

Project Overview for Arctic Council Working Groups and Permanent Participants

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Arctic PASSION: An EU-funded project of relevance to the Arctic Council and its Working Groups

Executive Summary

A key player in the support of multinational engagement for sustained and coordinated pan-Arctic observing and data-sharing systems is Sustaining Arctic Observing Networks (SAON), jointly co-sponsored by the Arctic Council and IASC for a number of years. To enhance integration of international environmental observing systems for the Arctic and to enable greater European support of SAON, the EU granted 15 million EURO in funding for the Horizon 2020 project: Arctic PASSION. The project includes 35 partners from 17 countries and is led by Germany's Alfred Wegener Institute (www.arcticpassion.eu). Arctic PASSION started in 2021 and will end in December 2025. The AMAP Secretariat, which serves as the Secretariat for SAON, joined the Arctic PASSION project as a partner with the goal of further developing and enhancing SAON. In this role, the AMAP Secretariat also offered to establish a dialogue among the Arctic Council (AC) and its six Working Groups (WGs) to provide information on Arctic PASSION activities of

relevance to the AC and its WGs, as well as to receive feedback and suggestions for further work in the project. However, owing to the pause in the work of the Arctic Council and its Working Groups for an extensive period starting in March 2022, the original aim of Task 7.2 of Work Package 7 to establish this dialogue and feedback mechanism was not able to be implemented according to the time frame envisaged.

This situation is gradually changing and there is now, near the end of the project, an opportunity to provide an overview of the main outcomes of the project that will be very valuable to the work going forward of the Arctic Council Working Groups and their expert groups. This deliverable serves to provide an overview of the main near-final results of the project as a whole, with an emphasis on Work Packages and Arctic Services of particular relevance to individual Arctic Council Working Groups, as well as the key outcomes of the project.

Arctic PASSION: An EU-funded project of relevance to the Arctic Council and its Working Groups

The Arctic Council and IASC have jointly co-sponsored the Sustaining Arctic Observing Networks (SAON) for a number of years. To enhance integration of international environmental observing systems for the Arctic and to enable greater European support of SAON, the EU granted 15 million EURO in funding for the Horizon 2020 project: Arctic PASSION. The project includes 35 partners from 17 countries and is led by Germany's Alfred Wegener Institute (www.arcticpassion.eu). Arctic PASSION started in 2021 and will end in December 2025.

As the AMAP Secretariat serves as the Secretariat for SAON, the AMAP Secretariat joined the Arctic PASSION project as a partner with the goal of further developing and enhancing SAON. In this role, the AMAP Secretariat also offered to establish a dialogue among the Arctic Council (AC) and its Working Groups (WGs) to provide information on Arctic PASSION activities of relevance to the AC and its WGs, as well as to receive feedback and suggestions for further work in the project. However, owing to the pause in the work of the Arctic Council and its Working Groups for an extensive period starting in March 2022, the original aim of Task 7.2 of Work Package 7 to establish this dialogue and feedback mechanism was not able to be implemented according to the time frame envisaged.

Now, however, near the end of the project, there is an opportunity to provide an overview of the main outcomes of the project that will be very valuable to the work of the Arctic Council Working Groups and

their expert groups. This deliverable serves to provide an overview of the project as a whole, with emphasis on Work Packages and Arctic Services of particular relevance to individual Arctic Council Working Groups, as well as the key outcomes of the project.

Objectives of Arctic PASSION

The overall objective of Arctic PASSION, which started on 1 July 2021, is similar to that of SAON: the co-creation and implementation of a coherent, integrated Arctic observing system: the 'Pan-Arctic Observing System of Systems - pan-AOSS'. It aims to enhance the present observing system by:

1. Refining its operability
2. Improving and extending pan-Arctic scientific and community-based monitoring and the integration with Indigenous and Local knowledge;
3. Streamlining access to and interoperability of Arctic data systems and services; and
4. Ensuring the economic viability and sustainability of the observing system for years to come.

This includes coordinating contributions to a key element in SAON's Roadmap for Arctic Observing and Data Systems (ROADS), namely, the identification, definition and implementation of the most impactful variables to observe in order to meet Arctic societal benefits. Arctic PASSION is developing a series of so-called Shared Arctic Variables (SAVs) in an open, consultative process, as a contribution to and support of the ROADS process.





SAVs are defined as being relevant to Arctic communities, driven by scientific understanding of the Arctic system, and linked to the global observing systems and interests. The ROADS guiding principles

1. of ensuring Indigenous Peoples' equitable partnership,
2. that the process should complement and integrate current planning approaches of existing activities and projects and that
3. the process should support stepwise development through a flexible and evolving structure, are all well-aligned with the priorities of Arctic PASSION.

Arctic PASSION has worked to improve current Arctic observing by co-creating an integrated, better coordinated, more useful and more equitable observing system for the Arctic. It so does in international collaboration, including Indigenous Peoples and local communities, that can continuously provide unrestricted, high quality, science-based Earth observation information tuned to address the urgent needs of people living in the Arctic and have relevance to the European and global society.

Structure of the project and main relevance to the AC and its WGs

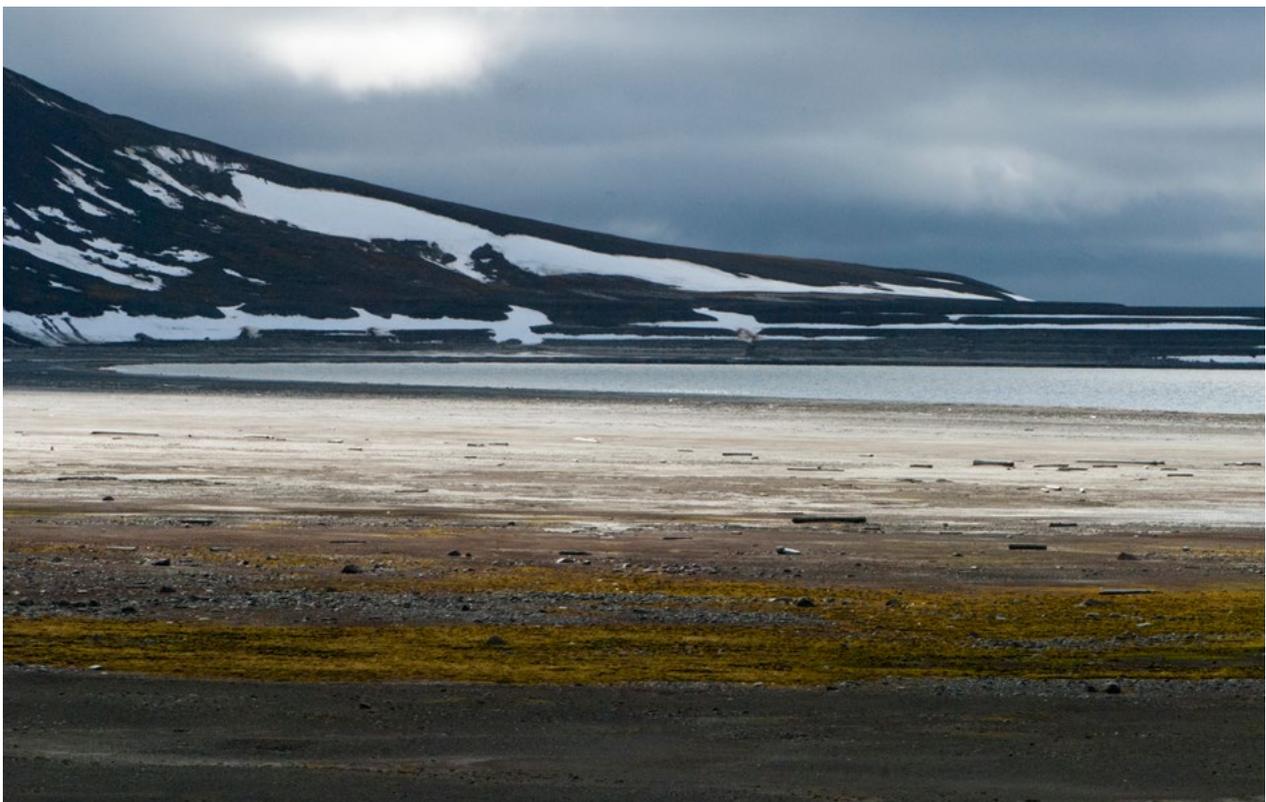
A brief overview of the main Work Packages (WPs) of this project, including the Arctic Services (ASs) it has been developing, together with highlights of key, near-final outcomes to date, is given below. Table 1, at the end of this text, indicates the interactions with or estimated relevance for the work of the various Arctic Council Working Groups and the Permanent Participants.

