सत्यमेव जयते
Ministry of Earth Sciences
Government of India

15th INDIAN ARCTIC EXPEDITION REPORT

2024 - 2025

NATIONAL CENTRE FOR POLAR AND OCEAN RESEARCH

Ministry of Earth Sciences
Government of India

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15^{th} Indian Arctic Expedition Report
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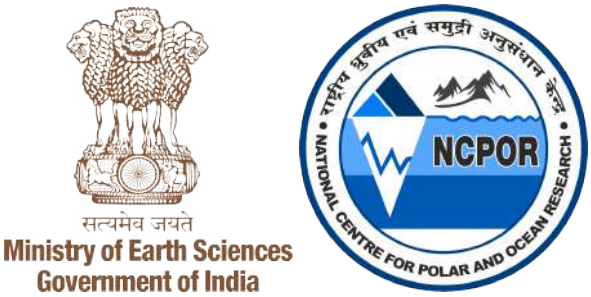

National Centre for Polar and Ocean Research (NCPOR)

Ministry of Earth Sciences (MoES)
Government of India

Headland Sada, Vasco-da-Gama, Goa
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National Centre for Polar and Ocean Research

National Centre for Polar and Ocean Research (NCPOR) is India's premier R&D institution responsible for the country's research activities in the Polar and Southern Ocean realms.

Indian Arctic Research Station - Himadri

India's Arctic research station, Himadri, established in 2008 at Ny-Ålesund, Svalbard, serves as a hub for studying climate change impacts and adaptations in the Arctic. Equipped with modern facilities, Himadri accommodates researchers investigating various aspects of the Arctic environment. Studies include long-term monitoring of fjord and ocean dynamics, analyzing physicochemical and biogeochemical parameters crucial for climate change models. Research also focuses on Arctic glacier mass balance, assessing its influence on sea-level rise and freshwater discharge. Additionally, scientists at Himadri examine the response of Arctic flora and fauna to human activities and extreme environments. India leverages the Gruvebadet Atmospheric Laboratory for comprehensive atmospheric studies, utilizing instruments like radiometers and radars. Through Himadri, India is actively contributing to the global understanding of the Arctic's role in the Earth's climate system.

This was prepared by Arctic Expedition Logistics section of National Centre for Polar and Ocean Research (NCPOR), Ministry of Earth Sciences (MoES), Government of India, Vasco-da-Gama, Goa, India

First release, 17 September 2025

डॉ. एम. रविचंद्रन
Dr. M. Ravichandran

सत्यमेव जयते

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FOREWORD

The Arctic is a critical indicator of global climate health, a reservoir of unique biodiversity, and a region of immense scientific and strategic importance. Emerging research highlights its significant influence on Indian monsoon patterns, underscoring the need for a deeper understanding. Recognising this, the Ministry of Earth Sciences has been conducting annual scientific expeditions to the Arctic region—specifically to Ny-Ålesund, Svalbard—through the National Centre for Polar and Ocean Research (NCPOR), to advance research and address key environmental challenges.

India carried out the 15th Indian Expedition to the Arctic during 2024-25, studying various aspects of polar sciences, including atmospheric, environmental, cryospheric, biological, marine, and space sciences. India commenced winter expeditions to the Arctic in 2023 during the 14th Expedition, which also continued during the 15th Expedition. In line with our policy to have a pan-Arctic presence to study it holistically, another expedition to the Canadian High Arctic Research Station (CHARS) in Cambridge Bay was undertaken during the summer of 2024.

Undertaking complex expeditions across the Arctic land and ocean involved the exceptional planning and round-the-clock involvement of scientists from NCPOR. This report comprehensively overviews India's scientific endeavours in the Arctic. Each chapter reflects the scientific rigour and unwavering commitment of our researchers, who navigated logistical complexities and embraced the inherent challenges of polar exploration. I extend my heartfelt appreciation to all the participants and commend the NCPOR team for their meticulous planning and coordination, which made these remarkable achievements possible.

(M. Ravichandran)

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Dr. Thamban Meloth
Director

Preface

The Indian expeditions to the remote and fragile ecosystem of the Arctic are driven by a commitment to uncover the mysteries of the Arctic environment, understand the impacts of climate change, and develop strategies for sustainable interaction with this unique region. This report synthesises the scientific field activities and logistics accomplishments of the 15th Indian Scientific Expedition to the Arctic during 2024-2025. A total of 35 projects were implemented under the summer component, and 10 projects were implemented under the winter component of the 15th Indian Arctic Expedition during 2024-25. These projects were selected after a nationwide call for proposals and a rigorous peer review by external expert committees.

During 2024-25, the IndARC mooring was redeployed after a long break since 2021. The winter expeditions to Ny-Ålesund, in Svalbard, during dark and cold polar nights were undertaken from November 2024 – March 2025 in 3 batches. The expedition's scientific work focused on marine ecosystems (nitrogen cycles, microplastics, and biodiversity), oceanographic observations, atmospheric sciences (precipitation, aerosols, and atmospheric transport), and the cryosphere (glacier and permafrost monitoring). The expedition included six summer and three winter batches from various institutions. In addition to scientific work, the teams celebrated various events, including International Yoga Day, Independence Day, Republic Day, and Onam. The members also conducted a cleanliness drive at the Himadri Station and its surrounding areas.

Our vision is to transform India's scientific activities in the Arctic with a pan-Arctic perspective as envisaged in India's Arctic Policy 2022. To achieve this, the second expedition to the Canadian High Arctic in Cambridge Bay, Canada, was undertaken during August-September 2024.

I would like to thank Dr. Manish Tiwari, Dr. Rohit Srivastava, and the Arctic Operations Group team for their commendable work on all scientific planning and logistics arrangements during the expedition. I sincerely thank all the team coordinators and members of the 15th Indian Arctic Expedition for participating in different batches and for providing their inputs for the on-field activities used in the report.

(Thamban Meloth)

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1.1 Introduction

NCPOR as the designated nodal agency responsible for the implementation of the Indian Polar Science Programme on behalf of the Ministry of Earth Sciences (MoES) has been sending scientific teams to Ny-Ålesund since 2007-08.

1.2 Summer and winter Components

To concretize the scientific and logistics aspects of the Indian scientific endeavors in the Arctic during the year 2024-25, NCPOR had floated an advertisement during December 2023 at the national level calling for proposals for initiating scientific research at the Ny-Ålesund research base in Svalbard, Norway. Taking into consideration the ongoing long-term programs and the collaborative studies planned to be initiated between India and Norway, the call for proposals for the year 2024-25 was restricted to the following focus areas:

- Atmospheric Science with special reference to study of aerosols, trace gases and precipitation over the Arctic
- Space Sciences, Astronomy and Astrophysics

- Marine Science: Dynamics and functioning of Arctic fjords (Kongsfjorden - Krossfjorden System)
- Environmental Science: Natural contaminants in food webs and long-range pollutants
- Cryospheric studies: Glacier monitoring and snow /ice chemistry.

