



# ARCTIC PASSION

Deliverable 4.1

Lake Ice Service Readiness Report

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## 1. Introduction

Lake Ice Service for Arctic Climate and Safety is one of the eight pilot services of the Arctic PASSION project. The purpose of the Lake Ice Service Readiness Report is to describe the current status of the Lake Ice Service as well as the future steps towards the expanded service.

The Lake Ice Service collects lake ice information from multiple sources and visualizes the information in a format that is easy to access and understand. This information will be exploited by citizens and local communities as well as for scientific purposes. Lake ice is sensitive to intra-annual temperature fluctuations and long-term temperature trends. Climate change will likely have dramatic impacts on lake ice phenology in Arctic regions. Beside the climate change aspect, lake ice data are important regarding transport, arctic livelihood, and safety issues. Additionally, lake ice affects water quality, the lake ecology and local weather by reducing the energy exchange between water and the atmosphere. In the framework of Arctic PASSION, the first version of the Lake Ice Service is implemented in SYKE's TARKKA+ service. This service will be further extended to cover more features to be exploited by the users. The predecessor of TARKKA+ is TARKKA, where part of the service features was developed and will be further transferred to TARKKA+.

Arctic PASSION is an innovative pan-Arctic Observation and Monitoring action that rises to the challenges of climate change facing the people living and working in the Arctic, and to European society at large. The purpose of Arctic PASSION is co-creation and implementation of a coherent, integrated Arctic observing system. This will be achieved by refining its operability, improving and extending pan-Arctic scientific and community-based monitoring systems and services, streamlining the access and interoperability of Arctic Data systems, and crucially ensuring the economic viability and sustainability of the observing system for years to come. The Arctic PASSION project is described in more detail in the project website <https://arcticpassion.eu/>.

## 2. Service requirements

People living and working in the Arctic have been demanding a holistic approach to environmental information services. The service should provide information in an easy-to-access and simple format preferably on daily basis. Importantly, the service is expected to enhance sustainable economic activity and wellbeing. Also, the significant changes observed in the climate during the past decades have created pressure to increase the effectiveness of environmental monitoring in the Arctic regions. Timely detection of changes in the environment – particularly concerning the cryosphere – has a significant role in intervening, resilience and early adaptation to undesirable changes. Satellite-based Earth Observation (EO) techniques provide the only effective means to monitor the vast areas on the Earth. Although in-situ observations of ice cover are valuable, they are typically made from shore when the ice is freezing or melting, while satellites offer information about all parts of the lake. However, the economic aspects set limits on the available remote sensing methods. High spatial resolution data is often expensive and covers only small areas at the same time. Thus, high spatial resolution goes often hand in hand with low temporal resolution (at local level, there may be several days gaps in the data). For environmental monitoring satellite acquisitions with short revisiting time is typically exploited: these provide a pixel size of hundreds of meters. In addition, cloud cover and polar darkness obstructs the visibility to the earth surface when

using optical satellite data which are the main source for detecting lake ice. This causes a strong need for enhanced collecting of in-situ observations.

There is an increasing need to develop an observing system for lake ice that combines data from different sources. Lake Ice Service will fill this gap by collecting, combining, and visualizing EO-derived lake ice data, in-situ data of governmental network and community-based monitoring (CBM). Additionally, people living and working in the Arctic are increasingly facing the challenges brought by climate change, so there is growing need to provide language support for user interfaces and the observation submission questionnaires in different local languages. Use of local languages in surveys is a culturally valuable and increases the motivation/opportunities of the indigenous communities to make observations. In addition, it is important to conduct surveys in cooperation with the local communities. Citizen involvement in different voluntary crowdsourcing on local observations, analyzing local conditions from EO data based on local knowledge and other types of CBM approaches fundamentally require internal motivation for participation of the stakeholders involved. Basically, this will depend to a great extent on the utility and results achieved in these activities as a contribution to other needs and requirements in other aspects of the life in the local communities. As a result, it would be highly important to have the involvement of the local communities in planning and implementing the CBM activities, including those on crowdsourcing in association with EO.

### 3. Data sources and status

The Lake Ice Service will make both Earth observation and in-situ data available to the users. The service will include a practical tool to find available information about a lake with a search based on the lake name. The tool navigates to the specified lake and the datatypes of interest can be selected for display. In the following, the data sources are described in more detail.

#### 3.1. Earth observation data

Lake Ice Service module collects information from the Copernicus services. Current and future satellite data sources and interfaces in TARKKA+ for “Lake ice service” are presented in Table 1. Currently, the service utilizes Lake Ice products of Copernicus Global Land Service (CGLS) including 250m resolution daily Lake Ice Extent (LIE) product for the Northern Europe (LIE-NE) (Figure 1). LIE-NE is based on Terra satellite Moderate Resolution Imaging Spectroradiometer (MODIS). LIE-NE daily product is available from March 2017. In addition, the service includes daily (CGLS) Northern Hemisphere LIE (LIE-NH) product which covers Northern Hemisphere in 500m resolution (Figure 2). LIE-NH is based on Sentinel-3 Land Surface Temperature Radiometer (SLSTR) data. More information about the LIE-NE and LIE-NH products can be found in the Copernicus Global Land website <https://land.copernicus.eu/global/products/lie>.