WP1: Establishing an adaptive and more complete Arctic observing system

The objective of this WP has been to establish the foundation for a comprehensive Arctic observing system of systems (pan-AOSS). This builds on, coordinates and enhances existing observing infrastructures and networks to provide the most vital observations for understanding how the Arctic system is functioning. The observations are made in the atmospheric, terrestrial and marine domains and help to decipher the variability, trends and changes in the system, covering time horizons from short-term extreme events (e.g., storms) to long-term change (e.g., climate). WP1 has worked with CAFF on improving and harmonizing biodiversity monitoring through CBMP and INTERACT collaboration at terrestrial sites. WP1 partner, the

AMAP Secretariat, is directly involved in the continuous development of Shared Arctic Variables and will thus be able to draw on the group's expertise. Arctic PASSION has contributed to the expansion of the pan-Arctic suite of marine "Distributed Biological Observatories", or DBOs, with WP1 leading the establishment of the Atlantic-Arctic DBO in the Eurasian Arctic Ocean. The DBOs are interdisciplinary observatories for the marine environment that track the impact of changing environmental drivers on the Arctic marine ecosystems.

The work has included prioritizing which indicators should be collected routinely in this enhanced new marine observational system in international collaboration, with input from members of CAFF, AMAP, the ICES/PICES/PAME Working Group on the Integrated Assessment of the Central Arctic Ocean (WGICA) and the Central Arctic Ocean Fisheries Agreement (CAOFA) Joint Program of Scientific Research and Monitoring (JPSRM). Another important undertaking in WP1 has been the harmonization of processing sea ice and snow thickness data from drifting buoys in the Central Arctic Ocean, which will ensure higher-quality data being available for, e.g., AMAP assessments. Another major activity, co-funded by Arctic PASSION, has been the conduct of the





international Synoptic Arctic Survey (SAS). This survey featured extensive ship-based sampling of the Arctic Ocean during the summer and autumn months of 2020 to 2022. A workshop to review the results of the SAS has led to the development of fifteen synthesis papers, which are currently under preparation for publication in a special journal issue. The papers provide the results of the SAS cruises allowing for an assessment of the state of the physical and chemical properties covering the full depth of the Arctic Ocean. These results, particularly those in relation to the carbon cycle and ocean acidification, will be useful for assessments under AMAP and CAFF. The pan-Arctic DBO network is closely linked with the SAS consortium in working towards the initiative for SAS-II (around 2030).

A comprehensive summary of the observational activities undertaken during Arctic PASSION is provided in the final deliverable of WP1, Deliverable D1.8, "Road map for future long-term Arctic observing system". This outlines recommendations for advancing toward a long-term, integrated observing system that holistically supports societal needs and addresses both ongoing and emerging challenges. The report emphasizes methodologies for obtaining observations, including in-situ and remote sensing techniques, Community-Based Monitoring (CBM), Indigenous Knowledge, and Local Knowledge. The recommendations target both immediate gaps and long-term objectives, with a particular focus on scientific needs, technical solutions to current and future observational challenges, and reducing fragmentation. The latter context encompasses the means to improve integration across both geographical and temporal scales, between the system components themselves, as well as among communities, organizations, and nations.

WP2: Bringing the Arctic Data System to action

The overall objective of this WP is to enhance data availability, long-term data preservation, and the interoperability of data through collaboration and coordination with ongoing activities at the Arctic and European level (e.g., through the joint SAON/IASC Arctic Data Committee and related activities, INSPIRE, WMO, and the interoperability activities of the Canadian Consortium for Arctic Data Interoperability (CCADI) in Canada). The ambition is to increase the volume of actionable discovery metadata and data and enable the integration of these into the decision-support systems of various communities.

More specifically, the Work Package has established the SAON Data Portal¹, which is documented in Arctic PASSION Deliverable D2.3, "Website with data information, description of available and emerging web services and user clients to find data regardless of their location and regular updates on datasets that have been FAIRified". It is a website that provides information on available datasets and which allows data consumers to discover and access relevant datasets. The website is populated through the harvesting of information from existing and new data centres. This may enhance the availability of observational data for the assessment work of AMAP and CAFF. Arctic PASSION has, through the work in WP2, supported the mapping activity of the Arctic Data Ecosystem, as initiated by the joint SAON/IASC Arctic Data Committee and continued as the polar mapping activity under the Polar to Global Online Hackathons. With support from Arctic PASSION, the mapping tool (<https://mpde.gcr.ccarleton.ca/index.html>) has been updated according to a new data model (<https://github.com/POLDER-Crew/PDEMDataModel>) and



the content has been updated. This work is reported in Deliverable D2.5, "Updated mapping of the Arctic Data System". This mapping activity will continue. Throughout the project, meeting activities within the Polar Semantics Working Group and Polar to Global Online Hackathons have been supported. These activities bring the polar data management community together to address challenges when exchanging information about data. The originally planned activity on establishing an Arctic Window of Copernicus was replaced by an activity to provide input to the Copernicus Arctic Hub. The main focus of this input has been to ensure that Copernicus data are made available in an easy manner to relevant stakeholders in the Arctic. This input is documented in Deliverable D2.8, "Arctic Window of Copernicus".

In order to support the harmonisation of data, a web service has been built around the quality control and reformatting software Meteolo. This web service setup has been under open testing since 2024 (available through the SAON Data Portal) and final modifications are expected before the end of the project. The service is available at <https://service-meteolo.slf.ch/>. Instead of setting up a new data portal, the project decided to support the SAON Data Portal (<https://data.arcticobserving.org>). This is not a centralised data repository, but rather a discovery metadata broker which harvests discovery metadata (such as index cards in a library) from existing data repositories. During the project, several new data repositories have been added to the unified data catalogue. About 23 data repositories are actively harvested or are in the process of being harvested. For some of these data repositories, discussions are needed to improve the content of the

information harvested. The intention was to include the Copernicus services in this overview as well, but this has proven difficult (as also reported in Deliverable D2.8). Although many data repositories publish discovery metadata, the quality of the documents provided is insufficient to provide a real service to users.

The approach taken in the SAON Data Portal is that discovery metadata should lead as a minimum to landing pages for datasets, but ideally direct download or web services should also be available. This dialogue is ongoing with several information providers. In this work the FAIR (Findable, Accessible, Interoperable and Reusable), CARE (Collective benefit, Authority to control, Responsibility, and Ethics) and TRUST (Transparency, Responsibility, User focus, Sustainability, and Technology) principles have been instrumental, but admittedly most focus has been on FAIR and TRUST due to the nature of the data repositories being integrated.

