarkka is available in the User Manual.

In 2022 a new version was made available, which utilizes modern methods such as React, OpenLayers frameworks and OGC-compliant data providers, as well as custom in-house and third-party data providers. As a result, Tarkka is a highly customizable web application framework for visualizing spatiotemporal data both on a map and as statistical time series. The update has also made it easier to add materials to the system, making development and maintenance quicker.

Tarkka allows the user to select which materials the user wants to visualize in a spatiotemporal map view. The user can also access time series data from predefined regions of interest (ROI). The Tarkka app can access data from any production chain as long as the data interface implements well known standards. Both in-situ and Earth Observation data can be utilized simultaneously, as well as supporting GIS-datasets (e.g. regional divisions) to further tailor the users' viewpoint.

Most of the content in Tarkka is freely and openly available to any user. However, the current version also includes the possibility to use access management (password login) to restrict access to some materials. As an example, at the time of writing this report, the regional experts in Finland doing water body classification for the Water Framework Directive have access to EO based statistical water quality information not available to the public. Similar access control can be used with BalticAIMS users when necessary.

Under the current contract Tarkka has been linked to the new xcube Server located in the DeepESDL environment (see Chapter 2). The MSP (BalticAIMS) theme has also been updated (Figure **7**). An example map with many MSP materials activated and a time series plot of water temperatures is shown in Figure 8.

Figure 9 shows an example of the new Analysis dashboard of Tarkka. It is currently behind login (see above) as it is being used by the authorities. The user views of Analysis dashboard can be modified according to user requirements to show the data in charts, plots and tables bringing new versatility to the interface and user experience.

As a summary, the new options and functionalities now available in Tarkka provide additional versatility for the demonstrations of use cases and user stories during WP4.

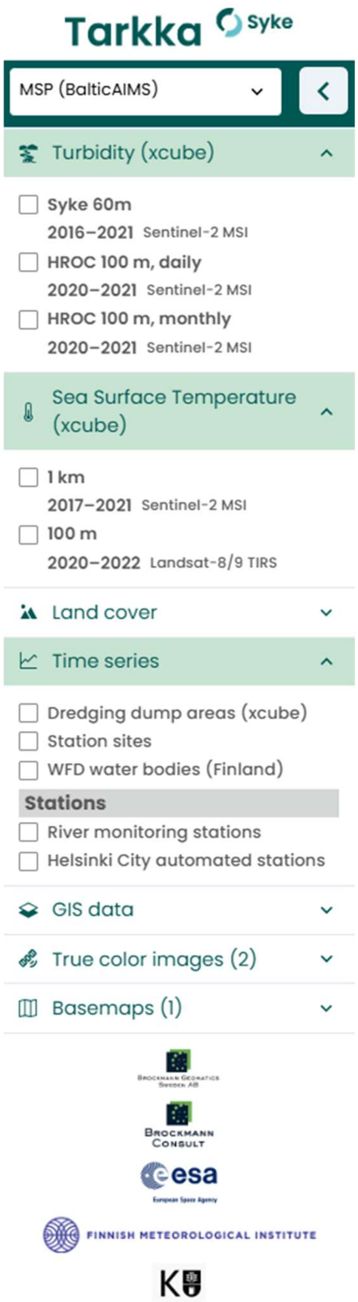


Figure 7. Updated MSP (BalticAIMS) -theme in Tarkka (themes can be selected from the pull-down menu at the top of the figure). The materials linked to the themes are grouped into categories. Each entry can be separately activated or deactivated by the user.