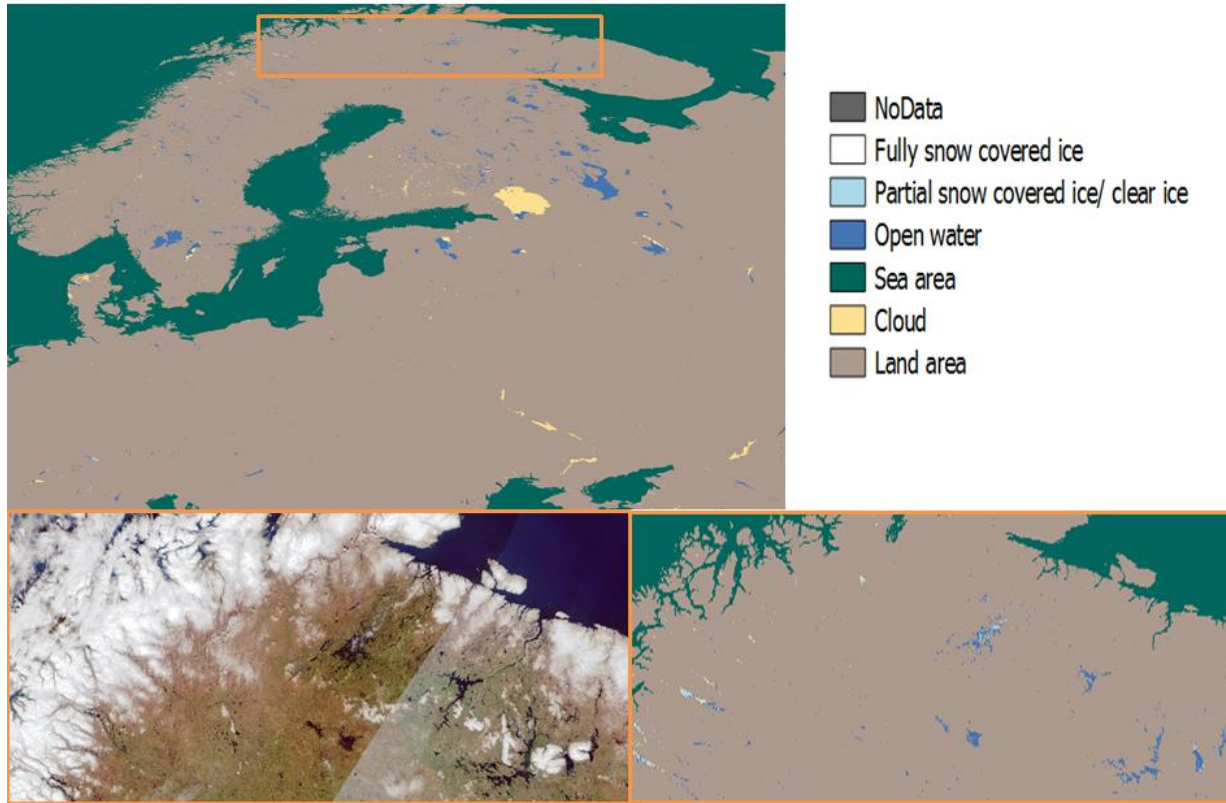


Figure 1. Top: Copernicus Global Land Lake Ice Extent product for Northern Europe in 250m (LIE-NE) resolution on 3<sup>rd</sup> June 2021. Bottom: A fragment of the product above (right) as well as a true color image (Sentinel-2 MSI and Sentinel-3 OLCI) from the same fragment (left).



Figure 2. Copernicus Global Land Lake Ice Extent product for Northern Hemisphere in 500m (LIE-NH) resolution on 21 April 2022

Based on the LIE-NH product, statistical information for lakes Lokka and Tjaktjajaure, were produced for years 2018-2022 and will be added to the Lake Ice Service (Figure 3). The next step is to build a processing pipeline to calculate daily statistics for individual LIE-NH lakes with an area > 10 km<sup>2</sup>. The number of lakes will be gradually increased.

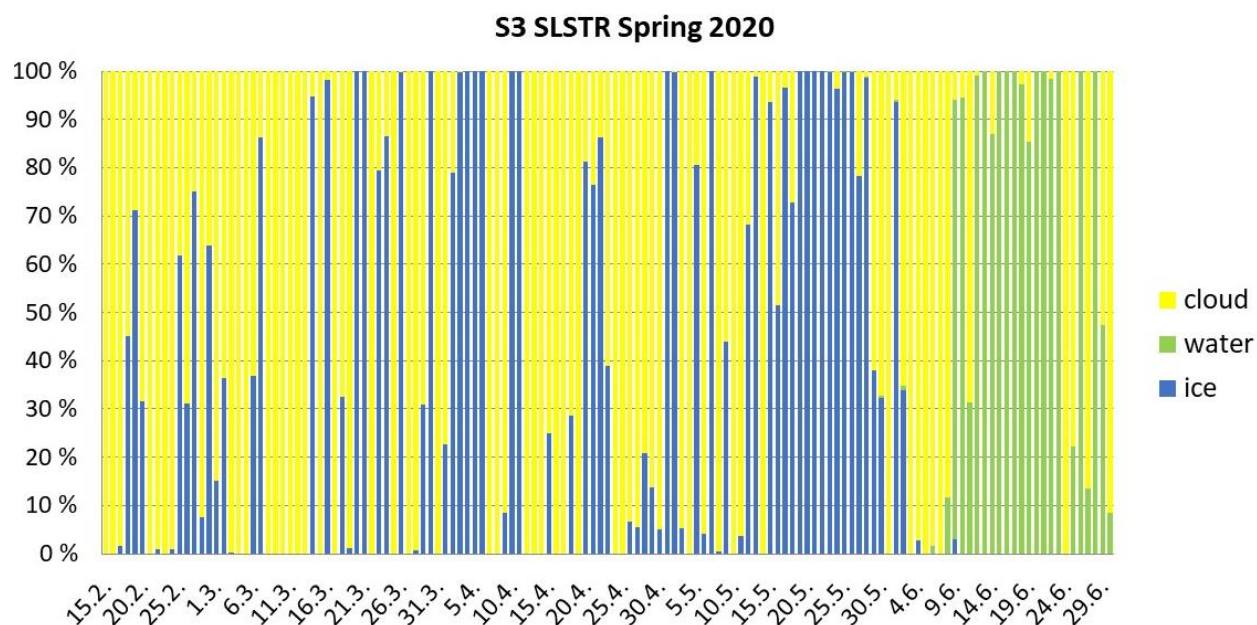


Figure 3. Sentinel- 3 SLSTR based Lake Ice Extent statistics for lake Lokka reservoir, Finland, during spring 2020. Statistical information like this will be available in Lake Ice Service for individual lakes with an area >10 km<sup>2</sup> during the next phase.

