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Polar research infrastructure network: the Ukrainian input

Abstract. The polar regions play a crucial role in the Earth's system. They are essential for our climate and are sentinels of climate change and human expansion. The polar research community needs access to world-class research infrastructure operating on-site to understand and predict essential processes in the polar regions and provide evidence-based information. To address that, a consortium of the European Union and international polar research operators is joining their efforts in the Polar Research Infrastructure Network (POLARIN) project. POLARIN is an international network of polar research infrastructure and services, aiming to address the polar regions' scientific challenges. The network includes various complementary and interdisciplinary top-level research infrastructure: Arctic and Antarctic research stations, ice-capable research vessels, observatories, data bases, and ice core and sediment repositories. This article aims to highlight Ukraine's role in the global effort to study and understand the polar regions, focusing on its participation in POLARIN project and the significance of its potential contributions. It is argued that Ukraine has played a role in shaping policies for creating an international network of polar infrastructure issues by sharing research facilities, contributing data and insights to global discussions on environmental conservation, climate change mitigation, and sustainable development in the polar regions.

Keywords: polar logistics, polar regions, POLARIN, research vessel *Noosfera*, Vernadsky Station

1 Introduction

A role of research infrastructure in the polar regions

The polar regions are remote, unique, and extreme environments that present significant challenges for conducting scientific research (Salazar, 2017). A robust research infrastructure is essential to overcome these challenges and advance our understanding of these regions (Ruck et al., 2022).

Research infrastructure, such as research stations, icebreakers, and specialized transportation, enables scientists to access these areas and conduct fieldwork. This access is vital for collecting data directly from the polar environments, which cannot be replicated elsewhere (Kennicutt et al., 2015). Infrastructure, such as weather stations, buoys, and

satellite systems, facilitates continuous data collection and monitoring of the polar conditions. These data are crucial for understanding climate change, sea ice extent, ocean currents, and other important factors that affect these ecosystems.

In this context, permanent and seasonal research bases offer essential facilities like laboratories, living quarters, and storage areas, enabling researchers to work and reside in the polar regions for extended periods. Such activity raises important questions about the carbon footprint of human presence in the polar regions. As Cordero et al. (2022) noted, the carbon footprint of research activities in Antarctica has likely increased as human presence in the continent surged in recent decades, resulting in accelerating snow melting and shrinking the snowpack in areas surrounding research facilities. In turn, icebreaking polar-class research vessels incorporate cutting-edge technologies to enhance fuel efficiency, minimize noise emissions, and ensure environmental protection in Antarctica through their design and operations (Rogan-Finnemore et al., 2021). In addition, polar research often requires specialized equipment and technology, such as ice cores, remotely operated vehicles (ROVs), and submersibles. Research infrastructure provides access to and supports such advanced tools, allowing scientists to make detailed observations and collect the best available data (Kennicutt et al., 2016). Moreover, tools and data resources are now available that facilitate the production of significant high-quality science in some fields, with reduced or even no need to visit Antarctica (Hughes, 2015). That is why more collaborative and coordinated approaches to polar research can avoid unnecessary duplication and reduce both impacts on the fragile Antarctic environment and scientific and logistic costs if remote science can result in similar insights.

To this end, the operation of research infrastructure in the polar regions often involves international cooperation between countries. Collaborative efforts enhance the scope and impact of research, as scientists from different nations can share expertise, resources, and data, leading to more comprehensive studies. At the same time, real-time data transmission and remote communication technologies allow scientists to collaborate, analyze data collectively, and disseminate findings more effectively (Kennicutt et al., 2015).

Therefore, research infrastructure in the polar regions is critical in enabling scientists to explore and understand these extreme environments. By supporting fieldwork, data collection, collaboration, and education, it drives advancements in polar science, contributes to our knowledge of global processes, and informs strategies for conserving these fragile ecosystems in the face of ongoing climate change. That is why several projects have been implemented to unify the efforts for efficient usage of polar research infrastructures (Ruck et al., 2022).

For this purpose, infrastructure is broadly defined not only as hard installations (like permanent research stations) but as "inevitably a flexible term, often defined with regard to context and situation" (Mattern, 2016, p. 2), which allows ice and sediment repositories and databases also to be considered infrastructure.

