ARCTIC PASSION

Deliverable 4.10

# Lake Ice Service Expansion and Utilization Report

Version 1

19-June-2025

101003472 | Arctic Passion

**Work package**

4 – Innovating user-driven Arctic EuroGEO Pilot Services

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**Status**

Project Coordinator accepted

**Dissemination level**

PU



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 101003472

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# 1. Introduction

*Lake Ice Service* for Arctic Climate and Safety is one of the eight pilot services developed within the Horizon Europe Arctic PASSION project. The service provides near-real-time information on lake ice conditions in the Arctic, combining satellite observations, in-situ measurements, and community-based monitoring. The data are made openly accessible through the Tarkka web map platform developed by the Finnish Environment Institute (Syke).

Since the publication of the *Lake Ice Service* Readiness Report in 2022 (Henilä et al, 2022), significant progress has been made to expand the service and improve its usability and societal relevance. The service has grown in data content, and in technical functionalities. New tools have been introduced to support community-based monitoring.

This report outlines the main developments in the expansion and utilization of the *Lake Ice Service*. It describes how the service is being used by communities, authorities, scientists, citizens, and businesses, and highlights key outcomes such as improved safety on ice-covered lakes, increased awareness of climate impacts, and strengthened engagement with Indigenous and local knowledge holders.

Lake ice is a key environmental variable in the Arctic. Its seasonal formation and breakup are closely linked to climate variability and change, with important implications for ecosystems, local livelihoods, transportation, and safety. As the Arctic warms rapidly, the need for timely and accessible lake ice information has grown, both for understanding climate impacts, and for supporting daily decision-making in northern communities.

The *Lake Ice Service* continues to evolve through user-driven design, technological development, and close collaboration with communities. It demonstrates how integrated monitoring services can contribute to climate resilience and informed decision-making in Arctic regions.

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 expansion

Since the initial launch of the *Lake Ice Service* within the Arctic PASSION framework, the service has undergone substantial expansion in both its technical scope and geographic reach. The developments have aimed to enhance the usability, relevance, and accessibility of lake ice information for Arctic users and anyone interested in the Arctic.

The service integrates multiple complementary data sources, each contributing to a more complete and accurate understanding of ice conditions. In the following, the data sources and functionalities are described in more detail.



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## 2.1. Integrated Data Sources for Ice Monitoring

### 2.1.1. Earth Observation Data

*The Lake Ice Service* integrates multiple satellite-based data sources summarized in Table 1. Currently, the service utilizes Near-Real-Time Lake Ice products from Copernicus Land Monitoring Service (CLMS), including i) 250m resolution daily Lake Ice Extent (LIE) product for the Continental Europe (CEURO LIE) (Figure 1) and ii) 500m resolution daily LIE Product for the Northern Hemisphere (LIE-NH) (Figure 2). The CEURO LIE is based on VIIRS (Visible Infrared Imaging Radiometer Suite) data from the NOAA-20 satellite and has been available since July 2024. It is a continuation of the earlier LIE 250 m product for Northern Europe, which was based on MODIS (Moderate Resolution Imaging Spectroradiometer) data from the Terra satellite. The Northern Europe LIE 250 m product is available in the service for the period from March 2017 to June 2024. The LIE-NH product is based on data from the Sentinel-3 SLSTR (Sea and Land Surface Temperature Radiometer) and has been available since April 2021. More information on the CEURO LIE, Baltic LIE, and LIE-NH products is available on the Copernicus Land Monitoring Service website Water Bodies — Copernicus Land Monitoring Service.

*Table 1. Current and future satellite data sources and interfaces in Tarkka for Lake ice service.*

| Dataset | Origin | Interface type |
|---|---|---|
| **Current raster data** | | |
| **CLMS Lake Ice Extent Continental Europe (250m)** | Syke open data (GeoServer)*, CGLS | WMS, ftp |
| **CLMSS Lake Ice Extent Northern Europe (250m)** | Syke open data (GeoServer)*, CGLS | WMS, ftp |
| **CLMS Lake Ice Extent Northern Hemisphere (500m)** | Syke open data (GeoServer)*, CGLS | WMS, ftp |
| **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-colour data (30m)** | Syke's open data (GeoServer)* | WMS |
| **Sentinel-3 SLSTR based Water Surface Temperature (1km)** | Syke's open data (GeoServer)* | WMS |
| **Landsat-8/9 based Water Surface Temperature (10m)** | Syke's open data (GeoServer)* | WMS |
| **Sentinel-1 SAR data (20m)** | Sentinel hub service with Syke modifications | WMS |
| **Coming raster data** | | |
| **CLMS Water Ice Cover Europe (20m) in 2026** | Copernicus Land Monitoring Service (CLMS) | WMS |



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*Figure 1. Copernicus Land Monitoring Service Lake Ice Extent data for Continental Europe (CEURO LIE) in 250 m resolution and Landsat OLI 30 m resolution true-colour image (background) for Lake Inari, Finland, on 23 May 2025. USGS/NASA Landsat Program, Syke, Copernicus Service information, funded by EU.*


*Figure 2. Copernicus Global Land Lake Ice Extent product for Northern Hemisphere (LIE-NH) in 500 m resolution on 23 March 2025.*