Lake Ice Service module visualizes high resolution satellite true color images using Sentinel-2 MultiSpectral Instrument (MSI) (10m resolution) and Landsat-8 The Operational Land Imager (OLI) (30m resolution). Additionally, Sentinel 3 Ocean and Land Color Instrument (OLCI) true color images at 300m resolution are available. Example of the true color Sentinel-2 MSI data is provided in Figure 4 Left.

In addition to CGLS LIE-products, the suitability of the Copernicus high resolution River and Lake Ice Extent (RLIE) products as a data source for the Lake Ice Service was investigated (<https://land.copernicus.eu/pan-european/biophysical-parameters/high-resolution-snow-and-ice-monitoring/ice-products>). The current version has occasional difficulties in ice classification and misclassifications are more frequent than with the Copernicus Global Land LIE-NE 250m resolution product. Figure 4 illustrates the misclassification from the lake Pepsi in Estonia on 21<sup>st</sup> April 2022, where wide areas of ice cover clearly visible in true color image (Left) are erroneously classified as water in RLIE (Middle). RLIE includes a confidence level, which could be very useful information to accept only high and medium quality interpretations to be visible in Lake Ice Service. However, at the moment it is not reliable since e.g., in the case presented in Figure 4, the confidence level is “High quality”, see Figure 5. Thus, it is decided that RLIE product will not be included to the Lake Ice Service yet (until their quality is improved).

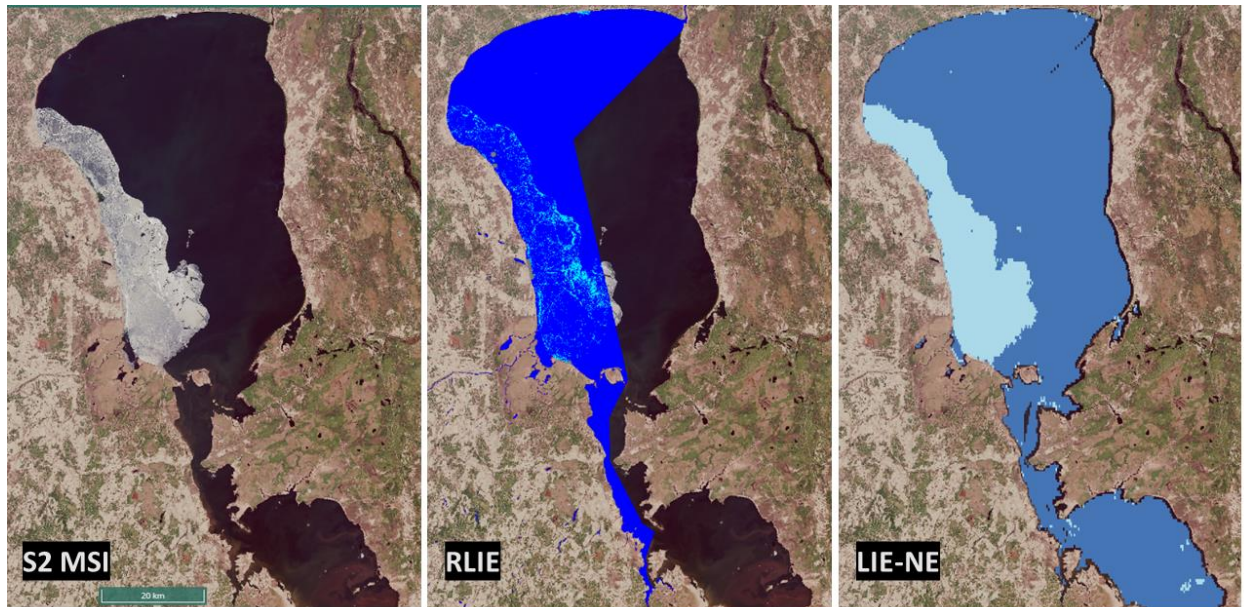


Figure 4. Sentinel-2MSI true color image (Left), Copernicus Land River and Lake Ice Extent (RLIE) product (Middle) and Copernicus Global Land Northern European Lake Ice Extent product (Right) from Peipsi, Estonia, on 21<sup>st</sup> of April 2022. In the products the light blue represents ice and blue represents water.



Figure 5. Confidence level of Copernicus Land River and Lake Ice Extent (RLIE) product from Peipsi, Estonia, on 21<sup>st</sup> of April 2022.

Table 1. Current and future satellite data sources and interfaces in TARKKA+ for “Lake ice service”.