In doing so, this research note generally describes recent cooperative projects in the polar regions, focusing on an international network of infrastructure for polar research and services. More specifically, it highlights the crucial role of Ukraine's participation in the EU-funded Polar Research Infrastructure Network (POLARIN) project, underscoring the significance of its potential contributions.

2 Optimizing research infrastructure use in the polar regions: enhancing polar exploration

The polar regions, particularly the Arctic, are experiencing rapid and unprecedented changes due to global warming. These changes have profound implications for sea level rise, weather patterns, biodiversity, and global ocean circulation. The European Union (EU) recognizes the importance of understanding these changes and aims to be a

global leader in developing effective policies and strategies related to climate change adaptation, sustainable development, and environmental protection (Fedchuk et al., 2021).

Many EU member states are involved in collaborative projects with other countries and organizations, fostering scientific diplomacy and knowledge sharing.

The EU allocates funding to support polar research through various programs, such as Horizon 2020 and its successor, Horizon Europe. These funds support research projects, the development of research infrastructure, and the training of scientists working in the polar regions. European projects focusing on polar research infrastructure play a vital role in advancing our understanding of the areas and their impacts on the Earth's systems. These projects often involve the development of state-of-the-art facilities, equipment, and networks that enable scientists to conduct cutting-edge research in these remote and challenging environments.

In this regard, several predecessor projects were crucial in advancing the POLARIN project by focusing on specific aspects of its activities. For example, the 2009–2023 Eurofleets project (https://www.eurofleets.eu/) enhances collaboration and access to European marine research resources.

The 2011–2024 INTERACT project (https://eu-interact.org/project/), as a platform for exchanging information among polar research infrastructure managers and stakeholders, facilitates improving the Arctic and northern boreal terrestrial research facilities.

The 2018–2022 ARICE (Arctic Research Icebreaker Consortium) project (https://arice-h2020.eu/) aimed to improve access to Arctic research icebreakers. Its efforts in fostering cooperation and infrastructure development directly contribute to enhancing research capabilities and coordination within Arctic marine environments.

The 2024–2028 AQUARIUS (Aqua Research Infrastructure Services) project (https://cordis.europa.eu/project/id/ET1001) provides a platform with datasets specifically tailored for the ocean, seas, and freshwater ecosystems. The project aims to provide efficient, single-point, transnational access to a broad range of integrated research infrastructure that can support the Restore our Ocean and Waters Mission by 2030.

The EU Polar Cluster is a network of collaborative polar projects funded by the EU, integrating a wide range of research and coordination activities. These activities include the enhancing observation capabilities, improving prediction models, networking research stations, and coordinating access to icebreakers. The cluster aims to foster collaboration, sharing resources and coordinating research activities related to the polar science and climate change within the EU. Within this cluster, the EU-PolarNet 2 project assembles the world's largest consortium of expertise and infrastructure for Polar Research (https://eu-polarnet.eu/). It brings together the expertise and knowledge of 25 partners from 21 European and Associated Countries with substantial polar activities to develop a strategic framework for European polar research (Vieira et al., 2020). The initiative aims to optimize research efforts, prioritize investments in polar infrastructure, and promote the EU's role as a global leader in polar science. The European Polar Infrastructure Database, developed in EU-PolarNet 2 and supported by the European Polar Board, provides a comprehensive overview of European polar research infrastructure and helps researchers find suitable facilities and resources for their studies in the Arctic and Antarctic regions (European Polar Board, 2019). The map on Figure 1 includes the Antarctic research facilities operated by the EU Member States and three other European Partner States, Norway, Ukraine, and the UK (Belarus operates one research station but is not a member of the Board).