The *Lake Ice Service* also provides information on the water surface temperature (Figure 3. Landsat-8/9 TIRS–based water surface temperature (foreground) and Sentinel-2 MSI true-colour image (background) for Lake Inari, Finland, on 12 October 2024. Water surface temperature data provide valuable information, for example, on the potential timing of lake freeze-up.Figure 3). These datasets are based on daily 1 km resolution Sentinel-3 SLSTR data, as well as on higher-resolution, but temporally sparse 30 m data from the Landsat-8/9 TIRS (Thermal Infra-Red Sensor). Water surface temperature data offer valuable insights, for example, into the potential timing of lake freeze-up. As with optical data, cloud cover can obstruct the retrieval of temperature information. To overcome the limitation of clouds and polar night, Sentinel-1 Synthetic Aperture Radar (SAR) data at 20 m resolution have been integrated into *the Lake Ice Service* (Figure 4), as radar can penetrate clouds and operate during darkness. However, interpreting ice conditions from SAR imagery is not always as straightforward as with optical instruments. Despite this, SAR has been specifically requested by users, particularly those involved in hydropower management and flood prevention, due to its ability to provide observations in the challenging Arctic conditions.



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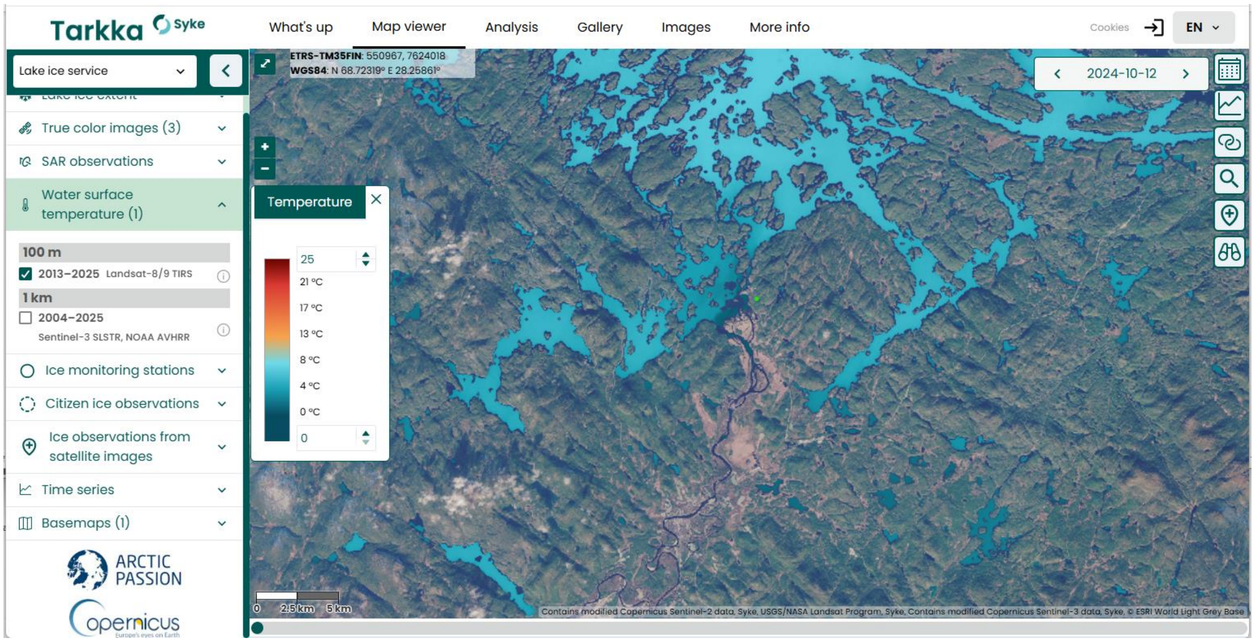


*Figure 3. Landsat-8/9 TIRS–based water surface temperature (foreground) and Sentinel-2 MSI true-colour image (background) for Lake Inari, Finland, on 12 October 2024. Water surface temperature data provide valuable information, for example, on the potential timing of lake freeze-up. Contains modified Copernicus Sentinel-2 data, Syke, USGS/NASA Landsat Program, Syke.*