The TRUST principles have also been instrumental in the activity to ensure long term data preservation. Ideally, long-term data preservation is not disconnected from actionable data that could be integrated into decision-support systems; the project has thus worked to improve the combination of these two aspects of data. However, as data repositories have legacy systems that are both costly and complex to modify, this is considered a long-term change that will come gradually as the focus on the topic is maintained. During the project, many new datasets have been ingested into data repositories for long-term preservation, but the full report on this is still pending.



WP3: Supporting a smart Arctic Observing System by model-based impact Assessments

The overall objective is to support the cost-efficient extension of Arctic monitoring and forecasting capabilities, paying particular attention to the Arctic Services of WP4, by carrying out specific modelling activities. WP3 comprises four tasks covering the ocean, atmosphere, land, and land ice. Task 1 contributes to safer Arctic navigation by outlining observation strategies that better meet the needs for improved sea-ice forecasting. The regions of interest are based on the historical analysis of shipping risk in relation to sea ice, which was performed in Arctic Service 6 (AS6). This analysis is therefore indirectly linked to PAME and EPPR via AS6.

The Observing System Simulation Experiment (OSSE) constructed in Task 2 quantifies the impact of developments in the use of satellite observations and indirectly supports decision-making in the Arctic region using numerical weather prediction products. Additionally, the OSSE study enhances the utilisation of satellite observations in the Arctic region, providing more precise and dependable atmospheric forecasts and contributing to the objectives of nearly all AC Working Groups, particularly AMAP and EPPR. The network design study in Task 3 improved permafrost monitoring capabilities (area and active layer depth) of interest to AMAP, thus reducing uncertainties in climate predictions related to greenhouse gas emissions and supporting decision-making relevant to the SDWG.

The work in Task 4 reduced uncertainties in the Arctic land-ice mass balance estimates. Accurate estimation of the mass balance is important for predicting future sea-level rise and assessing freshwater fluxes to the ocean, which are relevant to AMAP. This will support knowledge-based decision making and the development of effective policies to ensure societal benefits, particularly for coastal populations living in the Arctic region. This is in line with the objectives of the SDWG.

WP4: Innovating user-driven Arctic EuroGEO Pilot Services

The objective is to establish user-demanded Arctic EuroGEO Services that have high societal and economic benefits. Co-design and co-production of these services with end-users ensures their relevance, and open and free access to the Arctic Services will empower users to make knowledge-based decisions in support of a prosperous, sustainable, and environmentally secure Arctic.

WP4 Arctic Services aimed to interact with CAFF in several ways through collaboration with the focus on fires in the Arctic and through the Event Database (located at the portal <https://arcticseas.org/>), which documents and interprets Indigenous Knowledge of past and present environmental change in eight Arctic locations jointly with local Indigenous communities. Additionally, WP4 aimed to interact with EPPR, SDWG and the PPs to seek collaboration on strengthening the ways the Arctic Services can contribute to the overall Arctic Council activities. The Arctic Services (AS) are listed below together with their relevance to various AC WGs.

AS1: Arctic Service 'Event Database of CBM Using Oral Histories, Indigenous Knowledge and Local Knowledge'

AS1 has worked with hundreds of Indigenous and local knowledge holders since 2021 to prepare Event Databases across the North. These communities wish to share their knowledge because many past environmental events that Arctic societies have experienced remain largely unknown to contemporary scientific study. AS1 has developed a living database that can be added to and expanded on to cover the entire Arctic region. With a respectful engagement with Arctic co-researchers, community embedded Indigenous Knowledge and local knowledge can provide a more complete view of past environmental change, enhance



Figure 1. Screenshot of the Arctic Seas Portal showing locations of communities that co-created the event databases as part of Arctic PASSION.

present monitoring activities, and build trust between local and scientific communities. To prepare this database, Indigenous staff served as key co-researchers who also own their own knowledge. Free, prior and informed consent was implemented in each case. These Event Databases serve as unique repositories of climate and ecological change. They also translate observations from local languages into English and present contemporary weather and ecological monitoring and use of cultural indicators, visual and oral histories and other means to establish baselines of change. Event Databases also reconstruct key events and offer historic depth to many changes occurring at present. An example is shown in Figure 1.

The central node for all Databases is the Arctic Seas portal at www.arcticseas.org. Additionally they can be accessed at <https://www.snowchange.org/2024/06/a-major-northern-indigenous-hub-and-databases-launched-documented-observations-and-knowledge-widen-the-understanding-of-arctic-change-but-offer-also-potential-new-novel-responses/>

The information in these Event Databases is relevant to a number of Arctic Council thematic actions (mercury work under AMAP) and CAFF and EPPR on questions of ecological baselines of change, safety and questions of sea ice, mercury leaching and permafrost thaw events; CAFF, EPPR and AMAP work in relation to events of wildfires in the Arctic; and IPS, especially on questions of nomadic reindeer herding events.

AS2: Pan-Arctic requirements-driven Permafrost Service (ALEX):

AS2 is actively supporting the Global Terrestrial Network for Permafrost (GTN-P), funding the development of best practices for permafrost monitoring and developing a new version of the GTN-P Data Platform. The guideline has been made publicly available so that AC WGs can increasingly include permafrost thaw as a factor for change in the Arctic region. AS2 provides: a) an update on ground temperature and active layer trends at sites close to communities, or of high relevance for residents, which are underpinned by data from the Global Terrestrial Network for Permafrost (GTN-P), and b) maps of surface changes related to permafrost thaw at high resolution building on remote sensing imagery-derived products.

The permafrost observing best practices recommendations, a new guideline for measurements of permafrost essential climate variables (ECV), have recently been approved by the World Meteorological Organization (WMO) and were included in the updated WMO Guide for Instruments and Methods of Observation (WMO No. 8), Volume II - Cryospheric Variables, Chapter 4. The guidelines and best practices provide an important framework for consistent measurement of the currently three approved Permafrost ECV products, namely, permafrost temperature, active layer thickness, and rock glacier velocity.



Figure 2. The Arctic Landscape EXplorer (ALEX) story map illustrating shore erosion. The map displays satellite imagery overlaid with change data, with blue colors indicating erosion, alongside the positions of historic shorelines.

The Arctic Landscape EXplorer (ALEX) online portal, available at <https://alex.awi.de>, is an easy-to-use map service that shows and explains rapid permafrost landscape changes (Figure 2). Interactive maps provide up-to-date information on land surface changes and potential areas of active permafrost thaw indicated by hotspots of disturbance from fires, lake change, as well as erosion along shores, coasts and in hillslopes. The data are also available as a WebMapService (WMS) that can be actively reused by government and tribal entities in their own mapping systems.

AS2 provides useful information on the spatial distribution of permafrost thaw and permafrost disturbances relevant for several Arctic Council Working Groups:

- ACAP and AMAP (e.g., by providing geospatial data of where permafrost thaw and disturbances may affect industrial legacies and their contaminants in the Arctic);
- AMAP (e.g., by identifying sites of permafrost thaw in relation to methane emissions for the Short-Lived Climate Forcers Expert Group and by identifying areas where permafrost thaw and erosion affect communities in relation to infrastructure damage, loss of livelihoods, loss of areas and artifacts of cultural significance, etc., as part of the AMAP assessment of societal implications of climate change in the Arctic);

- AMAP and CAFF for their joint assessment of Climate Change Impacts on Arctic Ecosystems and Associated Feedbacks to Climate;
- CAFF (e.g., by identifying areas of lake drainage and drying wetlands relevant for migratory birds and fish, or of fire-impacted areas, both which can help and guide land resource and ecosystem conservation managers);
- SDWG (e.g., by providing geospatial details of permafrost thaw and erosion at and near communities, allowing assessments of risks to existing infrastructure, help with the planning of new infrastructure by avoiding disturbance-affected sites, and identifying risks from erosion to cultural resources such as historic camp sites).