Thirty-five (35) projects were implemented during the summer season of 2024. Ten projects were implemented in winter season in which eight (8) projects were implemented in both summer and winter.

1.2.1 Implemented projects

Table 1: List of implemented projects during 15th Indian Arctic Expedition 2024-25.

Ongoing Projects	
Sl. No.	Name of the scientific project/ tasks (Institutes)
1	Monitoring of Arctic clouds precipitation (Lead: NCPOR)
2	Study of characteristics of atmospheric aerosols and their climatic implications over the Arctic (Lead: NCPOR)
3	Fingerprinting the sources of organic aerosols at high Arctic: Formation processes and removal mechanism (Lead: SPL)
4	Detection and measurement of rare events and LET spectra of cosmic rays at North Pole (Lead: BARC)
5	Upper-Lower atmosphere Coupling and Radio Astronomy at Low Frequency (Lead: IIT Indore)
6	Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies (Lead: NCPOR)
7	Deployment of Ambient Noise system for Polar region measurements (Lead: NIOT)
8	Monitoring of cryosphere processes and dynamics using space-borne and in-situ data (Lead: SAC)

9	Tropical transfer of essential and non-essential metals in the Arctic food webs - A comprehensive analysis of Kongsfjorden and Krossfjorden ecosystems (Lead: Bharathidasan University)
10	Understanding the seasonal variation of microplastic pollution in the Arctic environment: extent and dynamics within the fjord (Kongsfjorden) ecosystem (Lead: IISER Kolkata)
11	Microbial Community Dynamics and Responses to Climate-Change-Induced Variations in the High Arctic Fjord Ecosystems (Lead: NCPOR)
12	Adaptive Response of Actinobacterial community in Ny-Alesund to climate change (Lead: Satyabhama IS&T)
13	Siderophores, EPS, and sea-ice microbial community in Kongsfjorden role in sustaining microbial loop in underlying waters (Lead: NCPOR)
14	Biodiversity assessment and documentation of the Polar habitat employing Fire Hawk honey badger optimization enabled deep learning (Lead: JAIN Deemed to be University)
15	Investigation of alteration of Airborne Microbial Diversity by long-range transport of continental aerosols over Arctic (Lead: Bose Institute)
New Projects	
16	Stable isotopic study of atmospheric water vapor and snow over Ny-Ålesund, Svalbard (Lead: PDEU)
17	Polar Space Electric and Magnetic Sensor (SEAMS) for Studying RFI in the polar region and very low frequency radio astronomy (Lead: SPPU)
18	Analyzing Ocean-Atmosphere-Sea Ice-Snow Dynamics and Growth Patterns in the Ny-Ålesund, Svalbard Region Using Advanced Neural Network Models (Lead: Chinmaya Vishwa Vidyapeeth)

19	Triple Oxygen Isotopologue of water vapour: tracing the local moisture recycling and linkage to glaciological parameters in Ny-Ålesund, Svalbard region, Arctic (Lead: SSBC, University of Delhi)
20	Comparing Arctic-Himalayan Permafrost Dynamics: Investigating Thaw Processes from Remote Sensing and Advanced Inversion Techniques (Lead: Amrita Vishwa Vidyapeetham)
21	Understanding the benthic foraminifera and its microstructures response to modern environmental gradients in High Arctic areas (Lead: Jadavpur University)
22	Relative distribution of GDGTs and 3-Hydroxy fatty acids in soil and lake sediments of the Svalbard region: Evaluation of membrane lipids as climate proxy in polar regions (Lead: IISER, Kolkata)
23	Carbon dynamics in Svalbard Permafrost using radiocarbon in soil organic matter, soil respired CO_2 and CH_4, and dissolved organic carbon in stream water (Lead: PRL)
24	Investigating Dust Mineralization in the Arctic: Implications for Ecosystem Dynamics and Climate Change (Lead: IISc)
25	Investigating the Characteristics and the Fate of Terrestrial Organic Matter in the Marine Realms of High Arctic Fjords (Lead: NCPOR)
26	Airborne invaders: Unveiling the Menace of Airborne Microplastics Transporting a Toxic Cocktail of chemicals to the Arctic Frontier (Lead: M.G. University)
27	Tracing Aeolian dust and footprints of forest fires over the Arctic: observation from Svalbard (Lead: BSIP)
28	Cultivation of "Yet To Culture" microorganisms using iCHIP and onsite cultivation strategies for biomanufacturing Innovations (Lead: National Centre for Cell Science)
29	Investigation and Monitoring of Planktonic epibiosis in the Arctic fjords (Lead: CUSAT)

30	A study on the endobiome diversity of Arctic plants (Lead: Manipal A.H.S.)
31	Genomic and metagenomic approach towards arctic meiobenthos with emphasis to their phylogeography and evolutionary history (Lead: CUSAT)
32	Role of migratory birds and potential release of ancient pathogens from melting glaciers in the dissemination of MDR (Lead: CUSAT)
33	Seasonal variability of plankton diversity and biogeochemical cycle in the Kongsfjorden and Arctic Krossfjorden-Svalbard, driven by glacial/sea-ice inputs (Lead: NCPOR)
34	MicrobOmics of the Arctic: Unveiling Microbial Diversity and Associated Functional Implications Through Comprehensive Multiomic Approaches (Lead: NIOT)
35	Nitrogen cycle and associated microbiome in the glacio-marine ecosystem of Svalbard (Lead: NCPOR)

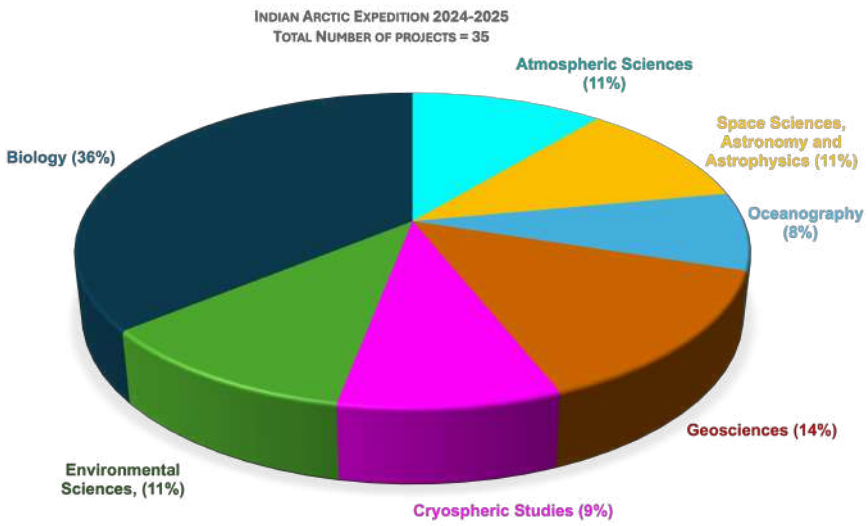

Figure 1.1: Distribution of projects under different scientific themes of 15^{th} Indian Arctic Expedition 2024-2025