All these projects collectively contribute to advancing polar research by providing researchers with the tools, resources, and platforms needed to conduct interdisciplinary studies in the challenging and remote polar environments. The data and insights gained from these projects are essential for understanding the impacts of climate change,

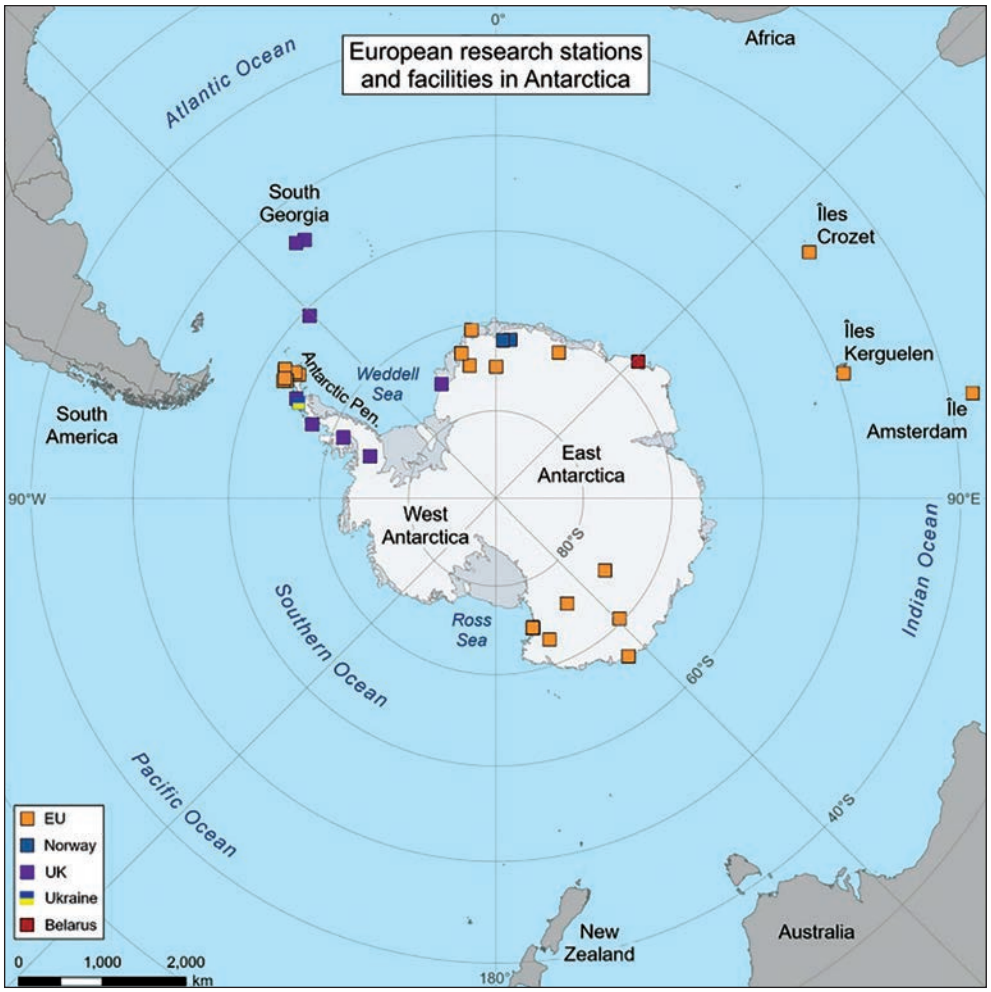

Figure 1. Location of European research stations in Antarctica (Dodds & Raspotnik, 2023)

improving climate models, and informing policy decisions on a global scale.

3 The POLARIN project for the development of polar science in the EU and beyond

The POLARIN (Polar Research Infrastructure Network) is a EU project funded under the Horizon Europe framework program. Its focus on creating an international network of infrastructure specifically tailored for polar research and services sets it apart from other projects.

The projects mentioned above (Eurofleets, INTERACT, ARICE, and AQUARIUS) form a supportive network of initiatives that collectively contribute expertise, infrastructure, and data crucial for the successful execution of POLARIN. By leveraging the outcomes and collaborations fostered by these projects, POLARIN can effectively address its objectives within the polar research domain. While the above-mentioned projects address important aspects of polar research, POLARIN uniquely aims to integrate various facilities of complementary and interdisciplinary research infrastructure, including research stations, vessels, observatories, and data storage facilities. This network facilitates interdisciplinary research into complex processes in polar regions by providing improved

Table. Organizations and their research infrastructure involved in the POLARIN project