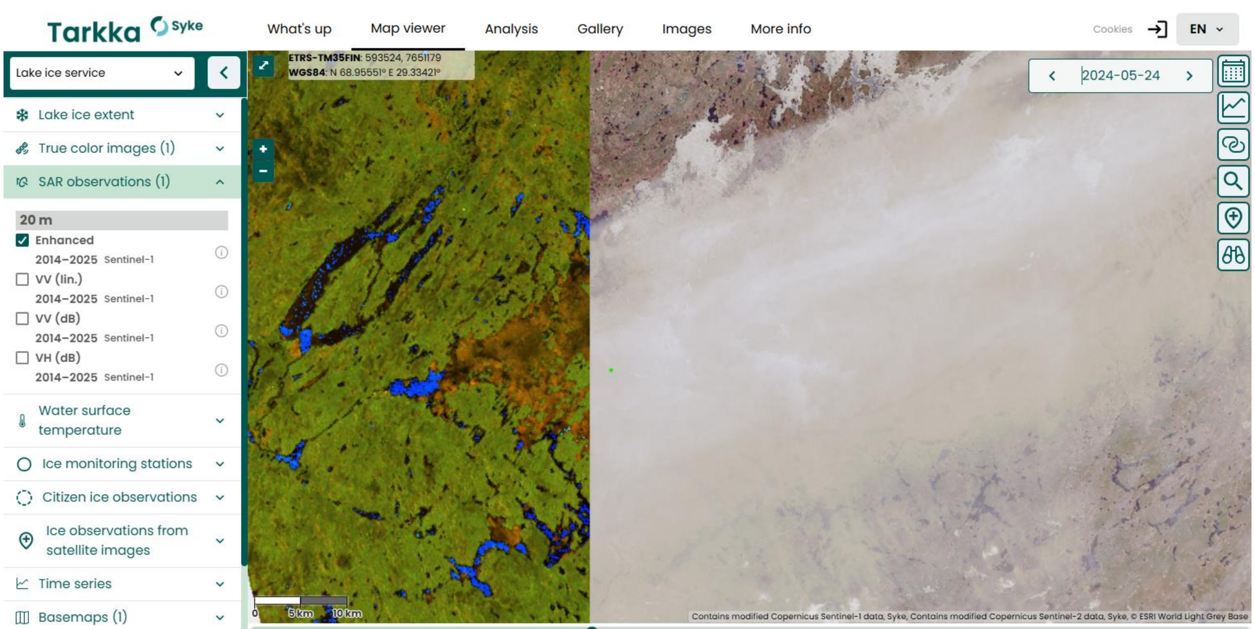


*Figure 4. Sentinel-1 SAR data is added to the Lake Ice Service with a several visualization options. Utilizing the swipe tool, it shows that the Sentinel-2 MSI true-colour image is cloud-covered (right side of the image), while the radar image provides observations of the lake despite the cloud cover. Lake Inari, Finland, on 24 May 2024. (Contains modified Copernicus Sentinel-1 data, Syke, Contains modified Copernicus Sentinel-2 data, Syke)*

The *Lake Ice Service* module visualizes high-resolution satellite true-colour images using Sentinel-2 MSI (Multispectral Instrument) with 10 m spatial resolution and Landsat-8 OLI (Operational Land Imager) with 30 m resolution. The temporal resolution of these datasets is typically a few times per week per sensor. In addition, daily Sentinel-3 OLCI (Ocean and Land Colour Instrument) true-colour images with 300 m



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resolution are available through the service, providing a more extensive view of the area for the user's convenience.

All true-colour images can be viewed with different visualization options, depending on environmental conditions and user needs. Available themes include snow cover, near-infrared, and false-colour composites.

In addition to CLMS medium-resolution 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* have been investigated (River and Lake Ice Extent 2016-2025 (raster 20 m), Europe, daily — Copernicus Land Monitoring Service). The current version has occasional difficulties in ice classification and misclassifications are more frequent than with the CLMS medium-resolution products. Thus, it is decided that RLIE product will not be included to the *Lake Ice Service* until their quality is improved. However, the product is currently under renewal. Syke will validate the upcoming Copernicus high-resolution Water Ice Cover (WIC) -product in 2025−2026, which is set to replace the current RLIE product in CLMS portfolio in autumn 2025. If the quality meets the required standards, the high-resolution WIC product will be integrated into the *Lake Ice Service*.

### 2.1.2. In-situ data and community-based monitoring

Syke has developed platforms to collect and store community-based observations. Community-based monitoring enables residents and others who travel or work on ice-covered lakes to contribute real-time, location-specific information that enhances satellite interpretation and increases situational awareness. To disseminate the *Lake Ice Service* and collaborate with users, we are linking with our community-based monitoring network, Arctic Monitoring and Assessment Programme (AMAP) and other user groups. Examples of activities combining Earth Observation and community-based monitoring are demonstrated in Figure 5. Reported ice observations from satellite images allow users to annotate the imagery with information about ice conditions—such as cracks in the ice—to warn others and contribute to a shared database of local knowledge. A mobile application *Iceobs.app*, also connected with the *Lake Ice Service*, allows users to submit ice observations from the field in just a few seconds even without internet access addressing the connectivity challenges of Arctic regions.



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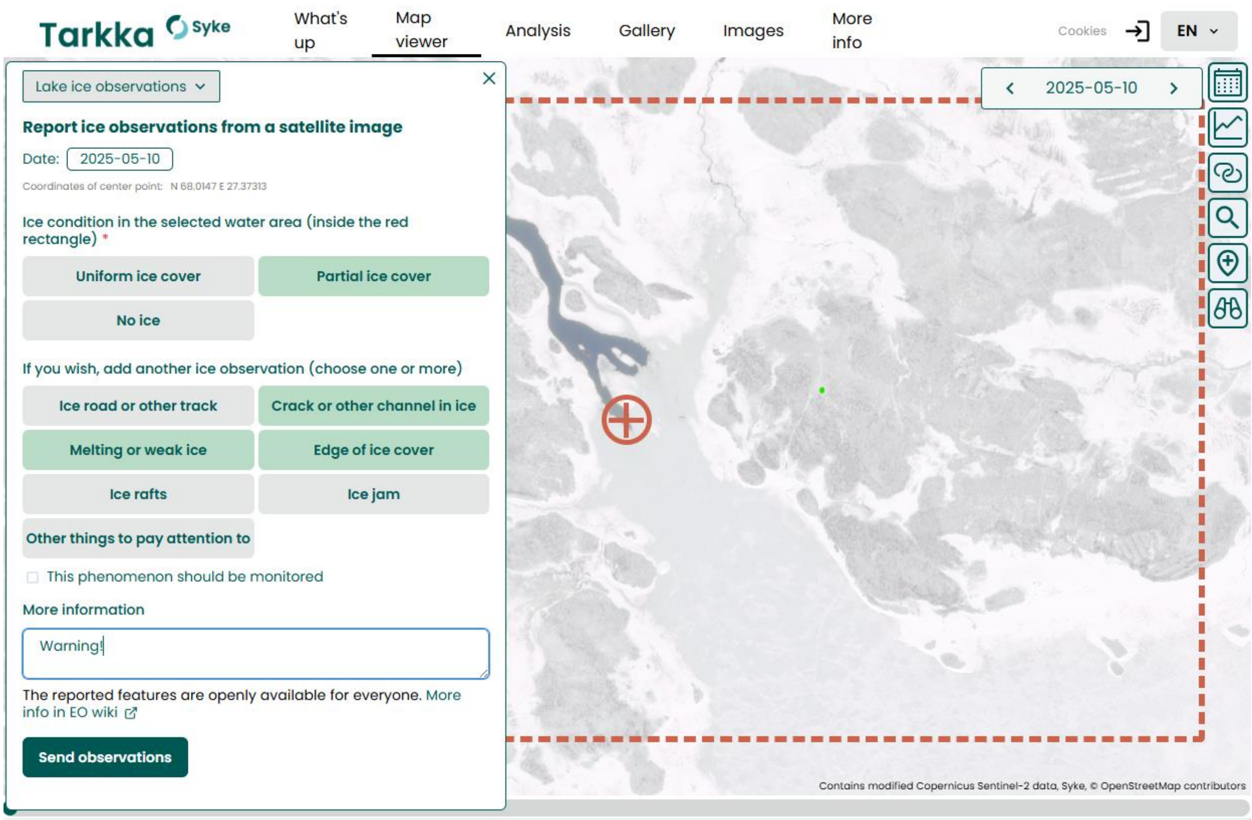