2. Summer Batch -1 & 2 (20 May-27 Jun 2024)

The first summer batch reached the Indian Arctic Research Station - Himadri on 20 May 2024 and undertook their activities till 17 June 2024. The second batch of expedition reached Himadri on 03 June and undertook their activities till 27 June 2024. A team of four members participated in the first summer batch and four batch in second batch. The comprehensive environmental sampling was conducted in Kongsfjorden to study marine and atmospheric microbial communities and biogeochemical processes. Water samples were collected from multiple stations and depths to assess spatial and vertical variability. These were analyzed for primary production and nitrogen fixation rates using stable isotope tracer techniques. Seawater was also filtered to collect microbial biomass for microbiological and molecular studies, with preserved samples transported on dry ice for further analysis in India. Sediment and water samples were processed to evaluate the composition of particulate organic matter, including proteins, lipids, carbohydrates, and pigments, for ongoing biochemical analyses. Air samples were collected using high-volume air sampler to capture airborne microorganisms and atmospheric aerosols. These samples are intended for molecular studies to assess microbial diversity, functional shifts, and the potential climatic impacts of aerosols in the Arctic. All laboratory analyses will be carried out at specialized research institutions in India.

In the second summer batch, advanced scientific instruments were installed at the Gruvebadet Atmospheric Laboratory to study Arctic atmospheric conditions, including an All-Sky Imager camera, GNSS receivers, and various Radio Frequency Interference (RFI) survey antennas. RFI surveys, using different antenna types, were conducted multiple times each week to ensure robust data collection under challenging Arctic conditions. These efforts aim to enhance understanding of atmospheric phenomena and climate change impacts. Concurrently, field sampling was performed across diverse Arctic environments such as exposed soils, glacier retreat zones, deep-sea sites, and plant rhizospheres. The collected samples will support metabiological assessments of microbial communities, with potential applications in ecological studies and biomanufacturing. Additional support was also provided for other ongoing research activities. Surface sediment samples were collected from Kongsfjorden and Krossfjorden for micropaleontological and grain size analyses. These included CTD measurements at each station, contributing to a broader understanding of Arctic marine sedimentology and paleoenvironmental conditions. By focusing on the Kongsfjorden- Krossfjorden system, oceanographers conducted extensive sampling at predetermined stations in the fjords (Figure 2.1).

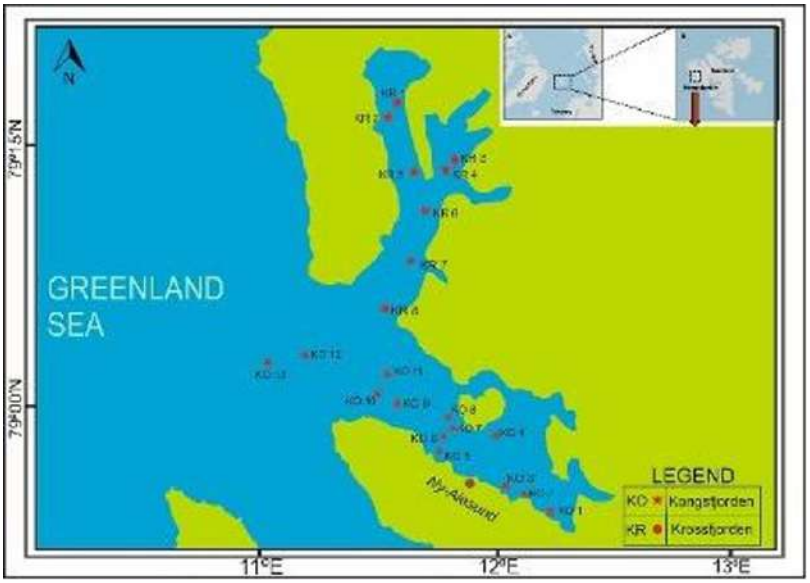

Figure 2.1: Sampling locations (red circles) in the Kongsfjorden-Krossfjorden system in Svalbard. Projects executed mostly rely on these predetermined locations for sample collection.

The project wise field activities undertaken at Arctic are described.

2.1 Field activities undertaken by summer batch-01 & 02

2.1.1 Nitrogen cycle and associated microbiome in the glacio-marine ecosystem of Svalbard

Nitrogen (N) is a vital nutrient regulating marine primary production. Understanding the processes of nitrogen fixation, assimilation, and removal is essential for elucidating the N cycle in marine ecosystems. Due to ongoing global warming, the fjord systems of Svalbard are experiencing significant variability in physico-chemical conditions. These changes are considered early indicators of broader environmental shifts that may occur across the Arctic region. The dynamics of sea ice and glacial melt strongly influence primary production and biogeochemical cycles in the coastal Arctic Ocean. Since the 1970s, Arctic sea ice has declined by approximately 9% per decade, coinciding with a 25% increase in primary productivity. To sustain this rising productivity, an additional nitrogen source is likely required; however, the origin of this nitrogen remains unclear. Fjord systems are expected to be key contributors. This study adopts an integrated approach to investigate the nitrogen cycle and its associated microbial communities within the glacio-marine environment of Svalbard. It aims to characterize the diversity, abundance, distribution, and ecological roles of these microbial communities. By estimating rates of nitrogen transformation processes—such as nitrogen fixation and assimilation—the study will also explore the functional significance of microbial taxa involved in Arctic nitrogen cycling.

2.1.2 Investigating the characteristics and the fate of terrestrial organic matter in the marine realms of high Arctic fjords

Thawing terrestrial cryosphere, coupled with increased precipitation and freshwater discharge, is anticipated to mobilize and transport TOM from Arctic watersheds to coastal waters. In fjords with robust glacial inflows, ongoing glacier retreat is anticipated to shift glacier systems from marine-terminating to land-terminating. The effects are anticipated to vary

between fjord systems, with predictions of declining OC burial rates in some, like west Spitsbergen fjords, and potential acceleration in others, such as Rijpfjorden. Arctic fjords supply more bioavailable OM from glaciers and rivers to the adjoining coastal regions have suggested the decoupling of age and stability in glacial OM and poses questions about subglacial microbial communities contributing more bioavailable OC. Though critical in evaluating the fate and the OC feedback, the nature and composition of TOM entering Svalbard fjords is poorly understood. Overall, seasonality persists in the Svalbard fjords, as seen in Isfjorden, with dominant MOM during May, followed by continuous terrestrial inputs from rivers, glacier melt, runoff and coastal erosion resulting in TOM signatures all over the fjord in summer months. Permafrost thawing also contributes to the fjord OC, especially humics, with significant implications. However, isotopic end members of OM show mostly overlapping distribution in Kongsfjorden, which makes it challenging to trace MOM and TOM. The C/N ratios are also often underestimated owing to the high clay content of sediments. Even the previous sedimentary biomarker profiles from the marine sediments were very inconsistent, making it challenging to identify the sources of different OM fractions. Hence, it is crucial to first i) characterize all potential sources of OM in terms of terrestrial end members (soil, river and lake sediments, vegetation, permafrost soil, coal, microalgal mats, etc.) and marine sources (glacial melt, phytoplankton, macroalgae, sediments, etc.) utilizing a source-specific multiproxy approach, followed by ii) estimating the impact of physico-chemical processes involved in interaction of different OM fraction and ultimately determining their fate within the intricate marine ecosystem. This study aims to deepen our understanding of the OM dynamics in the Arctic, with a specific focus on Kongsfjorden. By addressing these questions and objectives, we hope to contribute valuable insights that can enhance our knowledge of the complex interactions shaping the composition, availability, and fate of OM in this unique Arctic ecosystem.