Organization	Research infrastructure
	Germany
Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research	Neumayer Station III, AWIPEV Base, FRAM Observatory, Ice Core Repository, British Ocean Sediment Core Research Facility, RV *Polarstern*
GFZ German Research Centre for Geosciences (GFZ Helmholtz Centre Potsdam)	The GEOFON Program facilities, MESI (Modular Earth Science Infrastructure)
	Finland
University of Oulu	Oulanka Research Station
Helsinki University	Kilpisjärvi Biological Station
Finnish Meteorological Institute	Pallas Atmosphere-Ecosystem Supersite, ACTRIS Cloud Remote Sensing Data Center Unit (CLU), Arctic Space Centre (Sodankylä)
Turun University	Kevo Subarctic Research Station
	Italy
National Institute of Oceanography and Applied Geophysics	Concordia Research Station (Antarctic), Mario Zucchelli Station (Terra Nova Bay, East Antarctica), Dirigibile Italia Research Station (Ny-Ålesund, Svalbard)
National Research Council	RV *Laura Bassi*, A PC5 ice class A
ETT SPA	Supernap Data Center (Pavia)
	Denmark
Aarhus University	Zackenberg Research Station (Greenland), Villum Research Station (Greenland)
Technical University of Denmark	RV *DANA*, Arctic DTU Research Station (Greenland)
Københavns University	Arctic research station (Qeqertarsuaq, Greenland), Sermilik Station (Tasiilaq, Greenland), RV Porsild
Danmark Institute of Metrology	The DMI Geophysical Observatory Qaanaaq (Greenland)
	Norway
Svalbard Integrated Arctic Earth Observing System	The SIOS Data Management System
Norwegian Polar Institute	RV *Kronprins Haakon*, Ny-Ålesund Research Station, Troll Research Station
NILU organisation	EBAS database (http://ebas.nilu.no)
	Spain
Spanish National Research Council	Juan Carlos I Antarctic Station
Ministry of Science and Innovation and Universities	RV *Hesperides*, Gabriel de Castilla Summer-only Research Station (Deception Island, West Antarctica)
	Ukraine
National Antarctic Scientific Center	Akademik Vernadsky Research Station, RV *Noosfera*
	France
French Polar Institute	Jean-Corbel Research Base (Spitzberg Island, Svalbard), Concordia Research Station (Antarctic)

End of Table

Organization	Research infrastructure
Du Ponant Company	RV *Árni Friðriksson*, ice class 1B
Tara Ocean Foundation	Tara Polar drifting station, ice class IA super
	Greenland
Greenland Institute of Natural Resources	Greenland Institute of Natural Resources (GINR), Kobbefjord Research Station (West Greenland)
	Sweden
Swedish Polar Research Secretariat	Abisko Scientific Research Station, Wasa Summer Station (Dronning Maud Land, Antarctica)
Stockholm University	Tarfala Research Station (Kebnekaise)
	Iceland
Sudurnes Science And Learning Center	The Sudurnes Science and Learning Center
Rannsóknastöðin Rif – Rif research	Koltur Research Station (Niðri í Húsi restored stone house)
Conservation of Arctic Flora and Fauna (CAFF)	Arctic Biodiversity Data Service (ABDS)
	Canada
Laval University	Research Icebreaker CCGS *Amundsen*, CEN Whapmagoostui-Kuujjuarapik Research Station
Aurora College	Western Arctic Research Centre, Cold and Warm Storage
	Austria
Graz University	Sermilik Research Station (Greenland)
	Poland
Adam Mickiewicz University	Petuniabukta Polar Station
Institute of Geophysics, Polish Academy of Science	Hornsund Polish Polar Station (Svalbard)
Nicolaus Copernicus University in Toruń	Nicolaus Copernicus University Polar Station (Svalbard)
	USA
University of Alaska System	Toolik Field Station (TFS)
Science logistics support in the Arctic	Barrow Arctic Research Center (BARC), Barrow Environmental Observatory (BEO)
	Ireland
Irish Marine Institute	RV *Celtic Explorer*
	The UK
United Kingdom research and innovation Government Department	NERC Arctic Research Station Equipment
	Bulgaria
Bulgarian Antarctic Institute	St. Kliment Ohridski Seasonal Research Station (Livingston Island, Antarctica)

in-person and remote transnational access to research infrastructure, training opportunities, and virtual access to data and services.