*Figure 5: Melted area caused by river current in the Lokka reservoir, Finland, on 10 May 2025. Reported ice observations based on satellite imagery allow users to annotate images with information about ice conditions, such as cracks, helping to warn others and contribute to a shared database of local knowledge. (Contains modified Copernicus Sentinel-2 data, Syke (2025).*

Ice observations from the Finnish governmental observation network are also visible in the service. Syke maintains an extensive dataset of official in-situ ice phenology observations, with records dating back to the 18th century. The measurements include the thickness of the congelation ice. These long-term datasets enable the study of changes in lake ice climatology. Figure 7 illustrates both field-based and satellite-derived observations in the *Lake Ice Service*.



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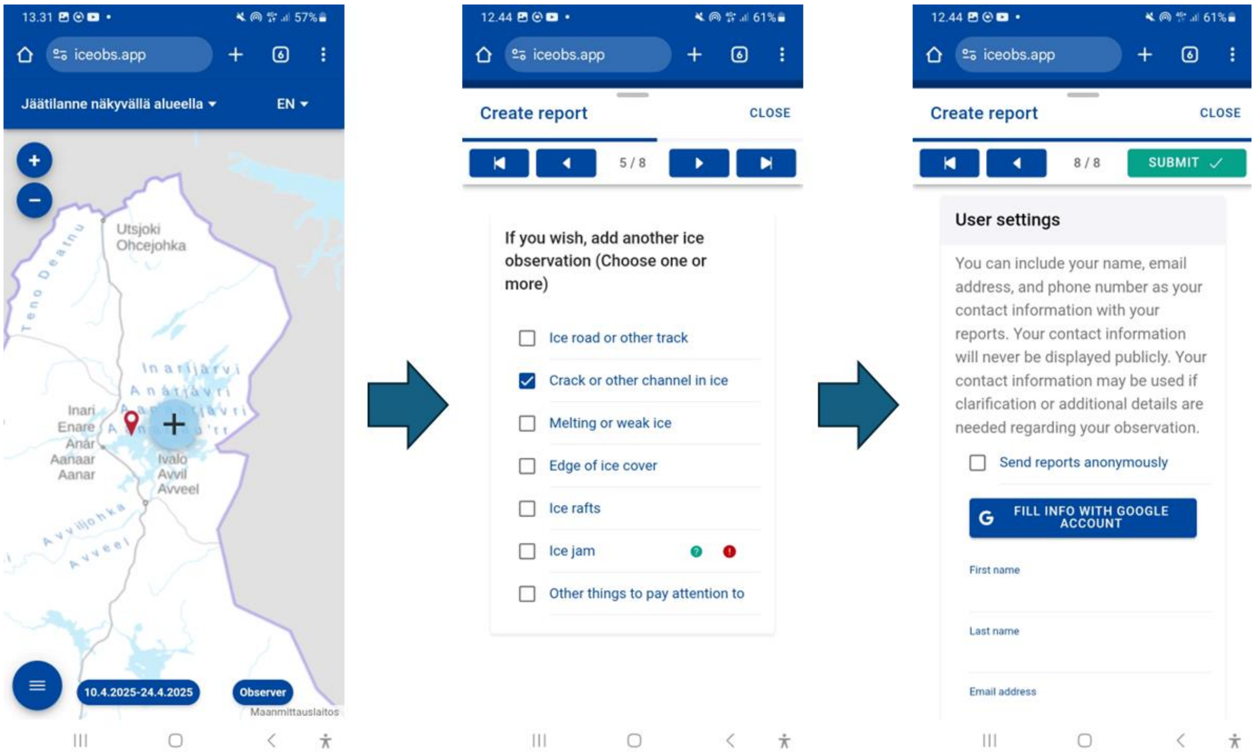


*Figure 6. Iceobs.app enables quick ice observation reporting from the field, even offline. Submitted observations can be viewed in the app (red pin on Lake Inari) and they are also visible in the Lake Ice Service.*