2.1.3 Investigation of alteration of airborne microbial diversity by long-ranged transport of continental aerosols over Arctic

This project investigates how long-range transport of continental aerosols influences airborne microbial diversity in the Arctic. By analyzing microbes associated with atmospheric aerosols, the study aims to understand shifts in microbial community structure and their potential ecological and climatic implications in a rapidly changing polar environment. The research focuses on characterizing airborne microbial communities in the Arctic atmosphere and assessing how they are affected by aerosols originating from distant continental sources. Air samples are collected using high-volume air samplers deployed at strategic locations, and microbial taxa are identified through DNA-based molecular techniques. The findings are expected to provide insights into microbial dispersal pathways, the survivability of microbes during atmospheric transport, and their possible roles in Arctic cloud formation, atmospheric chemistry, and ecosystem dynamics.

2.1.4 Study of characteristics of atmospheric aerosols and their climatic implications over the Arctic

Atmospheric aerosols are a significant contributors to the changing climate. They interact with incoming solar and outgoing terrestrial radiation influence the Earth's radiation budget. Under this study, NCPOR is setting up POlar AERosol NETwork (POLAERNET) for continuous and long-term monitoring of aerosols and their climatic impacts over the Arctic and Global climate. Black Carbon mass concentrations and aerosol scattering coefficients are being measured at 1-minute resolution using 7-channel Aethalometer and integrating nephelometer respectively. Aerosol size distribution is being measured at 30-minute resolution using Aerodynamic Particle Sizer (APS) spectrometer. Aethalometer and Nephelometer are calibrated for zero bias, and nephelometer's span calibration was performed using CO_2. High Volume Sampler PM-2.5 (particulate matter having size less than 2.5 μm) and aerosol samples were collected at 7-days intervals on quartz filter paper. The collected aerosol samples will be analyzed to understand the concentration of different aerosol species. The outcome of the study will be helpful in improving understanding on

aerosols over the Arctic.

2.1.5 Long term monitoring of Kongsfjorden-Krossfjorden for climate change studies

Monitoring environmental and ecological changes in the Arctic Ocean is essential because this rapidly warming region serves as an early-warning system of Earth, with shifts in sea ice, currents, chemistry, and ecosystems reverberating through global climate, sea levels, and human livelihoods. Fjords in the Arctic Ocean, particularly those connected to glaciers and the open ocean, are highly sensitive to these changes. Kongsfjorden and Krossfjorden, fjords in west Svalbard, are vital study sites due to their responsiveness to environmental shifts which then impact their diverse marine ecosystems. India has been monitoring Kongsfjorden since 2011 and Krossfjorden since 2014, collecting long-term data that help understand trends and variability in these fjords. Hydrography measurements in these fjords that is continued in the expeditions during the period provides invaluable scientific data, revealing the physical properties and circulation patterns, and the variability in them. This vertical stratification significantly impacts ecological processes and biological productivity. By measuring temperature, salinity, dissolved oxygen, photosynthetically active radiation, fluorescence of chlorophyll a, and turbidity, the project continues to create a repeat, station-based time series from glacier fronts to the fjord mouth that captures seasonal to interannual variability. This approach allows to separate the influence of melt water and sediment inputs from intrusions of Atlantic waters and to relate physical forcing to other biogeochemical processes starting with primary productivity. Standardized protocols and QA/QC make the dataset suitable for trend detection, process studies, and regional model validation. Together, these sustained observations establish a critical baseline for assessing climate-driven change in Kongsfjorden–Krossfjorden and for informing conservation and management in the high Arctic.

2.1.6 Upper -Lower atmosphere coupling and radio astronomy at low frequency

The polar regions are highly susceptible to geomagnetic storms caused by solar activity, which can disrupt satellite communications, GPS systems, power grids, and increase

radiation exposure for astronauts and airline passengers. Space weather also affects Earth's atmosphere and climate, making it crucial to understand and predict these storms for mitigating their impact on technology and human activities. The ionosphere and space weather can be studied using GNSS measurements and radio telescopes, offering a high-resolution alternative. Using both methods provides a complementary approach to study astronomical objects visible only in polar skies. The polar regions offer a unique vantage point for observing near-Earth space weather and are already explored in Antarctica. As we approach the solar cycle peak, continuous monitoring of space weather's impact on the lower atmosphere and ionosphere at both poles is essential. Measuring ionospheric and lower atmospheric parameters will help understand the coupling between the upper and lower atmosphere. Radio telescopes in the Arctic can detect cosmic signals from distant space and Earth's neighborhood, aiding astronomical research and student outreach programs focused on the polar ionosphere and astronomy.

2.1.7 Cultivation of "YET TO CULTURE" microorganisms using iCHIP and onsite cultivation strategies for biomanufacturing innovations

This research project is focused on the exploration and cultivation of previously uncultured microorganisms from various Arctic environments using advanced techniques like iCHIP and onsite cultivation strategies. The goal is to discover new microorganisms that hold potential for biomanufacturing applications. Samples were collected from diverse geographical niches, including exposed soils, glacier retreat zones, the deep sea, and the rhizosphere of Arctic grasses, with the purpose of assessing the diversity and potential of microbial communities in these extreme environments. At the Himadri station, various substrates were used to cultivate specific groups of organisms, and samples were kept in their natural ecosystem within 96-well plates equipped with permeable membranes. This setup allowed them to access environmental nutrients while facilitating cell-to-cell cross-talk in the natural environment. The project aims to identify and cultivate unknown microorganisms, isolate those with unique metabolic pathways, and explore their potential in biotechnological processes. Through comprehensive genomic sequencing and metabolic analysis, the project

seeks to uncover novel genes and biochemical pathways that could contribute to significant scientific and biotechnological advancements, ultimately fostering sustainable industrial solutions.