Dataset	Origin	Interface type
<b>Current raster data</b>		
CGLS Lake Ice Extent Northern Europe (250m)	SYKE open data (GeoServer)*	WMS
CGLS Lake Ice Extent Northern Hemisphere (500m)	SYKE open data (GeoServer)*	WMS
Sentinel-2 true colour data (10m)	Sentinel hub service with SYKE modifications	WMS
Sentinel-3 true colour data (300m)	Sentinel hub service with SYKE modifications	WMS
Landsat-8/9 true color data (30m)	Sentinel hub service with SYKE modifications	WMS
<b>Coming raster data</b>		
River and Lake Ice Extent Europe (20m) in 2023	Copernicus Land Monitoring Service (CLMS)	WMS

### 3.2. In-situ data and crowdsourcing

SYKE has developed platforms called Järviwiki ([www.jarviwiki.fi](http://www.jarviwiki.fi)) and CitobsDB to collect and store citizen observation data. To disseminate the Lake Ice Service and collaborate with users, we will link with our Citizen Based Monitoring (CBM) network, AMAP and other users. Connections will also be built to future Arctic GEOSS activities. Examples of potential activities combining EO and citizen observations are demonstrated in Figure 6 and Figure 7. These examples highlight the ability to crowdsource phenomena observed in EO data sources. TARKKA public satellite EO data viewing service has a recently implemented service for crowdsourcing: Highlighting service for phenomena of interest (HISP) was recently introduced by FPCUP EO-Crowd project to be available in different activities, including combination to in-situ observations ([www.syke.fi/tarkka/en](http://www.syke.fi/tarkka/en)). URL references to EO data views of interest are collected with classification data, and on location observations of in-situ parameters and general environmental conditions can be all connected to same CitobsDB platform to coordinate them in synergy. For EO data, local features of interest can be highlighted and several different EO observation sources compared. The higher resolution minor open water area seen in Figure 6 is not visible in the corresponding 250m resolution LIE product in Figure 7. With crowdsourced citizen observations, actual situation on location could be verified by information submitted by the local community members. This service for crowdsourcing will be soon implemented to Lake Ice Service in TARKKA+.

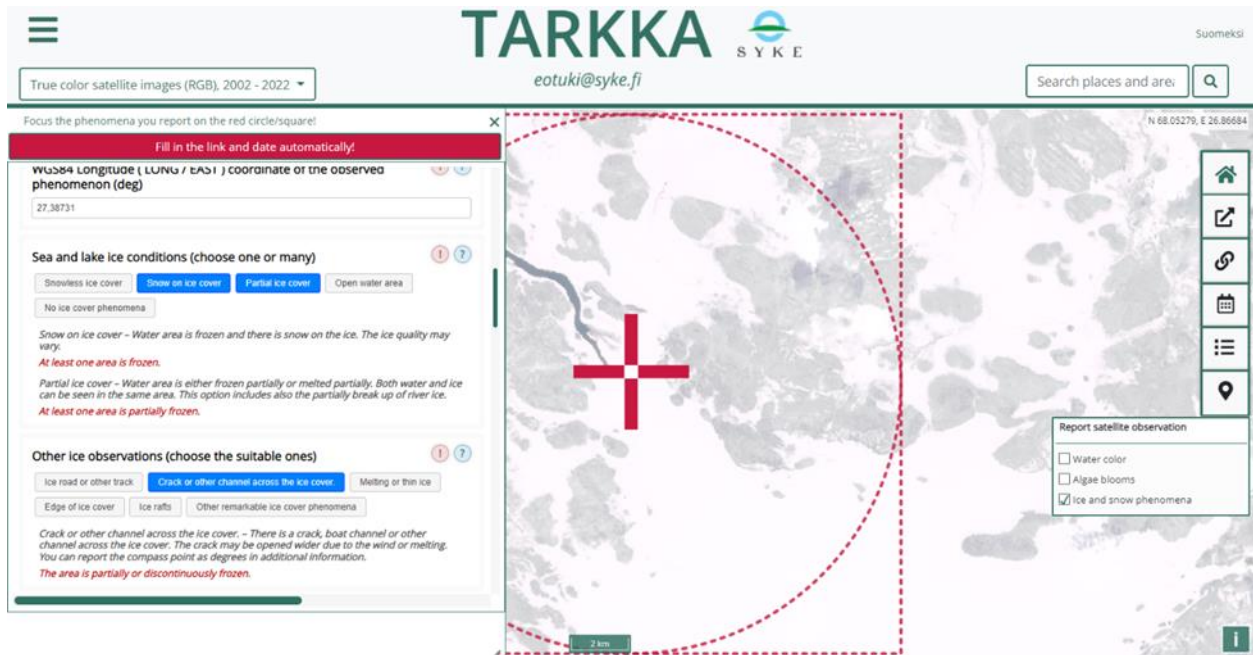


Figure 6: Minor melted area due to river current in Lake Lokka (Sentinel 2 MSI with higher resolution than LIE products) (Contains modified Copernicus data, SYKE (2022))