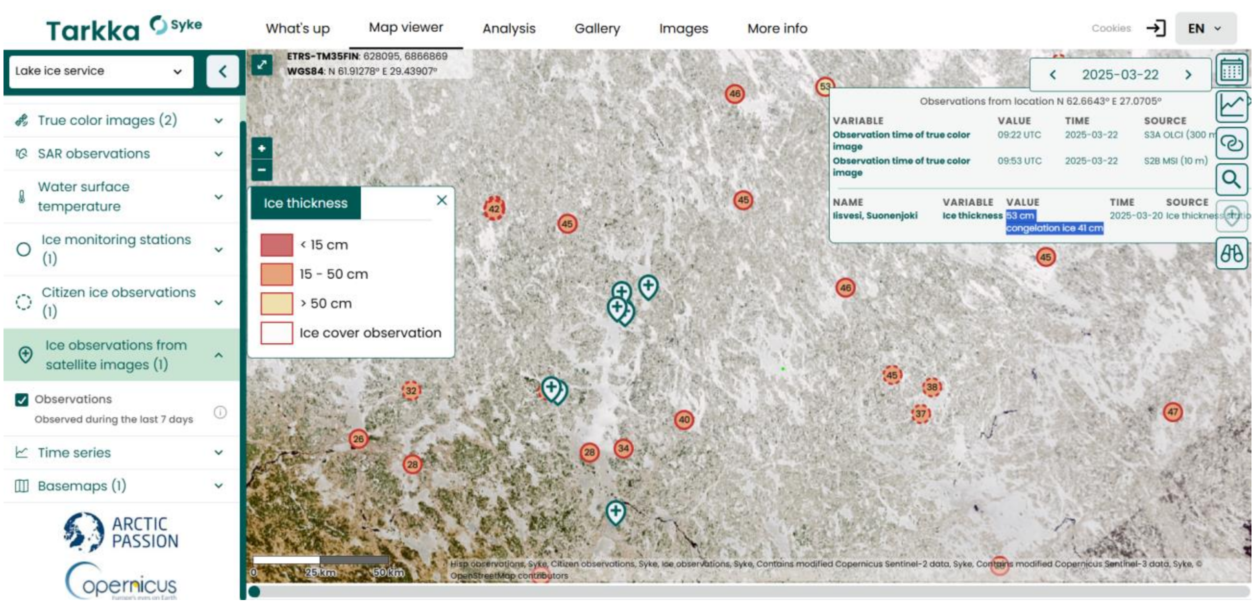


*Figure 7. In situ ice observations submitted instantly from the field, for example via the Iceobs.app, are visualized on the map as dashed circles, with the number inside indicating the measured ice thickness. Solid circles represent measurements from the official observation network, which also include the thickness of congelation ice. The green pins with a plus sign represent observations reported based on satellite imagery (HISP Ice). Image: Hisp observations, Syke, Citizen observations, Syke, Ice observations, Syke, Contains modified Copernicus Sentinel-2 data, Syke, Contains modified Copernicus Sentinel-3 data, Syke,*



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## 2.2. Innovative User Tools and New Functionalities

The *Lake Ice Service* includes tools to increase the user-friendliness as well as the usability of the data. The service includes a practical tool to find available information about a certain 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. Convenient swipe tool allows to swipe between different data sources. When noticing an interesting event on ice, a user can share a direct link to the map view with the selected date, products, and area of interest. By selecting option 'cloudless observations', the days providing cloud-free true-colour observations for the map view are displayed in colour in the calendar. The user should note that this feature requires a relatively strict close-up to the area of interest.

One of the most innovative developments is the ability to highlight phenomena on satellite imagery (*HISP, Highlighting service for Phenomena*), which enables users to visually inspect satellite images, identify features like cracks or weak ice zones, and report them directly through the interface. This empowers users to alert others, improve personal safety, and contribute to a shared knowledge base.

Complementing this, the mobile-friendly *iceobs.app* was launched to allow quick and intuitive field reporting, for example, submitting measured ice thickness or photos from a lake. The app is available across the entire Northern Hemisphere and has already been translated into Sámi languages, demonstrating its adaptability and accessibility for Indigenous communities. Additional languages can be easily added to meet local needs. Offline reporting from the field is also supported, which is particularly valuable in remote Arctic environments.

Another major enhancement is the availability of lake-specific statistical time series, allowing users to monitor daily and yearly changes in ice extent for individual lakes (Figure 10). The statistics are calculated using CLMS 500 m resolution Lake Ice Extent data and, at the time of this report, are available for thousands of lakes in Finland, Sweden and Norway. This feature improves situational awareness and supports long-term trend assessment.