2.1.8 Understanding the benthic foraminifera and its microstructures response to modern environmental gradients in High Arctic areas

Benthic foraminifera are valuable tools for studying historical Arctic palaeoceanographic and climatic changes. The microstructure of foraminifera provides insights into the changing environmental conditions in the Arctic Ocean, including nitrate and oxygen levels. A better understanding of the ecological preferences and microstructure of these species in present-day environments is necessary. The project aims to identify stressors impacting Arctic foraminifera and their ecology across different regions. Various locations in Kongsfjorden and Krossfjorden were sampled for sediment in late spring. The samples will undergo processing for geochemical, sedimentological, and micropaleontological purposes. The collected data will be used to create a mathematical model, which will be analyzed to forecast future changes in foraminifera proliferation.

Figure 2.2: Field activities of the members of Summer Batch -1.

Figure 2.3: Different field observations and samplings conducted during Arctic expedition (Summer batch-02)

2.2 Participants Details

Table 2: Participants of 15^{th} Indian Arctic Expedition - 2024-25 summer Batch -01

Sl. No.	Name	Designation/Affiliation
1	Dr. Saurabh Das	Associate Professor, Department of Astronomy, Astrophysics and Space Engineering, IIT Indore (Team Coordinator)
2	Dr. Avinash Sharma	Scientist D, BRIC-NCCS, Pune
3	Dr Anupam Ghosh	Associate Professor, Department of Geological Sciences, Jadavpur University, Kolkata
4	Mr. Ahammed Shereef M S	Senior Research Fellow (SRF), NCPOR, Goa

5	Dr. Vipindas PuthiyaVeetil	Project Scientist II, NCPOR, Goa (Team Coordinator)
6	Dr. Ashok Shivaji Jagtap	Project Scientist I, NCPOR, Goa
7	Mr. Rithesh Kumar	Junior Research Fellow (MRFP), NCPOR, Goa
8	Mr. Mohammad Abu Mushtaque	Research Scholar, Bose Institute, Kolkata

2.3 Other Activities

2.3.1 Celebration of International Yoga Day - 2024

The participants celebrated International Yoga Day - 2024 in the Arctic on 21 June 2024 Figure 2.4.

Figure 2.4: Celebration of International Yoga Day in the Arctic on 21 June 2024

2.3.2 Ny-Ålesund Science Talk

Dr. Vipindas P.V. delivered a talk on the topic “Microbial diversity and biogeography in the glaciomarine ecosystem of Svalbard" to the researchers from different countries at Ny-Ålesund Figure 2.5.

Figure 2.5: Ny-Ålesund Science Talk by Dr. Vipindas P.V.

3. Summer Batch -3 (01 Jul to 29 Jul 2024)

The Third summer batch reached to the Indian Arctic Research Station - Himadri on 01 July 2024. The third batch comprised 8 members undertaking 7 different project proposals covering terrestrial, oceanic and atmospheric studies. The multidisciplinary activities covered almost 22 days of field activities (with intermittent restriction due to polar bear movement and unfavorable weather) for water and sediment, biomass, soil and permafrost, and atmospheric (aerosol and precipitation) sampling. Apart from field samplings, regular maintenance of the continuously operating instruments at the atmospheric laboratory (such as MRR, Radiometer, Ceilometer, OTT Parsival) was carried out. The location of the sampling is given in Figure 2.1.

3.1 Field activities undertaken by summer batch-03

3.1.1 Study of characteristics of atmospheric aerosols and their climatic implications over the Arctic

The Arctic region is undergoing rapid climate change, with surface temperatures rising significantly faster than the global average. Long-range atmospheric transport of aerosols has introduced both micronutrients (e.g., Fe) and toxic contaminants (e.g., Pb, Cd, Hg) into this otherwise pristine environment, despite the absence of significant local pollution

sources. A well-known phenomenon, Arctic haze, peaks during late winter and early spring (February–April), driven by the transport of polluted air masses from mid-latitude regions such as Europe and Russia. This atmospheric isolation during winter, combined with low removal rates, leads to pollutant accumulation, while summer months see reduced pollution due to enhanced removal and circulation changes. The project addresses the critical gap in understanding the composition, sources, and anthropogenic influence of aerosols in the Arctic, through trace elements (TEs) and isotopic signatures. The main objective is to identify natural versus anthropogenic sources in Arctic aerosols using Sr-Nd-Pb isotopic ratios, and determine each end-member contributions. The Sr-Nd-Pb ratios are preserved during long-range transport and vary with sources. Hence, they are a robust source apportionment tool. Under NCPOR's POLarAERosolNETwork (POLAERNET), long-term observations are being carried out, which includes the collection of PM2.5 samples using high-volume sampler at the Gruvebadet atmospheric laboratory. These aerosol samples, along with local biomass, soil, sediment, ship fuel and seawater samples are collected from multiple Arctic sites as end members The locations for the sampling are listed in the table below. This study will help quantify anthropogenic vs natural influence and improve our understanding of aerosol geochemistry in the Arctic.

3.1.2 Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies

One of the most important responses that have been observed in Ny-Ålesund due to the ongoing atmospheric- and oceanic-induced changes is the warming, and Atlantic water intrusions, and glacial melting. It is known that fresh water influx is a direct result of glacier melting during summer which generally peaks in July-August. Hence the hydrography and biogeochemical measurements during these months in the fjords are especially important. Moreover, how ocean and atmosphere interact to develop a given state of conditions in the fjord is relatively less known. With this background, , by continuously monitoring the twin fjord systems through subsurface mooring and vertical water column measurements through CTD surveys all over the fjords, the project aims to address the following: 1. Atlantic Water (AW) intrusion to the fjord, its effects on water mass formation, subglacial melting, and

circulation in Kongsfjorden and Krossfjorden. 2. How does the freshwater discharge into the fjords from associated glacial systems affect the hydrography, circulation, and other associated processes? 3. *Stratification and mixing variations*- associated with the increased AW intrusion and glacial freshwater discharge; its implications. 4. How will the AW and glacier melt affect the timing, magnitude, and composition of phytoplankton bloom in Kongsfjorden?

3.1.3 Carbon dynamics in Svalbard permafrost using radiocarbon in soil organic matter, soil respired CO_2 and CH_4

Svalbard is one of the fastest-warming regions in the world, with a warming rate of five to seven times more than the global average. Therefore, it is one of the most appropriate places in the globe to understand the permafrost soil carbon loss due to global warming. Rapid warming could directly affect its soil carbon reserve due to the thawing of permafrost and enhance the emission of CO_2 and CH_4, the main greenhouse gases. This study aims to estimate the loss of soil carbon and identify the loss pathways through which soil carbon is transported to the atmosphere or water body by measuring the radiocarbon content in soil organic matter, soil-respired CO_2, and CH_4. The carbon loss pathways from the Arctic will be compared with those in the high-altitude Himalayan permafrost for a comparative assessment of the impact of climate change on different permafrost soil carbon reserves. For this study, soil samples were collected from two locations at different depths using a soil corer (Diameter = 10 cm). We collected three core samples from these two Locations: 1 core from Stuphallet (78^o 57' 36.6" N, 11^o 39'57.6" E) with core depth of 70 cm and two cores from Blomstrand (78^o 59'13.1" N, 11^o 58'43.2" E) with core depths of 1.4 m and 70 cm respectively. Soil air samples (for CO_2 and CH_4) were also collected from the above sampling points at different depths. Radiocarbon ages of the soil and soil gaseous samples were analyzed by Accelerator mass spectrometer.