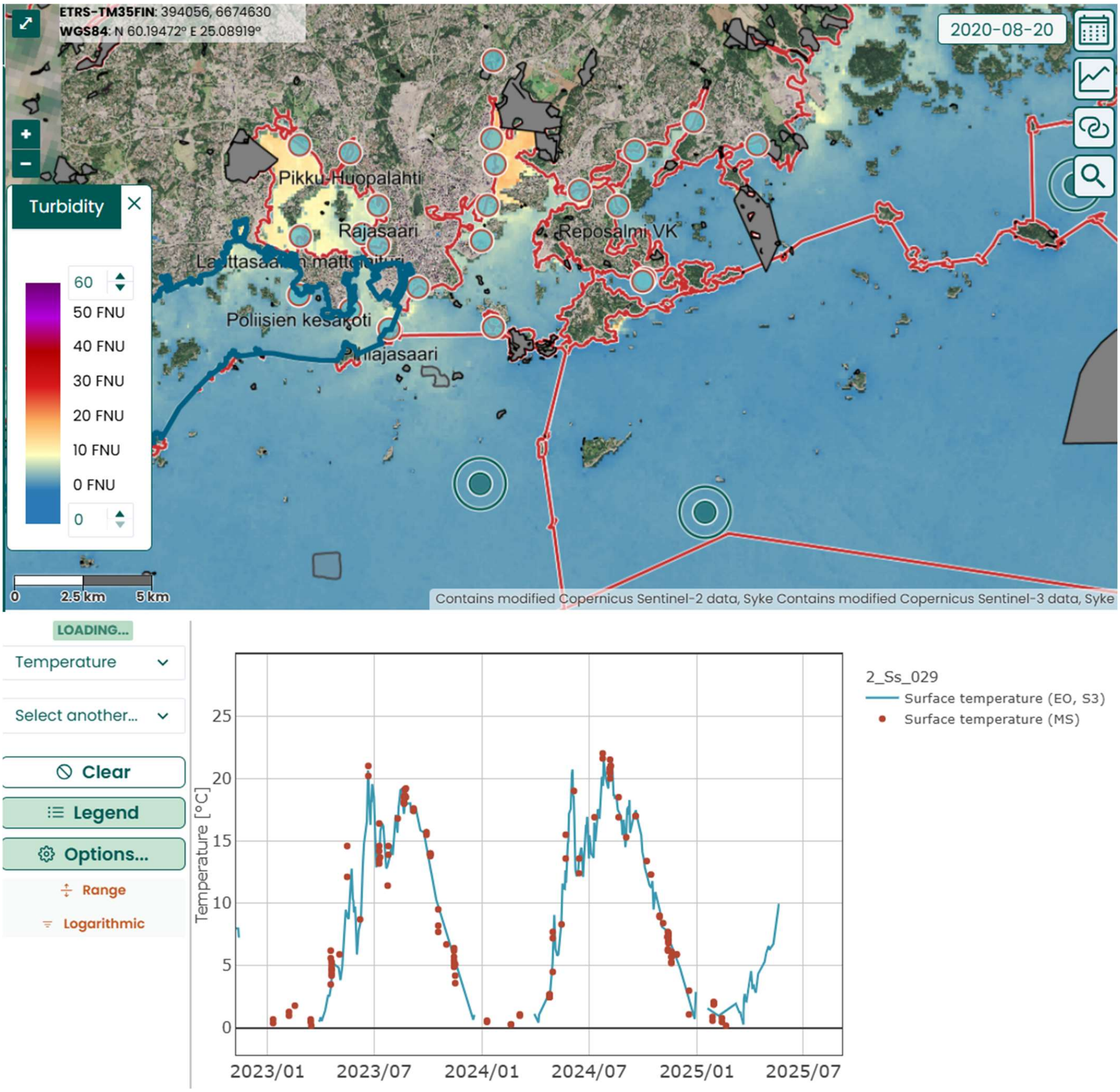


Figure 8. Top: A view of the Map viewer part of Tarkka showing several activated MSP-theme datasets. Bottom: A sea surface temperature time series plot showing the EO (S3 = Sentinel 3) and in situ (MS) values at one of the monitoring stations.