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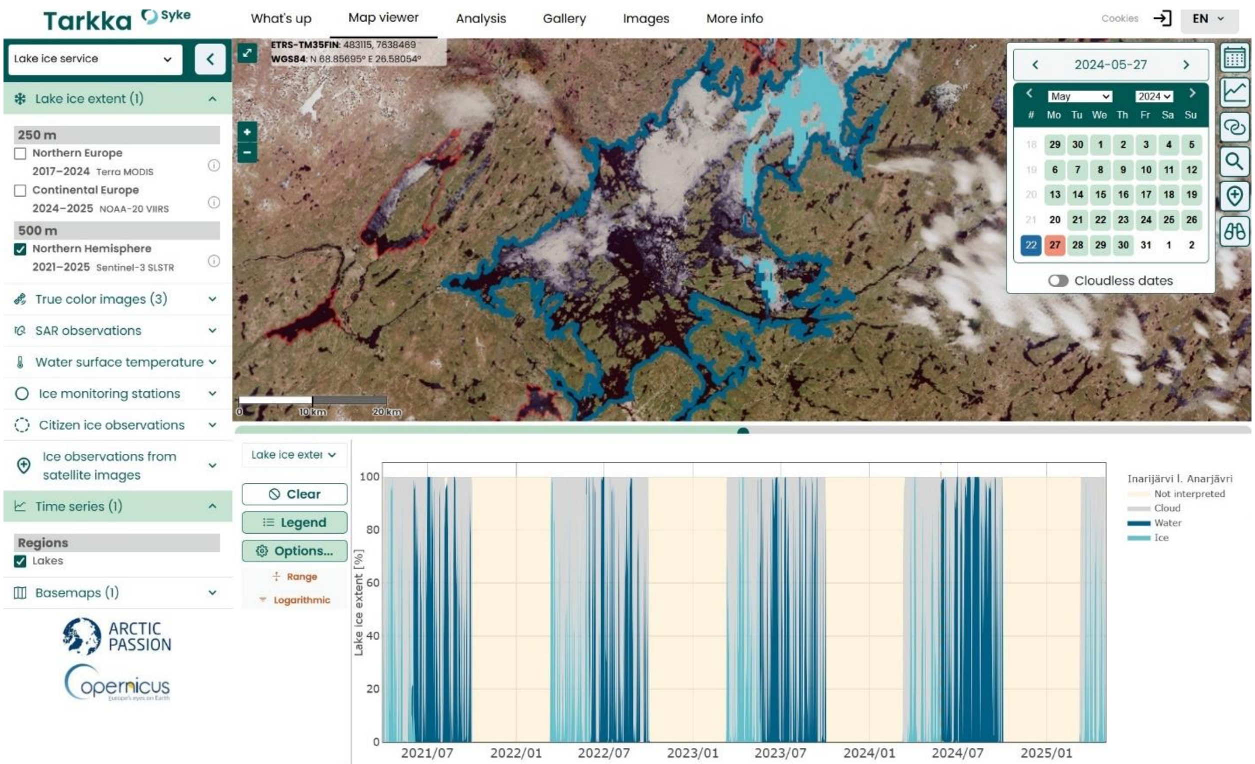


*Figure 8. Screenshot from Syke's Tarkka Lake Ice Service showing lake ice conditions on Lake Inari, Finland, on 27 May 2024, along with an ice extent time series for the same lake. In the image, the swipe tool displays a 10 m resolution Sentinel-2 MSI true-colour image on the left. On the right, the same Sentinel-2 image is shown in the background, overlaid with the CLMS 500 m resolution Lake Ice Extent product for Lake Inari.*

## 2.3. User-Driven Co-Design

The *Lake Ice Service* has been developed not only as a technical system, but as a collaborative platform shaped by its users. Arctic PASSION has emphasized co-production as a guiding principle, aiming to build services that reflect real-world needs and strengthen the capacity of Arctic communities to respond to environmental change. The importance of local and Indigenous knowledge in environmental monitoring and decision-making has been widely recognized in the Arctic context (Johnson et al., 2016).

User engagement has taken many forms throughout the project. Multiple workshops, public seminars, webinars, and surveys have been organized to collect feedback, present new functionalities, and co-design future developments. These have brought together a diverse community of users, including representatives from local and Indigenous communities, emergency services, public authorities, hydropower companies, educators, and researchers.

One key factor in the co-production process has been the development of the *HISP Ice*: Ability to highlight ice phenomena on satellite imagery in the service. This enables users to directly contribute observations and knowledge. Through this tool, users can interpret satellite images and report conditions such as cracks, open water, or unusual ice patterns. This information becomes part of a growing database of local observations, which complements satellite-based data and enhances the spatial and temporal resolution of the service. The *iceobs.app*, designed for mobile use across the Northern Hemisphere, makes field-based ice thickness reporting fast and intuitive, and its availability in Sámi languages marks an important step toward cultural accessibility and inclusion.



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In addition to these observation tools, the *Lake Ice Service* maintains a dedicated support channel at *eotuki@syke.fi*. This address serves as both a help desk and a feedback channel, where users can report issues, ask questions, or suggest improvements. The support team aims to respond to all messages within one business day, and all feedback is systematically reviewed and considered in the ongoing development of the service.

## 3. Service utilization

The service has expanded its spatial coverage beyond Finland and Northern Europe to include a broader range of Arctic regions, with preparations underway to support applications in Canada and Alaska, through partnerships with local stakeholders such as the Tahltan community and the Fresh Eyes on Ice observing network. The Finnish company Spatineo conducted an analysis of *Lake Ice Service* usage, examining how the service was used over the year 2024. The analysis showed that the service had over 18,000 users during 2024. While most users were located in Finland, Figure 9 illustrates that the service reached users from across the Northern Hemisphere.