3.1.4 MicrobOmics of the Arctic: Unveiling microbial diversity and associated functional implications through comprehensive multiomic approaches

The present study aims to identify key taxa and understand the distribution of microbial communities in response to climate-induced changes through metagenome sequencing. Further, it intends to uncover dynamic changes in gene activity, elucidating how microbial communities adjust their gene expression in response to environmental variations associated with climate change through metatranscriptome study. The study employs microbial single-cell sequencing to obtain detailed genomic and transcriptomic information on the rare microbial groups. This objective enables a finer-scale analysis, allowing the identification of rare or niche microbial populations towards understanding the heterogeneity within communities and identify key metabolites, understand metabolic shifts, and unveil biochemical interactions, providing a comprehensive insight into microbial metabolic adaptations.

3.1.5 Role of migratory birds and potential release of ancient pathogens from melting glaciers in the dissemination of MDR pathogens in the fjord environment

Rapid Arctic warming accelerates glacial melt and permafrost thaw, releasing ancient microbes into fjord ecosystems. Concurrently, rising productivity attracts migratory birds, potentially introducing mesophiic bacteria into the system, several of them are drug-resistant. The interaction between ancient and modern pathogens remains poorly understood, posing a global One Health concern. This study investigates the microbiome and resistome of migratory birds (Arctic terns) and glacier-derived sediments in Ny-Ålesund, Svalbard, to assess antimicrobial resistance (AMR) dissemination. Samples include cloacal swabs, bird feces, fjord water, sediments, and glacier ice from Kongsfjorden and Krossfjorden. Culture-based and metagenomic approaches will characterize microbial communities, while antibiotic sensitivity testing (Kirby-Bauer, MIC) and PCR-based detection of resistance genes (ARGs) will evaluate AMR prevalence. Bioinformatics tools (ARGs-OAP, ABRicate, Cognizer) will analyze resistomes across avian and environmental samples. The study aims to: (1) profile microbial diversity and ARGs in Arctic ecosystems, (2) determine fjords as

probable AMR hotspots, and (3) assess gene exchange between ancient and bird-associated pathogens. Findings will establish baseline data for polar AMR surveillance and inform One Health strategies against climate-driven microbial threats in interconnected ecosystems.

3.1.6 Microplastic pollution in Arctic environment: Extent and dynamics within fjord ecosystems

In continuation with our winter expedition, the Arctic summer of 2024, we studied how seasonal changes, especially ice melt, influence microplastic (MP) transport and deposition across different environments. Soil samples were collected to understand how melting ice affects MP accumulation, while air samples helped track ongoing atmospheric deposition. Shoreline sand was examined to study the impact of wave action and bubble bursting on MP transport to coastal zones. From a fjord, we collected water column profiles and bed sediments to explore how MPs move and settle in marine systems. We also retrieved glacier sediment and conducted permafrost drilling at two depths to assess MP presence in rarely accessed frozen environments. These samples provide insight into how deeply MPs can travel and be stored in the Arctic. This work helps map the pathways and seasonal shifts of microplastic pollution in polar ecosystems. The findings will contribute to long-term environmental monitoring and inform strategies to manage plastic contamination in these remote and fragile regions.

3.1.7 Investigating dust mineralization in the Arctic: Implications for ecosystem dynamics and climate change

The Arctic region is undergoing rapid environmental changes due to global warming, impacting its ecosystems and climate dynamics. One key factor that can significantly influence Arctic ecosystems is dust mineralization. Mineralization of atmospheric dust has been identified as a key process influencing Arctic biogeochemistry and ecosystem health. While dust has been recognized as a transport vector for essential nutrients, the specific processes and impacts of dust mineralization in the Arctic remain poorly understood. This study aims to investigate the mechanisms and consequences of dust mineralization in the

Arctic environment. Understanding dust mineralization in the Arctic is crucial for:

• Predicting the future trajectory of Arctic ecosystems and their services.

• Developing informed strategies for managing and mitigating the impacts of climate change on the Arctic.

• Improving our understanding of global biogeochemical cycles and their connections to the climate system.

Figure 3.1: Different field observations and samplings conducted during Arctic expedition (Summer batch-03)

3.2 Participants Details

Table 4: Participants of 15^{th} Indian Arctic Expedition - 2024-25 summer Batch -03

Sl. No.	Name	Designation/Affiliation
1	Dr. Sourav Chatterjee	Scientist- D, NCPOR, Goa (Team Coordinator)

2	Dr. Vijaya Raghavan Rangamaran	Scientist- C, National Institute of Ocean Technology (NIOT), Chennai
3	Ms. Farsana A	Research Scholar, Cochin University of Science and Technology (CUSAT), Kochi
4	Mr. Rahul Kumar Agrawal	Senior Research Fellow, Physical Research Laboratory, Ahmedabad
5	Mr. Abhishek Mondal	Senior Research Fellow, Indian Institute of Science Education and Research (IISER) Kolkata
6	Mr. Satya I. V. Chanakya	Senior Research Fellow, IISc Bangalore
7	Ms. Iravati Ray	Senior Research Fellow, Jadavpur University, Kolkata
8	Mr. Ghulam Rabbani	Junior Research Fellow, NCPOR, Goa

4. Summer Batch -04 (01 Aug to 02 Sep 2024)

The members of the fourth summer batch of Indian Arctic Expedition 2024-25 implemented seven different scientific projects of those, two projects were from biology sciences, two from glaciology, two from atmospheric sciences and one from the geochemistry field. During the expedition hydrography surveys and collection of water and sediment samples on board MS Teisten in the Kongsfjorden and Krossfjorden were carried out. DGPS survey of the glacier was carried out. Several soil samples were collected in and around Ny-Ålesund. Weekly sampling of filter papers from high-volume samplers was also carried out. Locations of the studies under various projects are given in Figure 4.1