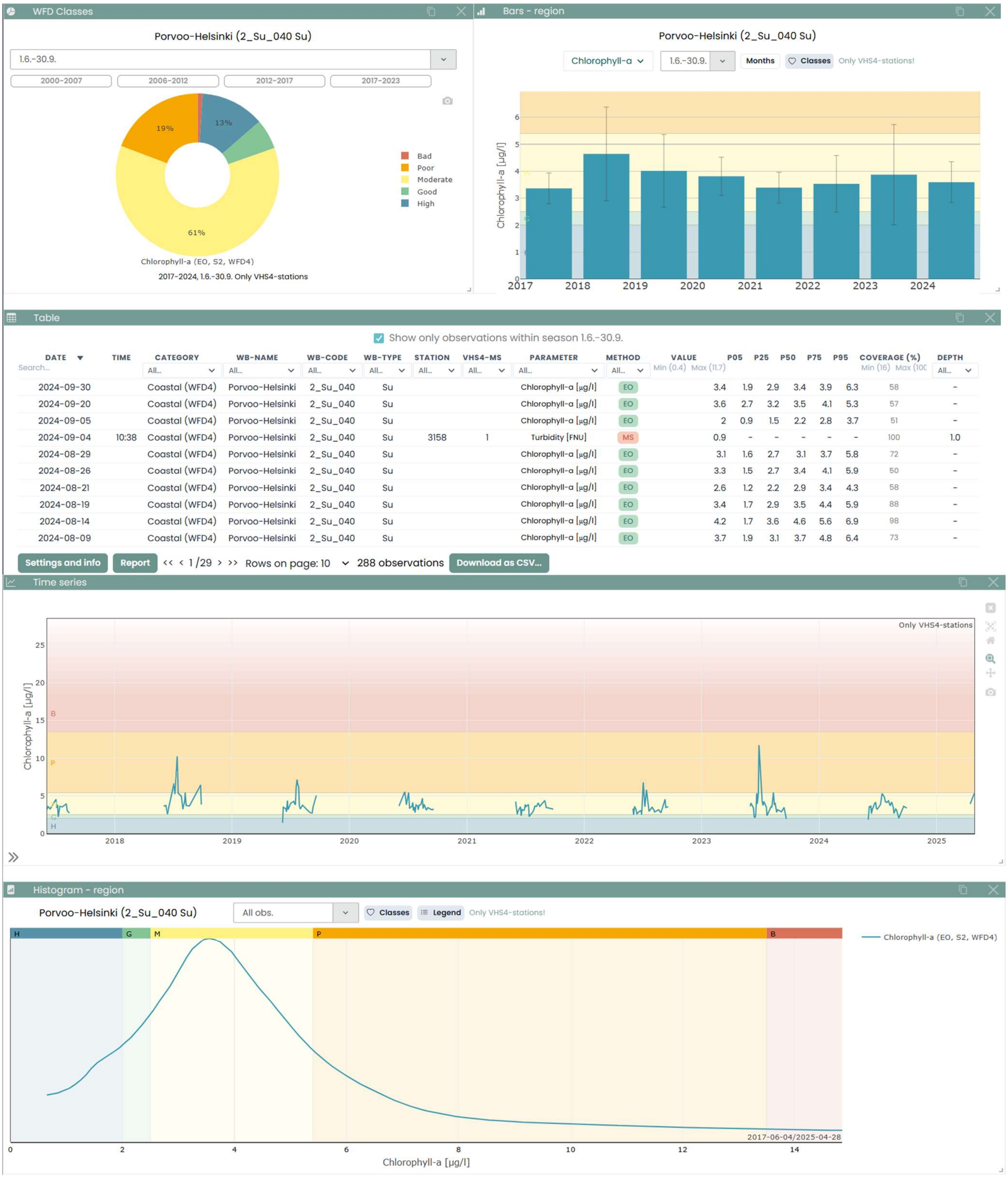


Figure 9. A view of the Analysis dashboard of Tarkka currently in use for the Water Framework Directive classification work. The doughnut plot on the top left shows the distribution of EO Chl-a observations according WFD classes (High to Bad) for the Porvoo-Helsinki coastal waterbody. The bar chart on the top-right shows summertime EO Chl-a averages of years 2017 to 2024. The table in the middle shows daily EO and in situ values. The figures on the bottom show time series and histogram of EO Chl-a values with WFD class limits indicated in background colors.

3 ICEYE Sea ice monitoring service

The Finnish Meteorological Institute provides a service on operational sea ice monitoring for the shipping industry based on satellite observations. Estimation of the essential sea ice parameters is an important task e.g. for sea ice navigation and other offshore operations in and on ice, and for assimilation in numeric sea ice and weather models. In this context the existing ice charting service is further developed and tested by extending it to 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. The service is focusing on the Baltic Sea addressing stakeholders from winter navigations authorities like the Finnish Transports Infrastructure Agency (FTIA) or VTS centers, which monitor vessel traffic in Finnish waters. The ice chart service is especially developed in close collaboration with users from Finnish icebreakers. Vessels can directly access all relevant information on sea ice, shipping route conditions and weather information on their ship bridges through IBNet, the official icebreaker information system, which allows also direct provision of those ice charts to the captains and personnel in charge.