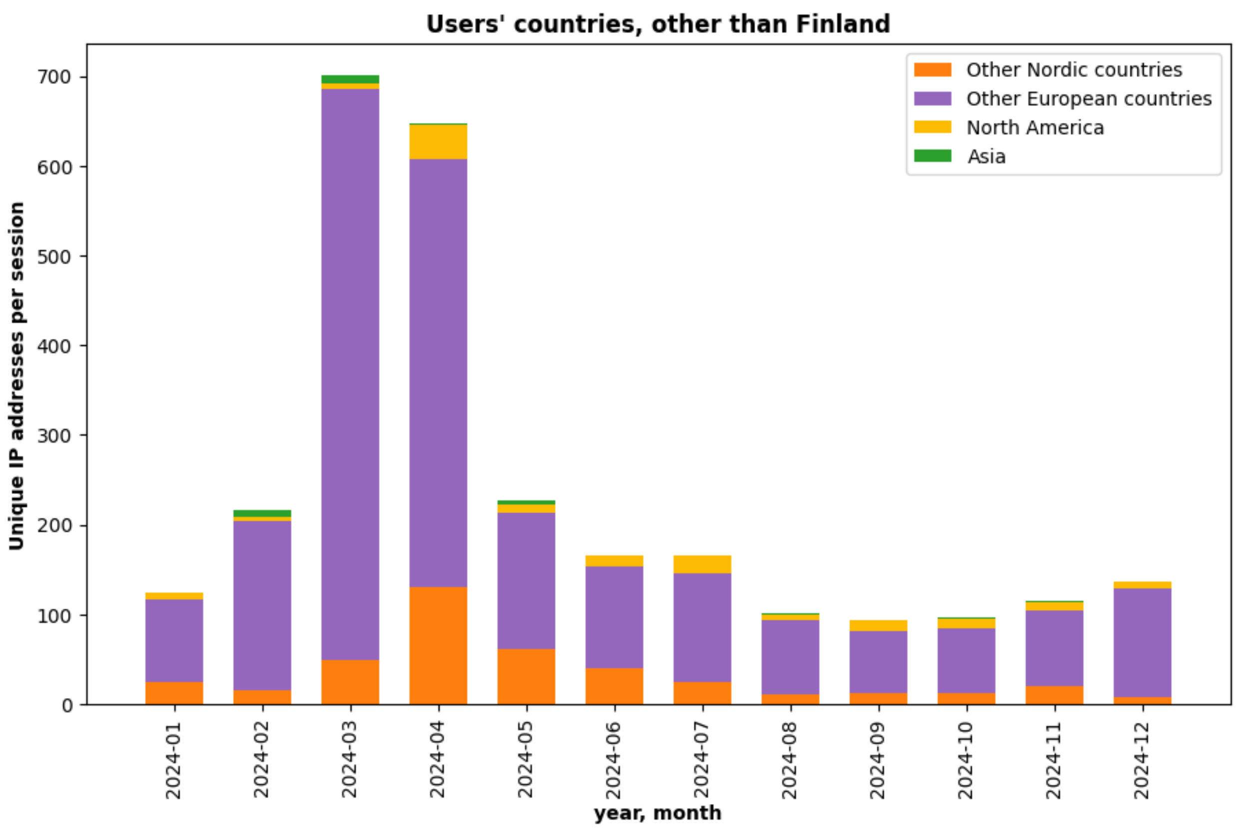


*Figure 9. Annual user statistics of Syke's Tarkka Lake Ice Service. Over 18,000 users per year access the service to search for lake ice information. Most users are from Finland; the diagram shows the geographical distribution of users outside Finland. Statistics by Spatineo.*

The diagram in Figure 10 shows the distribution of users across sectors such as business, government, education, and private use. Throughout the Arctic PASSION project, extensive interaction with users, including feedback gathered via public seminars, interviews, workshops, and surveys, has shaped the



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service. People have emphasized the need for daily, easy-to-use information that reflects both large-scale environmental changes and local, site-specific conditions. This applies not only to professional users such as hydropower operators and public authorities, but also to citizens and community members who rely on ice-covered lakes for transportation, recreation, and subsistence activities. Importantly, many of these users have expressed that traditional data sources alone are no longer sufficient, particularly as climate variability increases and lake ice becomes less predictable. The service has helped fill this gap.