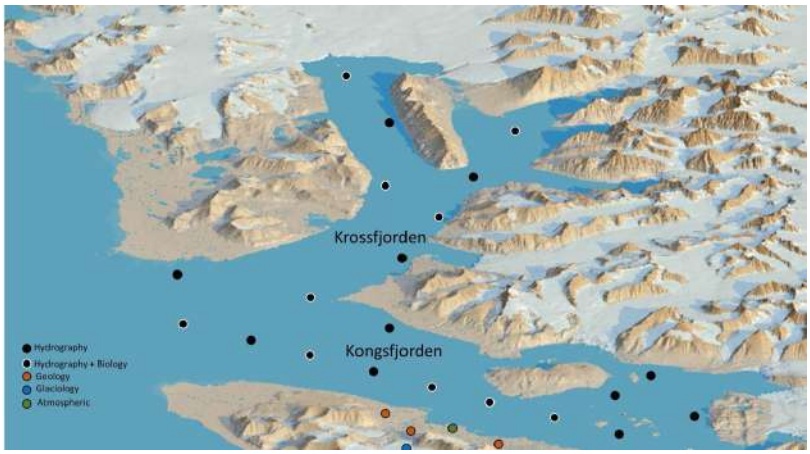

Figure 4.1: Sampling locations in Arctic fjords

4.1 Field activities undertaken by summer batch-04

4.1.1 Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies

Besides the continuation of the survey based measurements in Kongsfjorden and Krossfjorden, after two years of COVID-19 related break, the IndARC mooring was deployed for the sixth time in Kongsfjorden on 31 August 2024, onboard RV Helmer Hanssen of the Arctic University of Norway by NCPOR in collaboration with NIOT, Chennai. The mooring which is now in the southern part of Kongsfjorden (78^o 56.951' N, 11^o 52.521' E) at a depth of 137 m, right at the pathway of the Atlantic waters will monitor and record physical, acoustic, and biogeochemical data at an hourly resolution for the next two years with its retrieval planned in July 2026. The mooring line has sensors at discrete depths between 12-125 m depths measuring temperature, salinity, photosynthetically active radiation, and currents (Figure 4.2). The biogeochemical sensors measuring fluorescence of chlorophyll a, turbidity, and nitrate are in the upper 12-14 m depth. These mooring based measurements on an hourly resolution will give continuous temporal variability in the Kongsfjorden water column. The continuation of this year-round, time-series marine infrastructure-based measurements by India in the Arctic waters reaffirmed its role and collaborative effort in the international scenario to address climate change issues.

Figure 4.2: Deployment of IndARC-VI mooring in the southern part of Kongsfjorden

4.1.2 Microbial community dynamics and responses to climate-change-induced variations in the high Arctic fjord ecosystems

The increased intrusion of warmer and more saline Atlantic water (AW) has not only made Kongsfjorden devoid of land-fast sea ice but to a great extent controls the seasonality and magnitude of phytoplankton bloom. Also, species composition and biomass of benthic macroalgae in Kongsfjorden show strong seasonality. Seasonal variation in glacial melting and consequent variation in meltwater inputs contribute to differences in composition and amount of terrigenous organic Carbon inputs to the fjord. Thus, we anticipate that seasonal variations in the species composition and biomass production of phytoplankton and benthic macroalgae, as well as the contribution of terrigenous carbon, would have a profound impact on microbial community composition, their metabolic activity, biogeochemical cycling, and the climatic feedback mechanism in Kongsfjorden.

4.1.3 Stable isotopic study of atmospheric water vapour and snow over Ny-Ålesund, Svalbard

The stable isotopes, deuterium (D) and oxygen (^{18}O) are important tracers of the natural hydrological processes. Isotopic fractionation during phase change and slower diffusion rates for the heavy isotopes are the two physical processes that produce the isotope variations observed in precipitation. Recent studies have shown that isotopic signals recorded in coastal ice or firn cores are poorly correlated with surface temperature and show a weaker relationship. So, it shows the need to take into account the influences of atmospheric dynamics and local processes, in addition to the classical thermodynamics part on isotopic signals. Using these isotopes, the present work will help to understand various processes related to the precipitation (snow/rain) such as (a) changes in the stable isotopic composition of water vapour and precipitation (b) isotopic equilibrium between snow and water vapour and (c) effect of varying meteorological conditions on the isotopic composition of vapour and snow on small scale.

4.1.4 Seasonal variability of plankton diversity and biogeochemical cycle in the Arctic Kongsfjorden and Krossfjorden-Svalbard, driven by glacial/sea-ice inputs

The study is conducted to investigate how ongoing Arctic amplification influences the biochemistry and plankton community of the Arctic fjords both Kongsfjorden and Krossfjorden. Considering the knowledge gap, the present research proposal hypothesizes that (i) the sea ice decline and ongoing Arctic amplification will significantly impact the fjords' biogeochemical processes and plankton diversity which eventually impact the ecosystem function. (ii) Understanding the present and future ecosystem function and climate change of the region using satellite and model estimation for long-term observation in the Arctic fjords. Hydrography and plankton samples were collected on board MS Teisten in the Kongsfjorden and Krossfjorden during August 2024. The water samples and plankton samples were collected from various depths in both the fjords using a Niskin sampler and plankton net respectively. Nutrient samples were collected in 60ml plastic bottles and samples were stored at -20^{o}C. In addition to that, DIC/Methane samples were collected in 60 ml glass bottles and samples were preserved in $HgCl_2$ until further analysis at NCPOR, Goa. Three liters of water samples from each depth filtered through GF/F filter paper for pigment analysis. Filters are stored at -20^{o}C until further analysis. Subsequently, phytoplankton samples were collected from three depths covering surface, 10m and 50m and samples were immediately preserved in Lugols solution. Zooplankton net was hauled from 50 m to the surface at each location; the catch was preserved in 5% formalin until further analysis at NCPOR, Goa. The preliminary results revealed that the Kongsfjorden was influenced by glacial runoff than the Krossfjorden. Therefore, we anticipate significant changes in hydrological conditions in the Kongsfjorden than the Krossfjorden, thus mostly affecting the plankton community, where the zooplankton biomass was higher in the Krossfjorden than in the Kongsfjorden

4.1.5 Triple Oxygen Isotopologue of water vapour: Tracing the local moisture recycling and linkage to glaciological parameters in Ny-Ålesund, Svalbard region, Arctic

The primary objective of this project was to understand the seasonal behaviour of triple oxygen isotopes of water vapour at Ny-Ålesund and to elucidate the various post-depositional processes, i.e., melting, re-freezing, and sublimation, by measuring the precipitated (liquid and solid) samples at the station and near the glacier side. This study will characterize the water vapour isotopic variations at different heights with varying meteorological conditions. Understanding the characteristics of water vapour of polar regions is not only important for the climate change perspective but also for the global hydrological cycle and budget. This study will characterize the water vapour isotopic variations at different heights with varying meteorological conditions. Understanding the characteristics of water vapour of polar regions is not only important for the climate change perspective but also for the global hydrological cycle and budget.

4.1.6 Tracing Aeolian dust and footprints of forest fires over the Arctic: observation from Svalbard

Recent studies have shown that high-latitude dust sources significantly contribute to the global dust cycle and are important for surface ocean biogeochemistry. Existing studies over the Svalbard region are rather sparse, in particular, focusing on the relative importance of localised versus regional dust transport to the Ny-Ålesund region of Svalbard using radiogenic isotopes ($^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$). Furthermore, the Arctic region is especially sensitive to regional wildfires from Canada and nearby European countries. Therefore, the impact of regional wildfires on the surface soils of Ny-Ålesund and the sediments of the surrounding fjords will be investigated for forest fire-derived organic tracer compounds (e.g., levoglucosan and other related sugars) along with fatty acids and n-alkanes, soot carbon and stable C, N and S isotope composition of bulk particulate organic matter. Furthermore, radiocarbon measurements will be performed on different components of bulk organic matter to better constrain the impact of regional wildfires.