3.1 ICEYE service data flow

During development of the new ICEYE operations, images from winter 2024 on selected test regions in the Gulf of Bothnia have been received. New test datasets have also been ordered for winter 2025. The general structure of FMI’s Sea ice monitoring service on ICEYE images is developed in two independent processing streams (Figure 10). ICEYE multitemporal SAR data is received directly via ftp. The setup of the download module allows for later operational data reception, under the condition of persistent and consistent ICEYE file formats and data access. The operational processing of ICEYE SAR images provides automatized ice charting utilizing SAGA GIS and ESA SNAP tools. This processing chain has been embedded in an ecFlow environment, which is a client/server workflow management system. Such an implementation allows operators, without any background in the algorithms themselves, to monitor operational processors 24/7 in a controlled environment and restart processes across platforms in case of problems occurring. Such 24/7 monitoring setup is essential in offering operational services and is widely applied for other FMI services already.

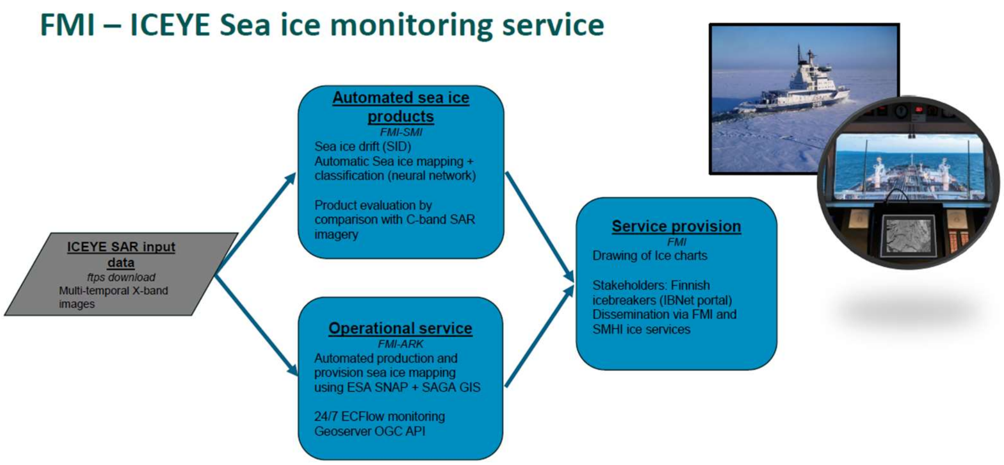


Figure 10. General structure of FMI’s sea ice monitoring service and ICEYE processing scheme.

The processing of more advanced automated sea ice product analysis, like information on sea ice drift and automated sea ice classification is part of current R&D. Nevertheless, this part of the processing chain is also foreseen to become an automated production.

The data flow for automated ICEYE data analysis algorithms is slightly different from the process for visual analysis (ice charting) because calibrated data in a predefined projection (Mercator) is required for the automated processing. The data are downloaded in near-real-time (NRT) from the ESA Rapid Response Desk (RRD) ftp server by using lftp get command. The NRT download is enabled by polling the ftp site every 15 min for new data. The preprocessing for automated algorithms includes calibration, georectification, land masking and also extracting incidence angle grid corresponding to each SAR frame. The incidence angle grid enables incidence angle correction in the SAR range direction. A flow diagram of the IEYE retrieval and preprocessing for automated analysis is shown in Figure 11. More details on the algorithm will be given in D4.2.