AS3: State of the Arctic Environment service:

AS3 has invited CAFF, AMAP and PAME to provide input on which indicators to show in the State of the Arctic Service and how to visualize the current status as well as historical context (trends and variability), in order to reach a broad audience in a meaningful manner. Interviews with a range of potential user groups and organizations resulted in the identification of themes of data that are of interest for inclusion on the State of the Arctic webpage: sea ice, polar bears and other marine mammals, snow cover on land, terrestrial vegetation changes, as well as temperature changes and other

The INFRA service is based on several modules and IT platforms, the most important being:

1. INFRA-AEGIS - A web-GIS platform through which it is possible to present, combine and integrate all the informational layers produced by INFRA, or collected from many other sources and services.
2. INFRA-SENTRY - A platform through which to distribute information and messages to users that can be easily adapted to specific needs.

Implementing these platforms through the cloud makes them highly flexible. Using them does not demand very advanced hardware/software resources, making them more accessible to users.

Focusing on a local scale, INFRA provides the possibility to generate and distribute messages on wildfires that are tailored to non-scientific end-users such as municipalities, as well as Indigenous Peoples and other local communities. The service currently covers Fennoscandia, Alaska and Sacha-Yakutia.

Information layers include: risk indexes, ignition risk level, active fires, meteorological conditions, damage assessment, infrastructures/points of interest (e.g., communities). High-resolution numerical weather prediction models can be implemented to provide thirteen meteorological information layers. An example of an INFRA product is shown in Figure 3. A detailed tutorial video has been prepared to instruct users in the use of this web mapping service <https://www.programmaricercaartico.it/integrated-fire-risk-management-infra-service>

AS4: Local Atmospheric Pollution Forecast service (AURORAE):

The Air Quality Forecast for Arctic Communities (AURORAE) service (<https://aurorae.azurewebsites.net>) developed in the framework of this project aims at releasing reliable short-term air pollution forecasts to support local communities, local authorities, policy-makers and citizens and to align with the new European Air Quality Directive 2024/2881 (<https://eur-lex.europa.eu/eli/dir/2024/2881/oj/eng>), to plan policies and to limit the exposure of the population. The production of an accurate and accessible PM10 forecast in northern European countries is therefore critical, especially to empower Arctic communities and support decisions on pollution reduction and prevention. In addition, the service provides information on observational coverage of air pollutants in the European Arctic, which is relevant to the modelling community of the AMAP Expert Group on Short-Lived Climate Forcers.

The AURORAE service is composed of three main modules:

- Data gathering module: collects daily PM10 concentrations from the European Environment Agency (EEA) and Finnish Meteorological Institute (FMI) monitoring stations at a one-hour resolution, Copernicus Atmospheric Monitoring Service (CAMS) weather meteorological fields forecast, and PM10 CAMS forecast for North Europe and treats the data to use them as input for the Forecasting Module.
- Forecasting Module: consists of a Deep Learning model (Crossformer) that provides PM10 concentration forecasts for the upcoming 48 hours for each monitoring station.
- Online Platform Module (dashboard): the near-real time PM10 concentrations and the forecast can be visualized on the Online Platform Module, an interactive map in which all monitoring stations are represented as dots and the near-real time data and the forecast are accessible as overlapping layers. The dashboard is the information access point for the users to visualize and download the PM10 observation time series and forecast for each station.

The AURORAE Service provides an easy-to-use web interface that allows access to near-real time PM10 concentration data and forecasts for about 100 air pollution monitoring stations. The landing consists of a web page divided into three main sections: a navigation panel, an interactive map and a time series window (Figure 4). The navigation panel is located on the left side of the web page; the user can choose which data to visualize on the interactive maps by selecting one of the three available buttons: "Measured", "Forecast 1-Day" and "Forecast 2-Day".

Once the user clicks on the chosen button, the selected air pollution data are displayed on the main panel of the web page consisting of the interactive map. The date to which the data refer is displayed at the top of the page. The map is a geographical layer where all the air pollution monitoring stations are drawn as coloured circles at their specific geographical location. The map allows zooming in and out of the view and facilitates the interpretation of the air quality status. Each circle is coloured in green, orange or red depending on the PM10 concentration level at the site according to the EEA health-based classification (<https://www.eea.europa.eu/en/analysis/maps-and-charts/up-to-date-air-quality-data>), while the grey colour indicates the absence of data.

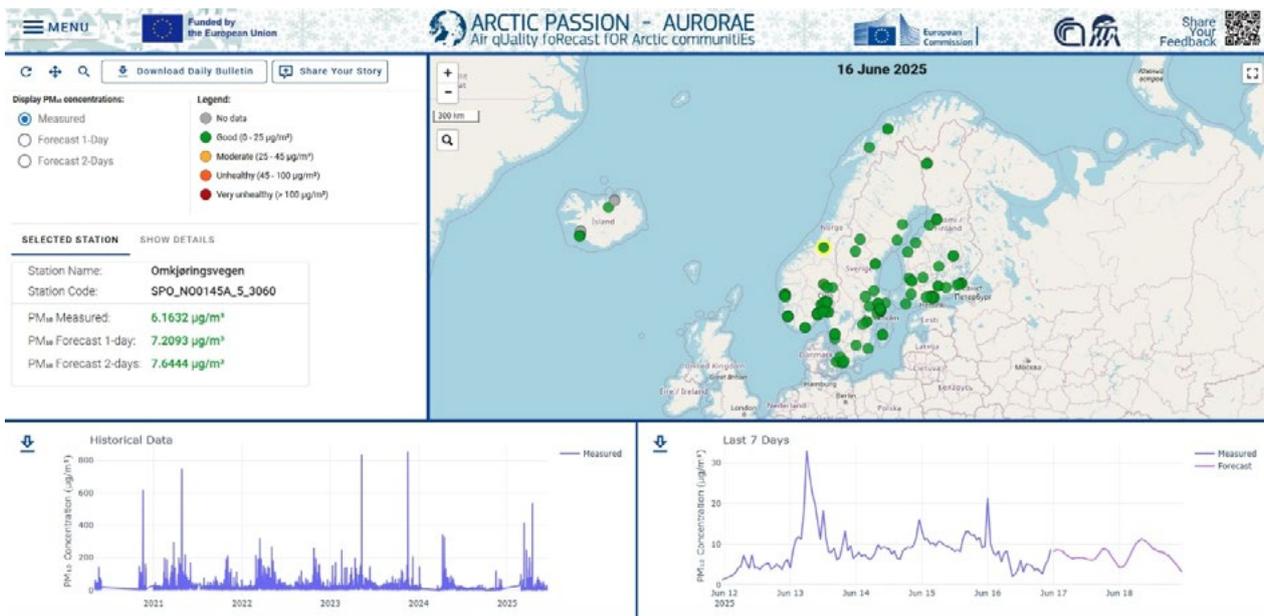


Figure 4. Landing page of the AURORAE dashboard

A warning message correlated with health protection advice appears when the daily average concentration exceeds $45 \mu\text{g}/\text{m}^3$ at a specific monitoring station. The PM_{10} concentration (24-hour average) at each station can be obtained by clicking on the chosen circle; the station information such as coordinates, station code and network are displayed on the left side of the map. If the user wants to search for a specific station, the lens icon on the navigation panel allows searching for a given monitoring station by name or code. After selecting a station, either using the lens or clicking on the station circle on the map, the hourly resolution PM_{10} concentration trend over time at that specific location is automatically displayed in the double window at the bottom of the page. The left panel shows the full time series recorded by the station, while the right panel displays the PM_{10} concentrations over the past week as a blue curve and the 48-hour and forecast for the following two days at hourly resolution as a purple curve.