The project started on March 1, 2024 and will be active for five years until the February 28, 2029. The POLARIN project represents the European Union's commitment to advancing scientific research and cooperation in the polar regions by uniting the efforts of the main polar research operators. The project's overall aim is to provide efficient and customised research infrastructure services and address the scientific challenges of the polar regions, including providing access to a wide portfolio of complementary and interdisciplinary top-level research infrastructure facilities ahead of the 5th International Polar Year (IPY) in 2032–2033.

By unifying research infrastructure and services through the POLARIN project, the EU aims to foster collaboration, innovation, and sustainable development in the polar regions. The project's comprehensive approach facilitates cutting-edge research, data sharing, and interdisciplinary collaboration, ultimately contributing to a deeper understanding of the polar regions and their significance for the planet and its inhabitants.

The project involves all operators of polar research from the EU, as well as polar operators from Chile, Canada, the USA, and the UK. In total, there are 47 organizations and 64 infrastructure facilities in both the Arctic and the Antarctic. Specifically, this includes 38 research stations (27 Arctic stations and 11 Antarctic stations), 12 vessels, 18 observatories (including one deep-sea observatory, two observational networks, and 15 key observatories associated with research stations), four ice and sediment repositories, and seven databases. The list of the participants and the facilities shared is shown in the Table.

The main Objectives of the POLARIN project are:

Challenge-Driven Transnational Access.

POLARIN will provide researchers with transnational access to a diverse and comprehensive portfolio of research infrastructures in the polar regions. By offering access to a wide array of facilities, including Arctic and Antarctic research stations, research vessels, icebreakers, observatories, and data repositories, the project facilitates interdisciplinary research and collaboration on complex processes that affect the polar regions.

Improved Data Access and Interoperability.

The project recognizes the critical role of data in advancing scientific understanding. POLARIN focuses on improving data availability and interoperability between different data infrastructures to enhance research capabilities. By making data more accessible and user-friendly, researchers can efficiently utilize valuable information from various sources.

Virtual Access to Data and Data Services.

POLARIN will provide virtual access to data and data services, allowing researchers to access and utilize data remotely. This approach enables scientists to work with data without physically visiting research sites, making data analysis and collaboration more efficient and flexible.

Data Products for the Scientific Community and Decision Makers.

POLARIN is committed to producing valuable data products relevant to the scientific community and decision-makers. The project supports evidence-based decision-making and policy development related to the polar regions by providing reliable and actionable information.

Training the Next Generation of Polar Researchers.

The project recognizes the importance of nurturing young talent and skilled researchers interested in polar science. POLARIN will train the new generation of polar scientists to exploit the available research infrastructures optimally.

Promoting Services and Engaging with Society.

POLARIN acknowledges the significance of effectively communicating its services and research outcomes to society. By duly advertising the project's offerings, it encourages researchers and infrastructure users to share their research findings with the public, raising awareness about polar issues and their global importance (Biebow et al., 2023).

4 The role of Ukraine in POLARIN

Ukraine's participation in Antarctic research is coordinated by the State Institution National

Figure 2. General view of year-round Vernadsky Station (photo from the SI NASC archive)

Figure 3. Research vessel *Noosfera* in Antarctic waters (photo from the SI NASC archive)

Antarctic Scientific Center (SI NASC), functioning under the Ministry of Education and Science of Ukraine. Through SI NASC, Ukraine is contributing two vital research infrastructures in Antarctica: the Ukrainian Antarctic Akademik Vernadsky Station (Vernadsky Station) and the research vessel *Noosfera* (Figs. 2, 3).

As Dykyi et al. (2023) highlighted, Vernadsky Station is an important reference point for long-term research in the Antarctic region. Its exceptional location enables an in-depth study of complex environmental processes and facilitates comprehensive monitoring of their changes. The well-equipped geophysical observatory at Vernadsky Station is esteemed as one of the premier Antarctic facilities. It consistently observes the magnetic field, ionosphere, and ozone layer above the Antarctic Peninsula and shares this valuable data with global databases.