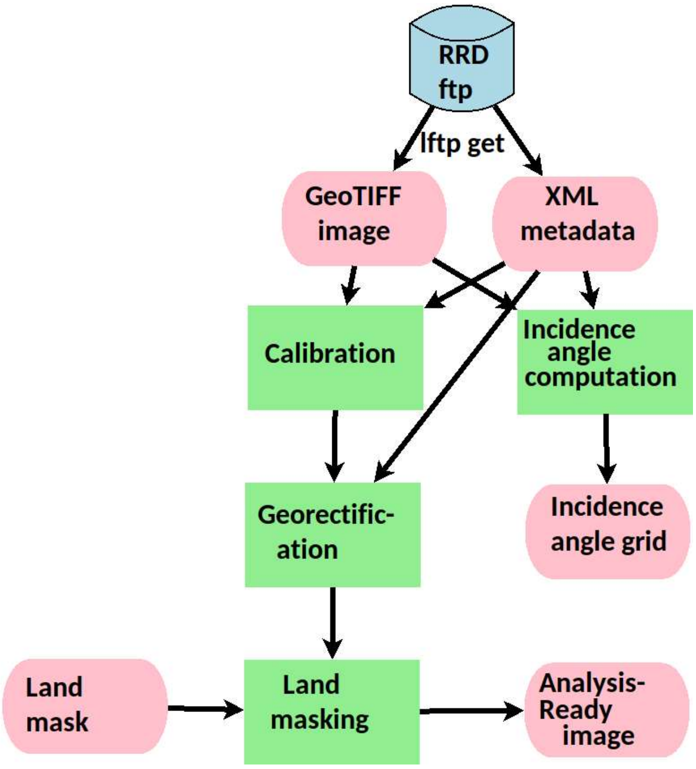


Figure 11. Flow diagram of the ICEYE data retrieval from RRD ftp and preprocessing for automated analysis. A georectified, calibrated and land masked image and a corresponding incidence angle grid are produced in NRT.

Both data streams feed the final sea ice monitoring portfolio. The interface from FMI to the existing service portals like IBNet is well established and allows provision of those newly developed ICEYE sea ice products and ice charts to the relevant user groups.

3.2 ICEYE data processing level, format, ordering and delivery

In the tests during the winter 2025 ICEYE data were delivered through the ESA Rapid Response Desk (RRD) ftp site (ftps). The image ordering is done by the online RRD user interface. Because the whole RRD system is new some deficiencies have been found. In the case of ICEYE SCAN mode data it has not been possible to include all the desired data properties in the orders, except in the comment field (a free text field). Probably because of the restrictions in the RRD data ordering the ICEYE data on the ftp site has been provided at different processing levels and in different formats. The data have often been in georectified GTIFFformat with JSON metadata. The desired format is georeferenced GTIFF data with XML metadata. This format enables proper calibration and e.g. incidence angle grid computation. Proper calibration and incidence angle grid are important for automated ICEYE image interpretation. Also, part of the 2025 test set were also provided on the RRD ftp as zip packages with both georectified and georeferenced data included. For automated operational data downloading it is necessary to have the data in a predefined format, either as separate GTIFF and XML files or as zip packages including these data. The 2024 data set was provided through ICEYE ftp and the format was always correct (georeferenced GTIFF and XML), this suggests that there has been problems with the ordering system or the way the order information are processed. If ICEYE data will be used as operational Copernicus Marine Service CCM data the ordering process and data delivery must be consistent, unambiguous and comprehensive. These format specifications, including file naming conventions, must be agreed in advance and possible changes must also be informed in advance.

3.3 Service provision and user interface

Even though FMI's Geoserver would allow access to all data products via API, the envisioned data provision to the marine sector is through IBNet, which is the official winter navigations awareness portal. The system is co-owned and developed by the winter navigation authorities in Finland and Sweden. FMI has a working interface from its own servers to this official portal (Figure 12). FMI provides satellite imagery and met-ocean data to the system and thus to both countries. 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 Finnish waters. The access to IBNet is restricted to licensed users only.

This system offers access to various relevant map layers, like wind fields, sea depth and many more, which can be selected by the users. Additionally, shipping route conditions, nautical charts and weather information are embedded in this portal. The system is interactive, and users can zoom into the area of interest. It helps to evaluate the condition of the shipping route. General information like location of lighthouses, harbors, sea depth and coastlines can be shown. Additionally, this service includes satellite-based information on ice conditions, as this contract tests to extend the service to the newly ICEYE derived ice charting products. Vessels can directly access all relevant information on their ship bridge with IBNet and supports captains and personnel in charge on their shipping routes.