The forecasted PM_{10} concentrations at monitoring station locations provided by the AURORAE service are also available as downloadable txt files. For each station, the PM_{10} concentration 48-hour forecast at hourly resolution can be obtained by clicking on the icon when selecting a monitoring station from the map or using the searching lens. The data can be then downloaded by clicking on the arrow in the bottom right panel (last seven days). Each file is named after the EEA or FMI unique station code. In addition, a “Daily air quality bulletin” is released every day from the service and can be obtained by clicking on the button “Download daily bulletin” at the top left of the page.

The bulletin is a txt file generated every day storing the information regarding the monitoring stations, such as station code, country, network name and coordinates, while the last four columns report the PM_{10} daily mean concentration registered by the station the previous day (d-1, until 00:00 UTC), the mean of the forecasted PM_{10} concentration for the following 24 hours (d) and for the following 48 hours (d+1). The last column is planned to evaluate the quality of the forecast.

Continuous engagement and collaboration with local communities, authorities and citizens is crucial to increase the usefulness of the service and to provide socio-economic benefits to the users. The AURORAE team has presented the service functionalities at various conferences and organized webinars to illustrate the service functionalities, involving potential users and obtaining feedbacks (https://www.youtube.com/watch?v=bqL3Edb_00o and <https://www.youtube.com/watch?v=ovaOpIVve4M>).

Moreover, to increase the level of involvement of the users, the dashboard is provided with a QR code linked to a survey on the service and a button “Share your story” through which users can share their experience related to air pollution.

Publications

Crotti, I., Cuzzucoli, A., De Marchi, D., Selmi, L., Eyraud, F., Ramalli, E., Pasini, A., and Dobricic, S. (2024). The AURORAE (Air qUality foRecast foR Arctic communitiEs) service, Publications Office of the European Union. <https://data.europa.eu/doi/10.2760/5041509>

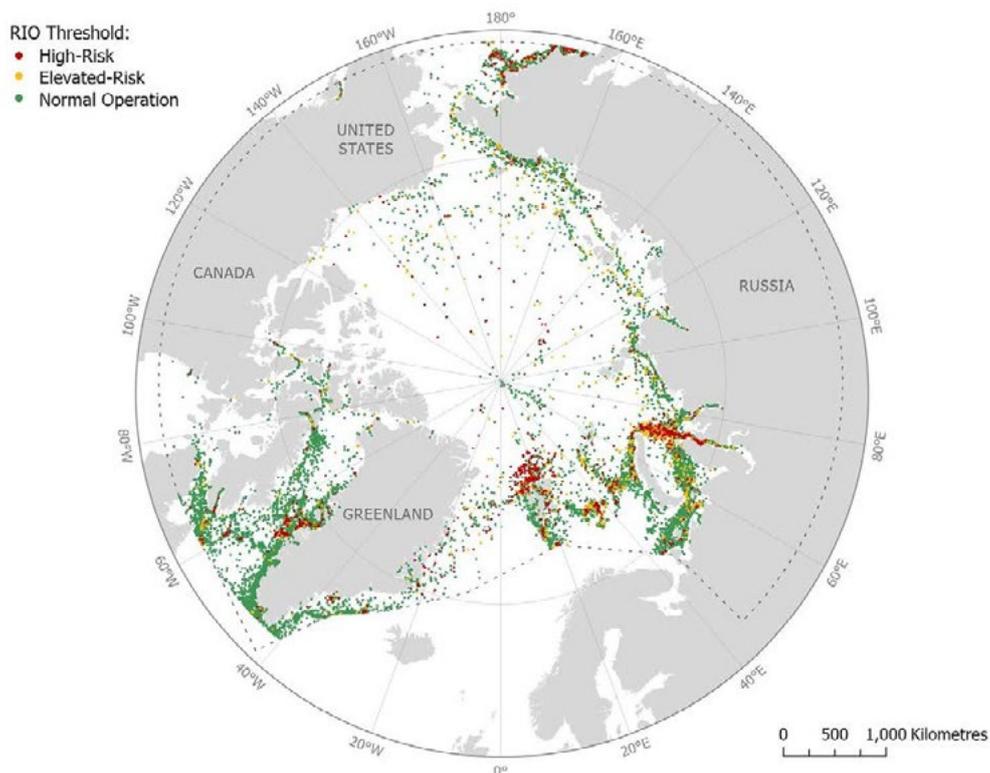


Figure 5. Weekly RIO-assigned ship positions in ice-infested waters within the Polar Code Area of the global Arctic (2015-2022). Ship positions are categorized by RIO threshold: high risk ($RIO < 10$), elevated risk ($-10 \leq RIO < 0$), and normal operation ($RIO \geq 0$)

AS6: Improving Safety for Shipping in the Polar Seas service (POLARIS):

AS6 aims to reduce the risk of a shipping incident by improved understanding of historical patterns of Arctic shipping and the development of a new International Maritime Organization (IMO) POLARIS forecast. The historical analysis of Arctic shipping provides the first spatial and temporal assessment of navigational risk across vessel types and polar classes in the global Arctic using the POLARIS framework. It enables the identification of long-term operational trends and emerging risk patterns in Arctic sea-ice environments. This analysis has made extensive use of the Arctic Shipping Traffic Database (ASTD) and extended available information about the polar class of vessels operating in the Arctic. The results of the analysis are currently being published in peer-reviewed journal articles. This work has been presented at a number of Arctic meetings including the Arctic Frontiers Conference.

The new forecasts of POLARIS risk-based outputs of several operational ocean-sea-ice models have been demonstrated to users onboard ships in the Arctic. These tests resulted in important findings about the uptake, usefulness and limitations of the current POLARIS methodology. This work has built on the findings of the International Ice Charting Working Group (IICWG) task team on Mariner use of POLARIS.

AS6 anticipates that PAME's Arctic Shipping Best Practice Information Forum will be interested in the findings from the historical analysis of shipping risk and findings from the user demonstrations of POLARIS (see Figure 5). Specifically, these findings will contribute to the PAME POLARIS Review Project which started in January 2025.

AS6 worked closely with PAME as a member of the Pilot Service Advisory Group. PAME has highlighted that the project has synergies with their work on the Arctic Shipping Traffic Database (ASTD) and has links to PAME's Arctic Shipping Best Practice Information Forum. The key work on the historical analysis of shipping risk in relation to sea ice is now complete and publications based on these outputs are being prepared. This work used the PAME ASTD database as a key input and part of the results will provide feedback on the experience of using this database. Specifically, this Arctic Service work has made significant progress in extending understanding of the polar class of vessels included in ASTD, which is required for the analysis of risk using the POLARIS risk methodology. In addition to publication of these results in peer-reviewed journals, AS6 is engaging with PAME to discuss the results, determine whether there is more information to be extracted and how best to publicise the findings. Initial results have already been presented at the Arctic Frontiers Conference in Tromsø (January 2024) and at an AS6-hosted session at the

European Polar Science Week in Copenhagen (September 2024). AS6 also plans to present a summary of the results online to be used for wider communication of this activity. AS6 anticipates that PAME's Arctic Shipping Best Practice Information Forum will be interested in the findings from the current user demonstrations of the POLARIS nowcast and forecast service. AS6 will consider how best to communicate these results to PAME and other interested parties when the demonstrations are complete. The results are presented in Deliverable D4.14 "Development of an operational POLARIS service".

AS7: CBM for Arctic Marine Climate Change, Noise Pollution and Impacts on Marine Living Resources:

Arctic Service 7 (AS7) is a community-led initiative that has built a long-term, Indigenous-centered monitoring program focused on climate change and the underwater soundscape in High Arctic Greenland. As sea ice retreats, anthropogenic activities in the Arctic are expanding. Increased noise from shipping, industrial development, and defence operations is raising serious concerns about the acoustic impacts on marine mammals.