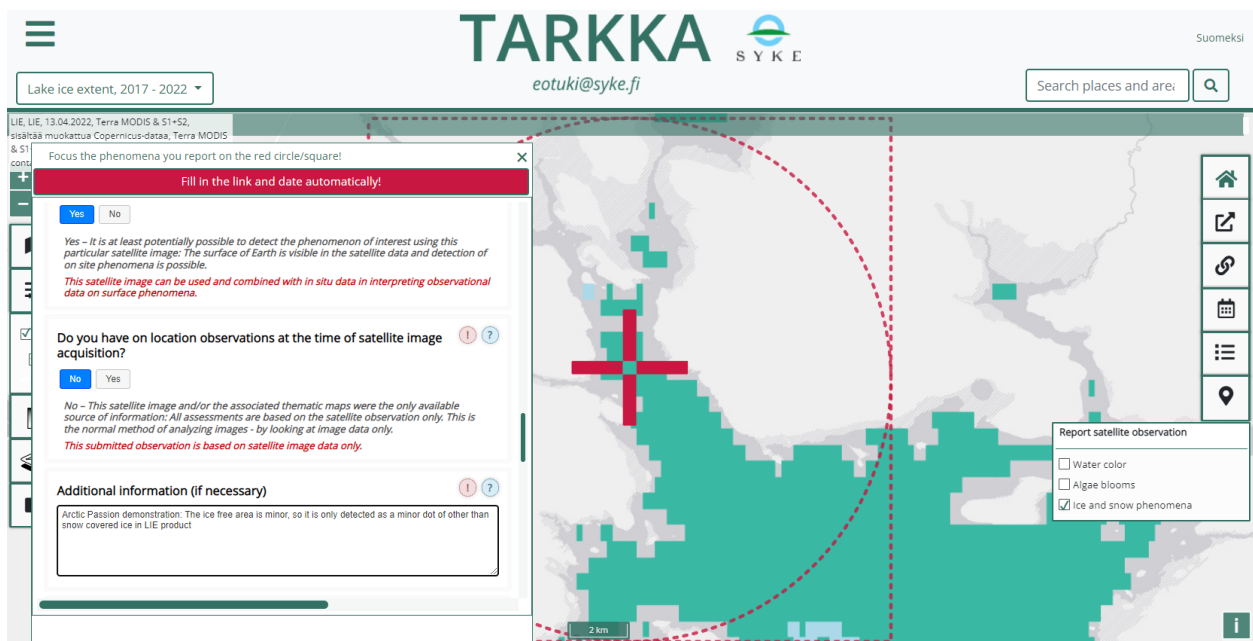


Figure 7: Lake Lokka LIE product at same time as Sentinel-2 MSI image presented in Figure 6 (SYKE data, contains modified Copernicus data (2022-04-13))

The HISP crowdsourced observations on EO data from current TARKKA system on snow and ice can be complemented with in-situ observations by local on-site observers. FPCUP EO-Crowd project implemented SYKE satellite data viewing service TARKKA with capacity to open dialogue windows for users to fill in input forms from SYKE CitobsDB crowdsourcing platform, which provides multiple systems input API interfaces and data models for different environment related observations and notifications.

Each type of submitted information corresponds to extended Open311 data submission service (<https://www.open311.org/> which are modified by SYKE for managing environment and for example HISP related questionnaires) which essentially defines the questions, selectable options, instructions etc. which are “answered” as the observation of a certain type is submitted. The technical capabilities of submitting information, defining the different questionnaires etc. are a service by this SYKE CitobsDB system for the Arctic PASSION project. For the this essentially is an API interface definition and management technical interface and associated data web service – and a modification for the TARKKA viewing services.

The laborious task of defining by iteration and testing the snow and ice related HISP observations and associated tested and finally accepted additional crowdsourcing in-situ services for citizen observers was completed by Arctic PASSION. These include commenting and defining few options to be selected in the interface, defined only by few words but containing and separating multitude of observable cases in a manner which could provide useful information even by a non-expert who looks at satellite images for e. g. ice and open water features on a lake. At the same time, the crowdsourcing services for marking date and location of similar features on location were designed. Definition of these data models are crucial, as it will not be possible to modify these for observations which are already made without compromising data accuracy: For long term use, static content of the questions asked is essential for understanding changes – and not to confuse them by e. g. changing observing instructions for citizen observers. Non-EO data requires separate input map form services to be installed elsewhere, with consideration to other pre-existing ice related services in CitobsDB, e. g., those used in [vesi.fi](http://vesi.fi) and [jarviwiki.fi](http://jarviwiki.fi) portals for water related information. Thus, creating the methods for crowdsourced data content was the essential task in Arctic PASSION crowdsourcing.

For TARKKA enabled HISP submission and satellite data product viewing and associated in-situ activities, a dedicated crowdsourcing service implementation gathering similar information was designed for HISP associated crowdsourcing (HISPCO): For practical implementation, QR codes printed on stickers were – and will be – disseminated as a gateway and a reminder for local population. By being reminded and by using the QR code attached with the sticker for example on the all-terrain vehicles or snow scooters, participants of observation will land to current web (or in future, previously loaded offline mobile version) of service for submitting HISPCO observations on location of HISP notifications, and potentially other citizen observations on winter conditions in general.

SYKE has an extensive dataset of official in-situ ice phenology observations; long records and good expertise in studying changes in lake ice climatology (Table 2). This data will soon be included in the Lake Ice Service. Additionally, SYKE’s official warnings considering lake ice will be shown. Example of the visualization of the SYKE’s official and citizen based in-situ ice phenology observations in Lake Ice Service is presented in Figure 8.

Table 2. Finnish Environment Institute's (SYKE) in-situ ice phenology observation network

In-situ dataset	Freezing and breakup	Ice thickness and snow on ice thickness
Coverage	Finland	Finland
Unit	Date	cm
Accuracy	$\pm 1$ day	$\pm 1$ cm
Observation interval	Daily observations	3 per month (10 <sup>th</sup> , 20 <sup>th</sup> , 30 <sup>th</sup> )
Areal extent	Entire observation period: 50 sites	Entire observation period: 46 sites
Temporal coverage	1753–2022	1912–2022