The developments done in this project now allow the new ICEYE products be added to the service systems. The operational processing chain for ICEYE images has been set up and the ice classification method has been developed. The interfaces between FMI's processing servers and the official marine mapping service IBNet have been extended to the new ICEYE ice charts. During the reporting period first images from winter 2024/2025 have been implemented for testing purposes. Figure 12 shows the first ICEYE ice charts how they look in the IBNet system. The processing chain is embedded in an ecflow system to ensure future operational monitoring of processors and process management. As soon as FMI receives more ICEYE images, new products will be processed accordingly, and ice charts will be automatically linked to IBNet. Due to the high spatial resolution of ICEYE SAR images, those new products on ice classification and ice drift offer a real added value in sea ice monitoring and the shipping industry. More images from the operative chains will be disseminated to FMI icebreaking service. Feedback on the usefulness will be collected from partners in the navigation industry (link to WP5). This development is conducted in collaboration with the Winter Navigation (a unit at the Finnish Traffic Infrastructure Agency responsible for operations around icebreaking). It is planned to invite end-user representatives, such as icebreaker bridge officers, to the upcoming Midterm Review meeting and discuss the potential of those new ICEYE products.

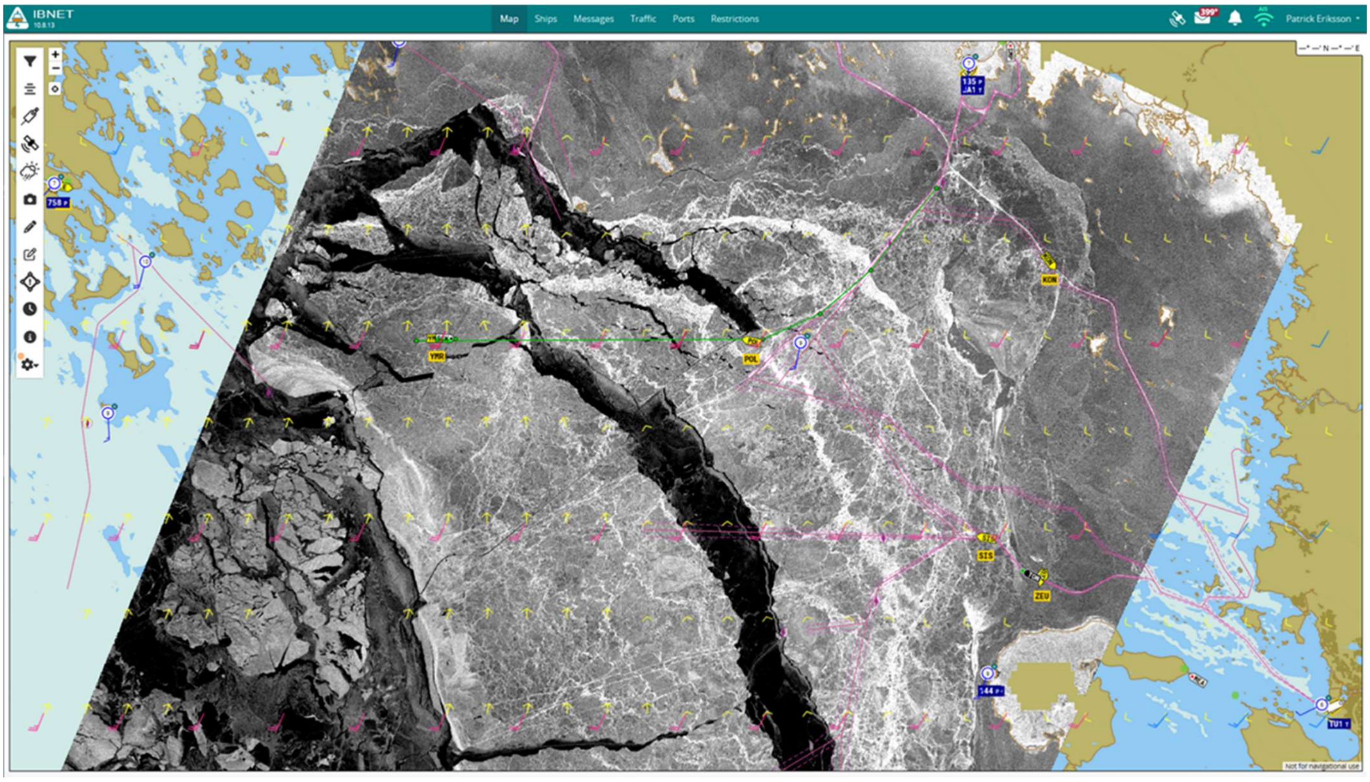


Figure 12. Example of ICEYE derived ice charts provided via the IBNet navigation tool accessible for marine services and navigation authorities, such as icebreakers, and captains at the ship bridges in general.