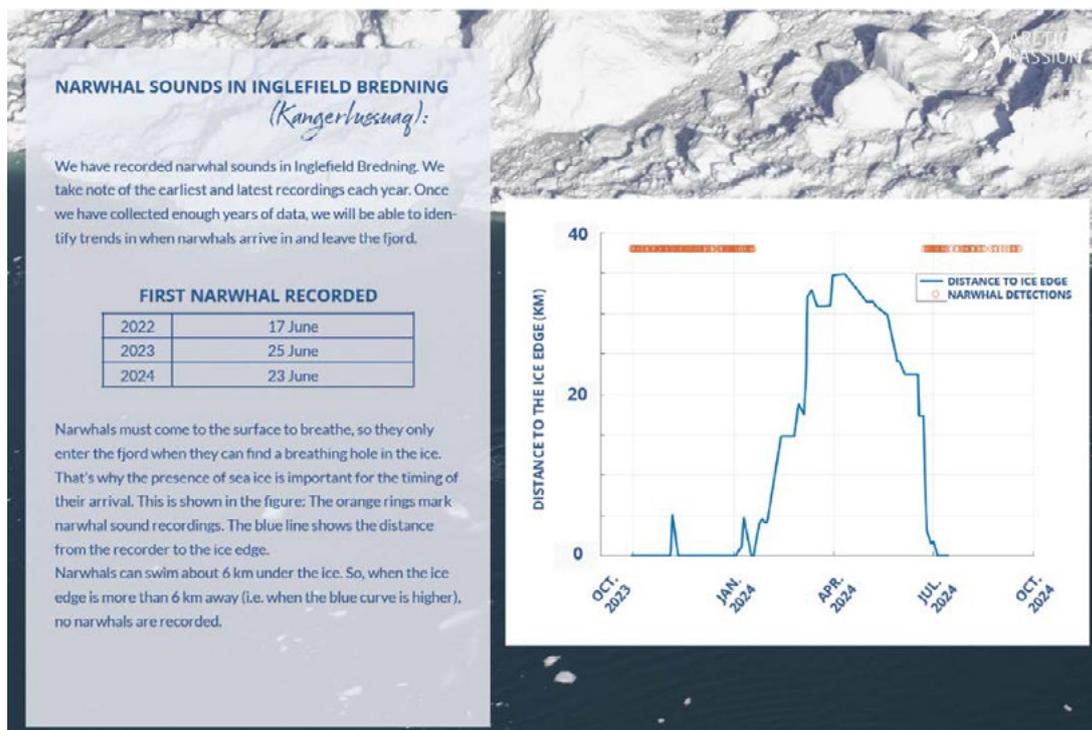
These concerns are echoed by Arctic communities and recognized by the PAME Working Group under the Arctic Council. AS7 was developed through co-creation and integrates Indigenous and local knowledge with Western scientific approaches, following guidance from the Inuit Circumpolar Council (ICC) and the Pikialasorsuaq Commission. The initiative addresses key

data gaps identified by Arctic Council Working Groups, including PAME (underwater noise), CAFF (biodiversity monitoring), and AMAP (climate trends and ecosystem response). AS7 is also engaging with AMAP to support implementation of the sustainable pan-AOOS and the SAON roadmap.

The Community-Based Monitoring (CBM) program of AS7 has been incorporated into two international Arctic science observatories. Its passive acoustic monitoring (PAM) component is now a part of the Arctic Acoustic Observation Network (AAON), a new initiative under the CAFF CBMP Marine Mammal Expert Network. All PAM activities within AS7 follow AAON standards for data collection, management, and sharing. The AS7 community-based monitoring program has also become a keystone in the High Arctic part of the Baffin Bay DBO. The program is recognised as a DBO site and, by linking to Ajuittuq community, it links the Baffin Bay DBO on a community and scientific level across the Pikialasorsuaq (North Water Polynya). This work is in progress.

A biannual Visual Atlas (Figure 6), published in both English, Greenlandic and Danish, transparently shares findings with communities, stakeholders, and policymakers. This dynamic tool supports local decision-making, enhances governance of marine resources, and fosters dialogue around sustainable marine activity. Key results are also being communicated to AC WGs as well as information on upcoming workshops in the Arctic Circle Assembly and the Greenland Science Week 2025.

Figure 6. Screenshot from the Visual Atlas showing the time series of the first narwhals acoustically detected in the fjord each year and a graph of the distance to the ice edge for each daily narwhal detection.



AS8: Lake Ice Service for Arctic Climate and Safety (LIS):

AS8 work on lake ice monitoring involved collaboration with AMAP to help define user requirements for the first version of the data service and provide comments for its further development. Lake Ice Service provides information on lake ice conditions by collecting, combining, and visualizing Earth Observation-derived lake ice data, in-situ data from governmental networks and community-based monitoring observations in a user-friendly format. An example is shown in Figure 7.

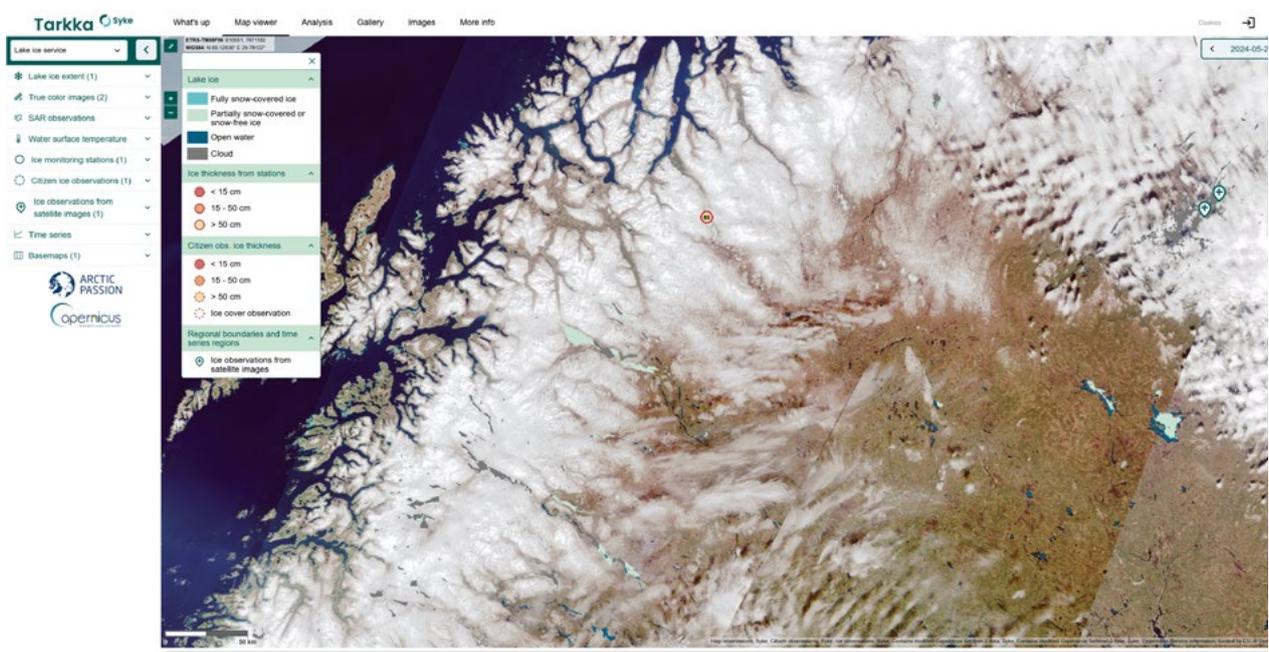
The service enables sharing of observations made from satellite data, such as the edge of ice cover on lakes or rivers. The service is also directly connected to iceobs. app, which allows users to report ice conditions in real time from the field even without an internet connection. This is particularly valuable in remote Arctic areas. Field observations, such as cracks in the ice, complement satellite-based data and improve situational awareness. Environmental changes are a growing cause of concern among Indigenous Peoples, whose livelihoods and habitats are being impacted.