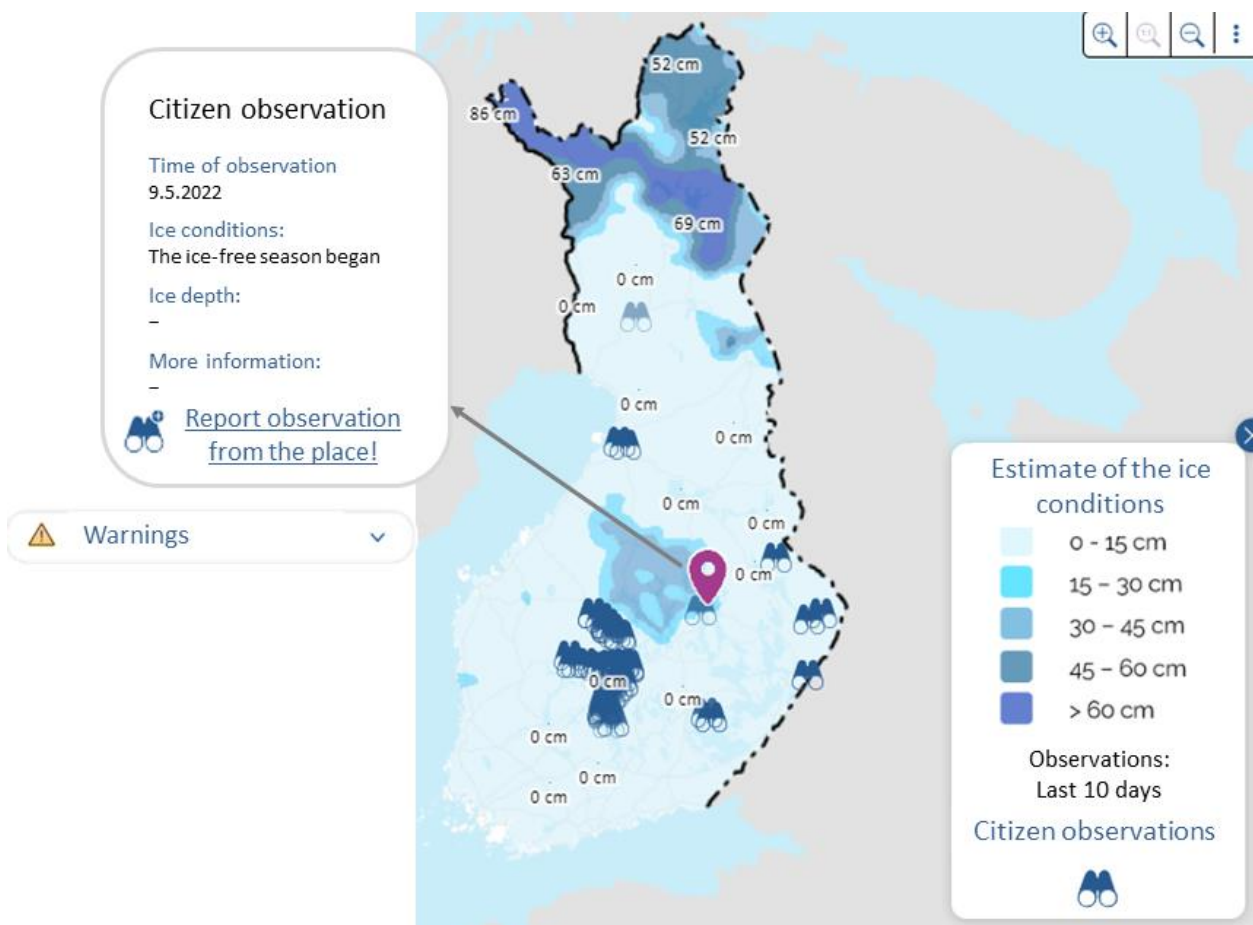


Figure 8. Example of the visualization of SYKE's official and citizen based in-situ ice phenology observations in Lake Ice Service.

## 4. TARKKA+ service

SYKE has developed the TARKKA interface ([www.syke.fi/tarkka/en](http://www.syke.fi/tarkka/en)) to visualize satellite and other observations in a user-friendly way. The first version of TARKKA was published in 2017 within a Finnish government funded VESISEN project (TARKKA 1.0). The TARKKA framework is undergoing life-cycle management, which will result in a modernized version of the TARKKA framework called TARKKA+ (demo version in [https://testbed.ymparisto.fi/eo-tarkka/mapandwaterareas/?bbox=-6.75376,60.64633,46.90663,71.24137&data=esri\\_gray\\_base,lake\\_ice\\_modis\\_data&collectionId=tarkka\\_lake\\_ice\\_service\\_data](https://testbed.ymparisto.fi/eo-tarkka/mapandwaterareas/?bbox=-6.75376,60.64633,46.90663,71.24137&data=esri_gray_base,lake_ice_modis_data&collectionId=tarkka_lake_ice_service_data)). TARKKA+ is a highly customizable web application framework for visualizing spatiotemporal data both on map and as statistical timeseries. The app builds on the React and OpenLayers frameworks. It utilizes OGC compliant data providers, with customizations implemented for several external data providers. Although the web app frontend presented for the end user is the most visible part of the TARKKA+ platform, the actual data handling relies heavily on backend APIs and data processing workflows which are not visible to the end user.

TARKKA+ provides the user with abilities to select which data the user wants to utilize, along with both temporal and spatial controllers. The user can access timeseries data for regions of interest (ROI) by selecting the ROI using map tools. Both in-situ and Earth Observation data can be utilized simultaneously, as well as supporting GIS-datasets to further tailor the users' viewpoint.

The Arctic PASSION theme "Lake ice service" is built on top of the TARKKA+ at its current development state. "Lake ice service" theme can be selected via theme selector on TARKKA+, see Figure 9. Currently "Lake ice service" utilizes data sources described in Table 3. The user can select the date of interest with the calendar and spatial area of interest by using map functionalities of TARKKA+ EO map viewer (Figure 10).

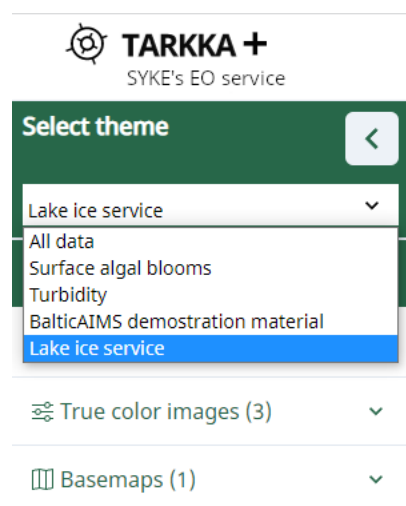


Figure 9. TARKKA+ theme selector, which allows user to select "Lake ice service" theme.