Simultaneously, the ice-capable RV *Noosfera* – a flagship of the Ukrainian research fleet – is available year-round for national and international research activities, offering a platform for world-class biological, oceanographic, and geophysical research in the polar regions and beyond. With its cutting-edge laboratories and winch systems capable of delving into the seabed at remarkable depths of 8 km, this vessel has become an indispensable tool for in-depth marine exploration.

Beyond its technical capabilities, the vessel accommodates a skilled crew of 27 individuals and can host up to 50 scientists, fostering a collaborative environment for comprehensive research endeavours. The RV *Noosfera's* remarkable autonomy, extending up to 2 months, empowers researchers to conduct investigations across various points in the vast World Ocean.

Potential initiatives for international collaboration encompass joint expeditions and research programs featuring the installation of state-of-the-art measuring equipment and the standardization of observations. It is expected that while RV *Noosfera* will be serving as a mobile platform for international maritime research, Vernadsky Station should operate as an Antarctic science hub for collaborative research with other parties to contribute significantly to globally impactful multinationally co-ordinated research and observing system to better understand and preserve the polar environment as a unique and crucially important area for the Earth System.

5 Conclusions

Polar initiatives, highlighted in this perspective piece, demonstrate that pooling resources, expertise, and perspectives can amplify our understanding of climatic shifts, ice dynamics, and ecosystem intricacies. Faced with the undeniable challenges of climate change, rising sea levels, and environmental shifts, it is through harmonious collaboration that effective solutions can be found.

Ukraine, among other partners, has been actively involved in Antarctic research. It has significantly contributed to developing Antarctic research infrastructure, providing opportunities for international research at Vernadsky Station and onboard the RV *Noosfera*. Ukraine has shaped policies by contributing data and insights to global discussions on environmental conservation, climate change mitigation, and sustainable development in the polar regions (Dykyi et al., 2023).

In general, the POLARIN's emphasis on international collaboration and its inclusion of various sites of research infrastructure make it stand out as a comprehensive initiative to address polar regions' scientific challenges. While the importance of being the last project funded by the European Union is noted, it is not the sole reason for POLARIN's significance. Instead, its strategic importance, scientific objectives, and support for polar research make it crucial ahead of the 5th International Polar Year (IPY) in 2032–2033 to understand and address the changes occurring in polar regions and their impacts on the Earth's systems.

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Мережа полярної дослідницької інфраструктури: внесок України

Реферат. Полярні регіони відіграють значну роль в екосистемі Землі. Вони є важливими для формування клімату Землі та є ключовими маркерами його змін. З метою дослідження таких змін вчені, які досліджують полярні широти, потребують доступу до дослідницької інфраструктури, щоб розуміти та передбачати ключові процеси в полярних регіонах та надавати достовірну прогностичну інформацію за результатами таких спостережень. Для вирішення цього завдання консорціум основних європейських та міжнародних операторів полярних досліджень об'єднує свої зусилля в проєкті POLARIN. POLARIN – це міжнародна мережа полярних дослідницьких інфраструктур та їх послуг, спрямована на вирішення актуальних наукових викликів, пов'язаних з полярними регіонами. До мережі входять різноманітні взаємодоповнювальні та міждисциплінарні інфраструктури верхнього рівня: дослідницькі станції в Арктиці та Антарктиці, дослідницькі судна, що працюють на обох полярних регіонах, обсерваторії, бази даних та інфраструктура для обробки даних, а також репозиторії наукових зразків. Відтак метою статті є висвітлення внеску ключових об'єктів антарктичної інфраструктури України в проєкт POLARIN – станції «Академік Вернадський» як геофізичної обсерваторії для комплексного моніторингу змін навколишнього середовища, та науково-дослідницького судна льодового класу «Ноосфера» як мобільної платформи для біологічних, океанографічних і геофізичних досліджень в полярних регіонах та за їх межами. Зазначається, що вказані об'єкти наукової інфраструктури та моніторингові дані, зібрані за їх допомогою, зробили значний внесок у міжнародно координовану систему досліджень і довгострокових спостережень для кращого розуміння та збереження вразливого полярного середовища Землі.

Ключові слова: POLARIN, наукова інфраструктура, науково-дослідницьке судно «Ноосфера», полярна логістика, полярні регіони, станція «Академік Вернадський»