Along with other Arctic PASSION services, the Lake Ice Service offers an accessible platform to share personal observations and/or view current conditions as well as changes over time. Lake ice is a sensitive indicator of climate change and also a critical factor in the daily lives of Arctic residents, affecting transportation, fishing conditions, and reindeer migration routes.

Documented information supports communication with decision-makers and can help justify emergency support in exceptionally challenging conditions.



Figure 7. A screenshot of the Tarkka Lake Ice Service presenting lake ice conditions in Northern Fennoscandia on 26 May 2024. Copernicus Continental Europe Lake Ice Extent data at front and Sentinel2/MSI, and Sentinel-3/OLCI true color images at background. The orange circles represent on-site ice thickness observation. Lake Ice Service



WP5: Assessing Societal Benefits and Economic Impacts

WP5 developed a systematic approach to evaluate the societal value of Arctic Services and information. Initially, WP5 produced a report introducing conceptual designs for the valuation of different observation/information services and the first attempt to link societal benefits with the Arctic Services (ASs) developed in Arctic PASSION. These preliminary evaluations were based on the Value Tree Analysis (VTA) estimating, in particular, the costs and weights of observing systems contributing to some ASs (Deliverable D5.1 “Description of a versatile benefit assessment approach and Arctic resilience societal indicators for the pan-AOSS”). Following the recommendations of D5.1, WP5 developed a flexible valuation approach and guidance for conducting economic evaluations of information services (Deliverable D5.2 “Toolset for societal benefit estimates”).

The economic evaluation process is based on Value Chain Analysis (VCA), supported by additional guidance material for its use and for the use of supporting methods with respect to valuation as well as stakeholder interaction. The final report of WP5, Deliverable D5.3 (“Assessing Societal Benefits and Economic Impacts”), builds on the work and recommendations presented in D5.1, and applies the toolset presented in D5.2 to selected Arctic Services and the assessment of the societal benefits of these services. All WP5 deliverables will be publicly available, supporting SAON by providing a means for the evaluation of societal benefits arising from any application that provides information based on Arctic observations. These reports should be of use to SDWG and AMAP as well.

WP5’s work contributes significantly to understanding and advancing the societal value of Arctic observations. It offers practical tools, insights, and recommendations to support future development and evaluation of climate services in the Arctic and beyond. The evaluation process highlighted the need for a multidimensional, interdisciplinary framework that considers not only economic and quantitative indicators, but also ethical, cultural, and contextual factors. Moreover, the D5.3 report highlights the inherent challenges in evaluating the societal and economic value of climate information services, particularly when they are new or still in a pilot phase. These challenges stem largely from the absence of user data, the difficulty in forecasting real-world impacts, and the complexity of monetising intangible benefits like cultural or environmental value.

Hence, economic evaluations are often limited in such contexts due to high uncertainty and reliance on assumptions. To address this, WP5 emphasises the need for early integration of benefit assessments into the service development process. Involving economic analysts from the beginning can help ensure that data needs for economic evaluations are met and that the service is aligned with actual user demands.

A clear understanding of who the end users are and what specific problems the service addresses is crucial to avoid underuse and wasted resources. Furthermore, WP5 stresses the importance of a more holistic evaluation framework—one that combines both quantitative and qualitative methods and takes into account ethical, cultural, and contextual factors—to better capture the full spectrum of societal benefits. This inclusive approach is vital to producing meaningful and policy-relevant evaluations of information services.





WP6: International Cooperation and Clustering for essential Arctic Integration

WP6 supports SAON by strengthening the European efforts in SAON. Through the SAON Roadmap for Arctic Observing and Data Systems (ROADS), SAON provides the most comprehensive international framework to set a course for developing a pan-Arctic Observing System and for specifying how partners will collectively work to achieve this, including engagement of, and partnership with, Arctic Indigenous People. Arctic PASSION is strongly involved in the ROADS process and has initiated three Shared Arctic Variable (SAV) Expert Panels on the themes Permafrost, Wildfires and Sea Ice with local foci in Finland, Canada and Svalbard. These SAV Expert Panels aim to identify key observables needed to be monitored for an improved handling of problems associated with these themes on a local level, thus empowering local communities. This work is documented in Arctic PASSION deliverables D1.2 (“The definition for the pilot set of Essential Arctic Variables”) and D6.3 (“Report on SAON Progress in ROADS”).

WP7: Supporting coherent Policy and decision-making

The objective of this WP is to provide decision-making and policy support by establishing meaningful dialogues with local to international policy makers. WP7 has been providing policy briefs on the needs and perspectives on sub-national data-driven policymaking, based on extensive interviews with policy-makers and local practitioners. The goal is to understand policy needs and bring them into the project so that they can be integrated into project actions, and to communicate the work of all Arctic PASSION WPs, their outcomes and their recommendations widely. This has resulted in two deliverables: D7.2 “Data-driven Subnational Decision-making in the Arctic: Towards identifying the key issues” and D7.9 “Policy-driven Subnational Decision-making in the Arctic: Towards future actions”). At the European level, a policy briefing was held to inform about Arctic priorities (D7.5 “Report of Briefing Meeting to inform MEPs and European Officials on Arctic topics of emerging priority”). WP7 also aimed to further the outcome of the Arctic Science Ministerials regarding sustained Arctic observations and establish a dialogue with Working Groups and Permanent Participants of the Arctic Council. This deliverable report is part of the work of WP7.

Table 1 Interaction of Arctic PASSION project components with Arctic Council Working Group and Permanent Participant areas of interest

Arctic PASSION	ACAP	AMAP	CAFF	EPPR	SDWG	PAME	PPs
WP1: pan-AOSS		✓✓	✓✓			✓✓	
WP2: Arctic Data System		✓✓	✓✓	✓	✓	✓✓	✓
WP3: Modelling		✓✓					
WP4: Pilot services		✓✓	✓✓	✓✓	✓✓	✓	✓✓
AS1: Event database		✓✓	✓✓	✓✓	✓✓		✓✓
AS2: Permafrost	✓✓	✓✓	✓✓	✓✓	✓	✓	✓✓
AS3: State of Environment		✓	✓		✓		✓
AS4: Wildfire risk		✓✓	✓✓	✓✓	✓✓		✓✓
AS5: Air pollution		✓			✓		✓✓
AS6: Shipping safety				✓✓		✓✓	
AS7: Marine impacts		✓	✓			✓✓	✓
AS8: Lake ice		✓✓	✓✓	✓	✓✓		✓✓
WP5: Benefits		✓			✓✓		✓✓
WP6: SAON support		✓✓	✓	✓	✓	✓	✓
WP7: Policy-making		✓			✓		✓
WP8: Synthesis	✓	✓	✓	✓	✓	✓	✓

Table 2. List of Arctic PASSION deliverables mentioned

Deliverable number	Title
Deliverable D1.8	Road map for future long-term Arctic observing system
Deliverable D2.3	Website with data information, description of available and emerging web services and user clients to find data regardless of their location and regular updates on datasets that have been FAIRified
Deliverable D2.8	Arctic Window of Copernicus
Deliverable D5.1	Description of a versatile benefit assessment approach and Arctic resilience societal indicators for the pan-AOSS
Deliverable D6.7	GEO Initiative report for Arctic GEOSS
Deliverable D7.2	Data-driven Subnational Decision-making in the Arctic: Towards identifying the key issues
Deliverable D7.5	Report of Briefing Meeting to inform MEPs and European Officials on Arctic topics of emerging priority
Deliverable D7.9	Policy-driven Subnational Decision-making in the Arctic: Towards future actions
Deliverable D8.1	Applications for GEO Initiative to GEO Program Board