Table 3. Data sources and interfaces currently utilized in TARKKA+ for “Lake ice service”.

Dataset	Origin	Interface type
<b>Raster data</b>		
CGLS Lake ice extent (LIE-NE, Terra MODIS based data)	SYKE open data (GeoServer)*	WMS
CGLS Lake ice extent (LIE-NH, Sentinel-3 SLSTR based data)	SYKE open data (GeoServer)*	WMS
Sentinel-2 true colour data (10m)	Sentinel hub service with SYKE modifications	WMS
Sentinel-3 true colour data (300m)	Sentinel hub service with SYKE modifications	WMS
Landsat-8/9 true color data (30m)	Sentinel hub service with SYKE modifications	WMS
<b>Base maps</b>		
OpenStreetMap	Base map native in OpenLayers library	WMS
NLS base map of Finland	National Land Survey of Finland, open data	WMTS
NLS terrain maps of Finland	National Land Survey of Finland, open data	WMTS
ESRI gray base map	Grayscale map provided by ESRI	WMS
Corine land cover of Finland	Land cover interpretation of Finland from year 2018	WMS
Corine land cover of Europe	Land cover interpretation of Europe from year 2018	WMS
	* <a href="https://www.syke.fi/en-US/Open_information">https://www.syke.fi/en-US/Open_information</a>	

“Lake ice service” in TARKKA+ will in the future collect information from various data sources, such as the Copernicus Global Land Service (CGLS), official ice monitoring station databases, and citizen observation databases. It already provides LIE-NE data through standard OGC interfaces hosted by SYKE’s geoserver to TARKKA+ visualization modules. LIE-NH data will be included later. This LIE data can be utilized in various GIS and map solutions. The current data flow to TARKKA+ and GIS users is described in Figure 11. For more information about data access see: [https://www.syke.fi/en-US/Open\\_information/Open\\_web\\_services/EO\\_web\\_map\\_services](https://www.syke.fi/en-US/Open_information/Open_web_services/EO_web_map_services).

Later also tools for selecting and downloading data will be added to TARKKA+ so that operational agencies and others can ingest data into their own processing and analysis systems.

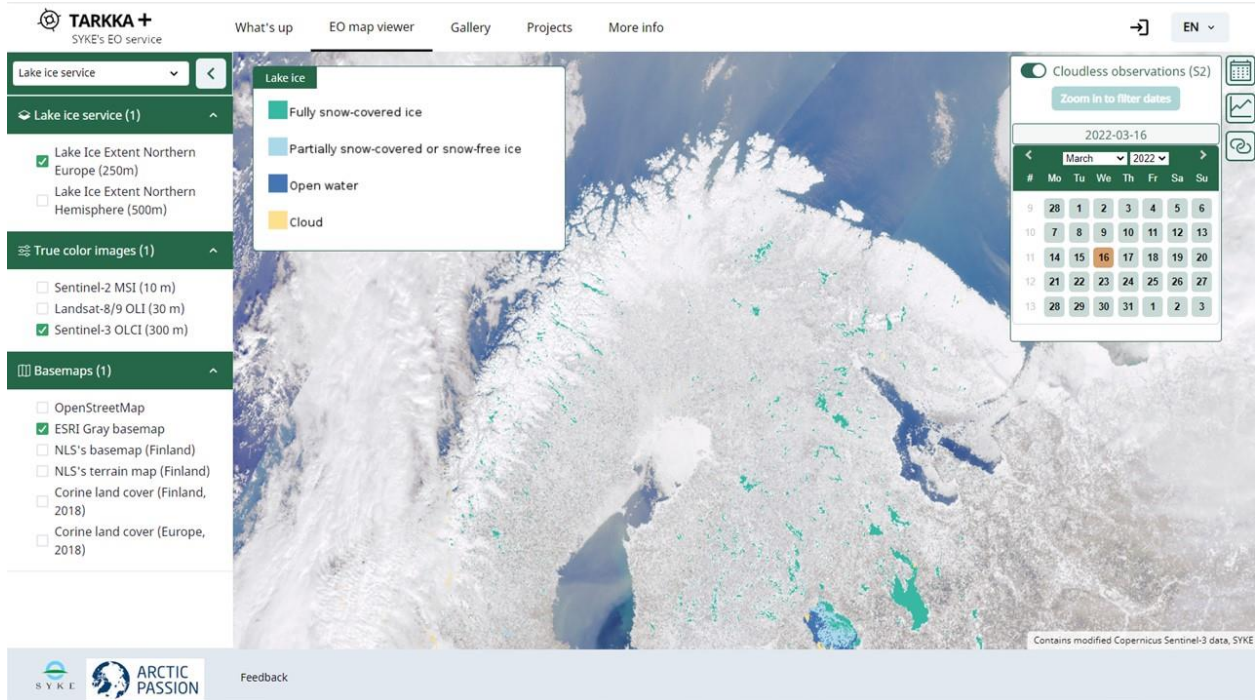
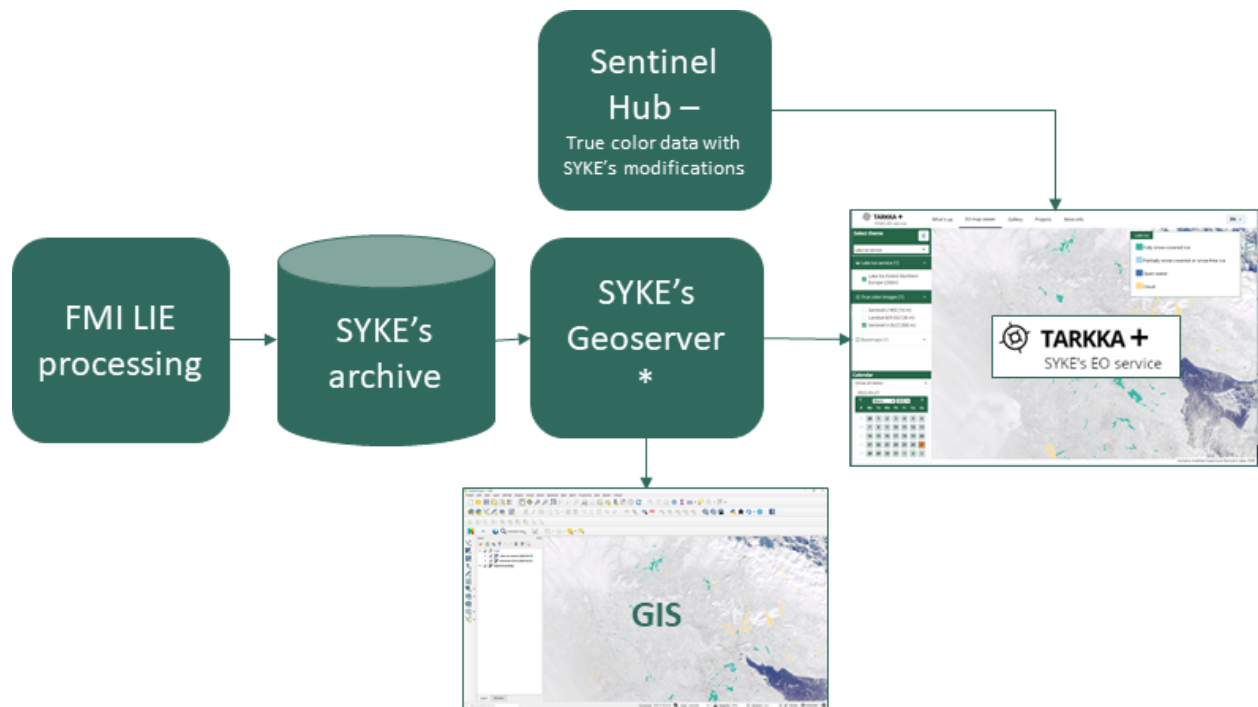