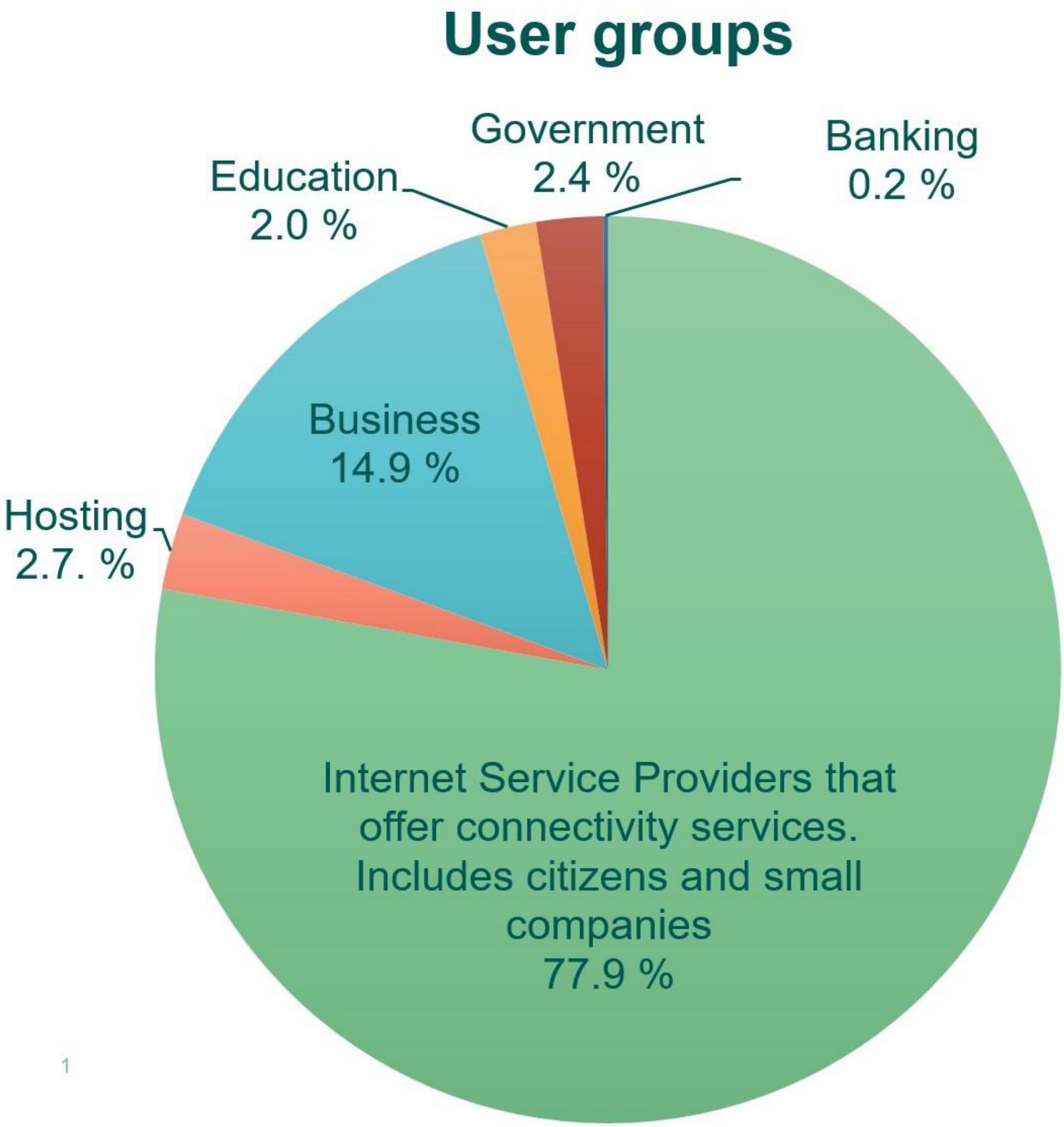


*Figure 10. Annual user statistics of Syke's Tarkka Lake Ice Service. Over 18,000 users per year access the service to search for Copernicus lake ice information. The diagram shows the distribution of users across sectors such as business, government, education, and private use. Statistics by Spatineo.*



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User surveys conducted during the project have demonstrated the service's relevance: a clear majority found it very or quite useful, and nearly 90% reported that the information influenced their decisions, ranging from planning safe routes to adjusting work and travel schedules. The usefulness of the *lake ice service* is reflected in the diverse ways users benefit from it. Many appreciate the ability to remotely monitor ice conditions when planning travel to remote summer cottages, sometimes located hundreds of kilometers away. The service helps users assess whether it is safe to cross the lake or when seasonal visits to island locations can begin. This is particularly valuable in spring and autumn, when ice conditions change rapidly. Users often combine satellite data with personal experience of local thawing patterns to make informed decisions. Professionals, such as personnel from the Finnish Border Guard, emphasize the essential role of satellite-based ice information in improving occupational safety, especially when assessing risks related to snowmobile travel in northern regions. Such users report that the service has significantly enhanced both work-related and general ice safety, with its insights now integrated into internal training. Residents in remote areas also highlight the year-round importance of understanding lake ice conditions to ensure access to their homes, whether crossing frozen lakes in winter or navigating open water in summer.

Positive feedback has also been received from fishers, who value the service's ease of use and the wide range of information it provides to support their seasonal activities. In addition, the hydropower industry actively uses the service, as up-to-date lake ice information plays a significant role in operational planning and decision-making related to safety and flow regulation. Interviews with reindeer herders have further emphasized the importance of lake ice monitoring for traditional livelihoods. Knowing when and where ice forms or breaks up helps anticipate the movement of reindeer herds, especially in regions where seasonal migrations cross lakes and rivers. Timely and accurate ice information supports better planning and adaptation in a changing climate, helping herders maintain safe and efficient routes. These varied user perspectives from individual households and recreational users to safety authorities, fishers, industry operators, and traditional communities, underscore the service's broad applicability and its vital contribution to safer, more informed, and climate-resilient decision-making across sectors.



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*Figure 11. Winter fishing is a long-standing tradition in the Arctic. Reference: Riku Lumiaro, Syke´s Image bank.*

implementation of the *Lake Ice Service* under Arctic PASSION has demonstrated the value of combining satellite data, in-situ measurements, and local knowledge into a single, accessible platform. The service has grown from a regional pilot into a scalable, pan-Arctic tool that supports safety, decision-making, and climate resilience in northern communities.

Through continuous collaboration with users, technical innovation, and community engagement, the *Lake Ice Service* has become more than just a data platform, it is a co-produced service grounded in Arctic realities. As this phase of work concludes, the foundation has been laid for further expansion and long-term impact. As the Arctic continues to warm, the demand for accurate, localized, and timely lake ice information will only increase. The *Lake Ice Service* will continue to serve Arctic communities and stakeholders beyond the project's lifetime evolving with their needs and strengthening the shared knowledge base for a safer and more informed Arctic future.

Link to the service: [*Tarkka - Lake Ice Service*]



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