Annex 1: Recent and current EU-funded projects related to the Arctic

Active projects

Project name and website	Brief description of aims
ACCIBERG Arctic Cross-Copernicus forecast products for sea Ice and iceBERGs https://acciberg.nersc.no/	Developing a new iceberg forecasting service and improving the quality of Arctic sea-ice forecasts across Copernicus Marine and Climate Change services
Arctic PASSION Pan-Arctic Observing System of Systems https://arcticpassion.eu/	Implementing observations for societal needs
ArcticHubs https://projects.luke.fi/arctichubs/	The strategic goal of ArcticHubs is to develop sustainable, solution-oriented tools for reconciling competing models of livelihood and land-use in Arctic hubs and their surroundings, whilst respecting the needs and cultures of local populations (e.g., Sámi in Fennoscandia).
CARPARDUS https://polarcluster.eu/members/ended/carpardus/	The focus of the project is to support the development of standards, guidelines and practices for environmental protection, economic development and other activities in the Arctic. There is growing human presence and footprint in the Arctic combined with a dramatic change in the climate and environment.
CHARTER Drivers and Feedbacks of Changes in Arctic Terrestrial Biodiversity https://www.charter-arctic.org/	The aim is to advance the adaptive capacity of Arctic communities to climate and biodiversity changes through state-of-the-art synthesis based on thorough data collection, analysis and modelling of Arctic change with major socio-economic implications and feedbacks
ECOTIP Investigating ecological tipping cascades in the Arctic Seas ECOTIP Arctic (ecotip-arctic.eu)	ECOTIP operates at the important link between the physical and biological systems, where a regional change in the hydrography of the Arctic Ocean might trigger a biological change at the base of the marine food web with cascading effects both on the regional and local socio-economic systems through fisheries, and on the global climate through carbon sequestration.
FACE-IT The Future of Arctic Coastal Ecosystems https://www.face-it-project.eu/	FACE-IT aims to enable adaptive co-management of social-ecological fjord systems in the Arctic in the face of rapid cryosphere and biodiversity changes.
HiAOS https://hiaos.eu/	HiAOS aims to advance the uptake of new ocean observing capabilities and capacity in the High Arctic to strengthen European and national infrastructures in their effort to support new and ambitious research within climate, environment and geohazards. HiAOS will develop, implement, and validate several ocean observing technologies to improve data collection in the ice-covered Arctic Ocean.
ICEBERG https://arcticeberg.eu/	The ICEBERG project studies ocean and coastal pollution and creates governance and resilience strategies with European Arctic communities
ILLUQ https://www.grida.no/activities/1033	The project builds on the "One Health" concept, which recognises that human health is interconnected with environmental and animal health. By bringing together an interdisciplinary consortium committed to participatory research with local stakeholders and rightsholders, ILLUQ will provide the first holistic look at permafrost thaw, pollution, and human and environmental well-being in the Arctic.

<p>INTERACT III International Network for Terrestrial Research and Monitoring in the Arctic https://eu-interact.org/</p>	<p>INTERACT is an infrastructure project under the auspices of SCANNET, an Arctic network of 74 terrestrial field bases (with an additional 21 research stations in Russia on pause) in northern Europe, U.S., Canada, Greenland, Iceland, the Faroe Islands and Scotland, as well as stations in northern alpine areas. INTERACT specifically seeks to build capacity for research and monitoring all over the Arctic, and is offering access to numerous research stations through the Transnational Access Program.</p>
<p>SIOS Svalbard Integrated Arctic Earth Observing System https://sios-svalbard.org/</p>	<p>SIOS is an international observing system for long-term measurements in and around the Norwegian archipelago of Svalbard addressing Earth System Science questions</p>

Projects that have ended

Project name and website	Brief description of aims
<p>APPLICATE Advanced prediction in polar regions and beyond https://applycate-h2020.eu/</p>	<p>The goal of APPLICATE was to develop enhanced predictive capacity for weather and climate in the Arctic and beyond, and to determine the influence of Arctic climate change on Northern Hemisphere midlatitudes, for the benefit of policy-makers, businesses and society.</p>
<p>ARCOS - an EO platform focusing on the Arctic https://arcos-project.eu/</p>	<p>The ARCOS platform hosts a series of products on Arctic Ocean conditions based on multiple satellite data including Sentinel-1, Cryosat-2, SMOS, AIS and social media. Products available on the ARCOS platform include ice charts and detailed information on the sea ice: concentration, thickness, type and drift. These specific products can be used for safe navigation and route planning in the Arctic waters.</p>
<p>ArcSAR Arctic and North Atlantic Security and Emergency Preparedness Network https://arcsar.eu/</p>	<p>ARICE provided a strategy for meeting the needs of marine-based research in the Arctic</p>
<p>ARICE Arctic Research Icebreaker Consortium https://arice-h2020.eu/</p>	<p>The focus of the project is to support the development of standards, guidelines and practices for environmental protection, economic development and other activities in the Arctic. There is growing human presence and footprint in the Arctic combined with a dramatic change in the climate and environment.</p>
<p>ICE-ARC Ice, Climate, Economics-Arctic Research on Change ICE-ARC Ice, Climate - Search</p>	<p>ICE-ARC (Ice, Climate, Economics - Arctic Research on Change) reviewed the current and future changes in Arctic sea ice - both from changing atmospheric and oceanic conditions. The project also investigated the consequences of these changes both on the economics of the area and globally, and social aspects such as on Indigenous Peoples.</p>
<p>INTAROS Integrated Arctic Observation System https://intaros.nersc.no/</p>	<p>The overall objective was to build an efficient integrated Arctic Observation System (iAOS) by extending, improving and unifying existing systems in the different regions of the Arctic.</p>
<p>INTERACT II International Network for Terrestrial Research and Monitoring in the Arctic https://eu-interact.org/</p>	<p>INTERACT is an infrastructure project under the auspices of SCANNET, an Arctic network of 74 terrestrial field bases (with an additional 21 research stations in Russia on pause) in northern Europe, U.S., Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas. INTERACT specifically seeks to build capacity for research and monitoring all over the Arctic, and offers access to numerous research stations through the Transnational Access Program.</p>
<p>HiA00S https://hia00s.eu/</p>	<p>HiA00S aims to advance the uptake of new ocean observing capabilities and capacity in the High Arctic to strengthen European and national infrastructures in their effort to support new and ambitious research within climate, environment and geohazards. HiA00S will develop, implement, and validate several ocean observing technologies to improve data collection in the ice-covered Arctic Ocean.</p>

<p>JUSTNORTH Towards a Just, Ethical, and Sustainable Arctic https://justnorth.eu/</p>	<p>JUSTNORTH brings the values of Arctic stakeholders to economic development decision-making through understanding current practices, policies, and perspectives of development in the Arctic. The results of the project provide policy recommendations for municipalities, regional or national governments, and the EU, by evaluating existing economic activities in 17 case studies. This work used both negative and positive indicators of value in economic activities.</p>
<p>NUNATARYUK https://nunataryuk.org/</p>	<p>NUNATARYUK was an international permafrost research project aiming to understand how thawing permafrost on land, along the coast and below the sea changes the global climate and life for people in the Arctic. NUNATARYUK means “land-to-sea” in Inuvialuktun, one of the Inuit languages spoken in Northwest Territories and Nunavut in Canada, where land meets the Arctic Ocean. NUNATARYUK combined permafrost research with modelling and socio-economic analysis and included stakeholders from all over the Arctic.</p>