Figure 10. A screenshot of TARKKA+ presenting Lake ice extent of Northern Europe and true color images.



\* [https://www.syke.fi/en-US/Open\\_information/Open\\_web\\_services/EO\\_web\\_map\\_services](https://www.syke.fi/en-US/Open_information/Open_web_services/EO_web_map_services)

Figure 11. Diagram of how the data ends up being used by users in TARKKA+ and GIS systems.

## 5. Service evolution plans and next steps

The next step in the data content enhancement is to build processing pipeline to calculate daily statistics for LIE-NH lakes with an area  $> 10 \text{ km}^2$ . Additionally, more convenient Citizen Observation user interface technology will be built. This will be mobile phone friendly system which is less dependent on web access. The language support for user interfaces will also be improved and the observation submission questionnaires will be available for different local languages.

In addition, for example local snowpack properties such as those relevant for SAR data interpretation on snow could be included in crowdsourcing systems. The ability to trigger requests for new relevant observations based on submitted information are in demonstration phase: E.g., EO observation of a phenomenon of interest on a location could be used as a trigger to ask for observations on the same day and after a few days from the interested participants of monitoring on location.

In the future, user requirements and feedback will further improve the information content and the functionalities of the Lake Ice Pilot Service for Arctic Climate and Safety. These will help to ensure safe commercial, cultural, subsistence and leisure activities on European Arctic lake ice. The first version covers Finland and includes the main features required by users. The expanded version will be improved based on user feedback, and cover Sweden and Norway, and potentially also Greenland, Canada and USA through our partners in those places. It is essential to co-design the Lake Ice Pilot Service (PS8) with users. The map user interface TARKKA+, into which the Lake Ice Service is integrated, has been developed in co-operation with users in various projects, with strong collaboration (EU Horizon 2020 funded Arctic PASSION and WQeMS, ESA funded BalticAIMS, Finnish Ministry of Finance funded CorEO, Finnish Ministry of the Environment funded MAAMERI, SYKE funded SYTYKE). Some of the projects are focused on marine theme, but the same principles are followed in the Lake Ice Service. Regarding the scientific community, the basic understanding of their needs has been gained based on the previous projects (e.g., in EU funded Copernicus Global Land, ESA funded Snow CCI and FP7 funded Cryoland). However, less attention has been paid to cooperation with indigenous and local communities. This defect will be corrected in Arctic PASSION. Major COVID restrictions have affected person-to-person meetings in the first year of the project, but from now on the user meetings will be arranged to demonstrate and discuss the possibilities. So far, we have promoted the service in National Snow Seminar on the day of Pyry (Helsinki, Finland, Feb 2022), ESA Living Planet Symposium (Bonn, German, May 2022) and Reindeer and fish science days (Ivalo, Finnish Lapland, Aug 2022). Additionally, the Arctic PASSION General Assembly (Marienlyst, Denmark, June 2022) enabled important contacts with representatives of indigenous peoples.

As a part of "Arctic PASSION Online Seminar and Dialogue Series", a webinar "Lake ice information in your pocket" will be organized in November 2022, enabling dialogue especially with early career scientists and other interested audiences such as co-creators. Later, the webinar PS8 Part 2 "Lake ice: What can it tell us about the current state and the future of the Arctic?" will be organized in November 2024. The cooperation with PS1 "Arctic Service 'Event Database of CBM Using Oral Histories, IK and LK", will enable connections with indigenous communities and improves the information content of Lake Ice Service for their needs. From now on annual user meetings should be arranged with the maximum support of and co-operation with the local communities and municipalities, to provide maximum amount of beneficial information for them as well. Additionally, the Lake Ice Service will be presented in other suitable workshops, conferences and seminars.

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