4.1.7 Relative distribution of GDGTs and 3-Hydroxy fatty acids in soil and lake sediments of the Svalbard region: Evaluation of membrane lipids as climate proxy in polar regions

Understanding how Earth has responded to past climate changes is essential for predicting future climate shifts. However, reconstructing past continental climates remains challenging due to the limited availability of temperature proxies that can be applied across different environments. In this context, membrane lipids preserved in soil and sediments have proven to be valuable climate proxies. Over the past few decades, GDGTs (glycerol dialkyl glycerol tetraethers) a group of membrane lipids produced by archaea and bacteria have attracted significant attention. This is because (a) their structures respond sensitively to environmental changes and (b) they are well preserved over geological timescales. Still, the requirement of proxy calibrations i.e. the exact identification of dependency of isomers on physicochemical parameters are needed to better extract climate signals from sediments and improve climate reconstructions that support model hindcasting. In this study, we incorporated 3-hydroxy fatty acids (3-OH FAs), produced by Gram-negative bacteria, alongside GDGTs. Both biomarkers have been successfully used to reconstruct past climates, but their application in polar regions remains poorly tested. To fill this gap, we analyzed the distribution of GDGTs and 3-OH FAs across ecological gradients in the Arctic, specifically in Ny-Ålesund, Svalbard. This included moss-dominated surficial and trench soils, and surficial fjord sediments. Compared to global soils, Svalbard soils showed a strong dominance of 6-methyl brGDGTs over 5-methyl forms, and a lower abundance of branched 3-OH FAs, suggesting microbial communities which may be unique to arctic conditions. Interestingly, Gram-negative bacteria did not respond uniformly to Arctic conditions. This was reflected by an increased anteiso-to-normal C15 fatty acid ratio (RAN15 index), compared to global patterns. While overall concentrations of branched and isoprenoid GDGTs were low likely due to the short growing season (the microbial activity highest in Mid-July to Mid-September, as reported from previous studies). The CBT'5ME index proved to be a reliable pH proxy, showing strong correlation even under extreme conditions. The 3-OH FAs based pH index (RIAN) also showed a good correlation with

measured soil pH, suggesting that the degree of 3-OH FAs branching is mainly controlled by pH in Arctic soils. In contrast, temperature sensitive indices such as MBT'5ME (GDGTs) and RAN15 (3-OH FAs) showed large variability, despite only minor differences in site temperature. This indicates that factors other than temperature, like vegetation or soil moisture, can play an important role in lipid distribution, as these things widely depend on physicochemical parameters. A key result from the depth profiles was the strong influence of moss cover on brGDGT distributions. Moss-dominated soils had higher brGDGT concentrations, distinct microbial communities, higher bacterial activity, and a lower fungal to bacterial (F/B) ratio. Stable carbon isotope (δ^{13}C) and total organic carbon (TOC) data confirmed that moss derived organic matter can be the main source driving brGDGT production. These findings emphasize the important role of vegetation, especially mosses, in controlling microbial lipid production and also the physicochemical parameters in Arctic soils. By linking microbial community structure, organic matter sources, and lipid distributions, this study improves our understanding of lipid-based climate proxies in polar regions and supports their use for paleoclimate reconstructions in the Earth's coldest environments.

4.1.8 Monitoring of cryosphere processes and dynamics using space-borne and in-situ data

The primary objective of this project was to perform the glacier survey which will be helpful to link the features on satellite data. Various glacier features have been identified to link it with satellite data. DGPS measurements over the glacier were carried out using a master and rover unit. Observation of selected glaciers and DGPS measurements will help monitor the changes of glaciers in the Arctic region to understand the impact of climate change and compare it with other mountain ranges like the Himalayas. This field data will be used to identify the various glacier features from space and monitor the glacier activity using historic satellite data. DGPS survey will be used to extract the DEM of the glacier surface which could be helpful to assess the glacier changes from the perspective of climate change in the Arctic region.

4.2 Participants Details

Table 5: Participants of 15^{th} Indian Arctic Expedition - 2024-25 summer Batch -04

Sl. No.	Name	Designation/Affiliation
1	Dr. Anand Jain	Scientist-E, NCPOR, Goa (Team Coordinator)
2	Dr. Sushil Singh	Scientist-G, Space Application Centre, Ahmedabad
3	Dr. Rohit Srivastva	Associate Professor, Pandit Deendayal Energy University (PDEU), Gandhinagar
4	Dr. B Srinivas	Scientist F, Birbal Sahni Institute of Palaeosciences, Lucknow
5	Dr. Shyam Ranjan	Assistant Professor, Shaheed Bhagat Singh College University of Delhi, Delhi
6	Dr. Venkataramana	Project Scientist II, NCPOR, Goa
7	Dr John Paul Balmonte	Assistant Professor, Lehigh University, USA
8	Mr. Vishal	Ph.D. Scholar, Indian Institute of Science Education and Research (IISER) Kolkata
IndARC mooring activities team [19 Aug - 05 Sep 2024]		
9	Mr. M. Arul Muthiah	Scientist F, NIOT, Chennai (Team Coordinator)
10	Mr. B. Kesavakumar	Scientist E, NIOT, Chennai
11	Mr. G. Raguraman	Scientific Officer Gr-II, NIOT, Chennai
12	Mr. C. Muthu Kumar,	Scientific Officer Gr-IF, NIOT, Chennai

4.3 Other Activities

4.3.1 Independence Day celebration at Himadri

The participants of fourth batch celebrated National Independence Day at Himadri on 15 August 2024 (Figure 4.4).

Figure 4.3: Different field observations and samplings conducted during Arctic expedition (Summer batch-04). 1) CTD deployment; 2) DGPS survey; 3) Collection of the filter from high volume sampler; 4) and 7) Atmospheric vapour collection; 5) Soil sample collection; 6) surface water collection;7) Water vapur collection 8) Plankton net deployment; 9) Glacier survey

Figure 4.4: National Independence Day celebration in the Arctic on 15 August 2024

4.3.2 Honorable Indian Ambassador to Norway visited Himadri

Honorable Indian Ambassador to Norway Dr. A. Vimal visited Himadri and interacted with the participants of Indian Arctic Expedition on 26 August 2024 (Figure 4.5).

Figure 4.5: Honorable Indian Ambassador to Norway Dr. A. Vimal with the member of Indian Arctic Expedition team members

5. Canadian Expedition (26 Aug-27 Sep 2024)

A month-long field work was conducted by two NCPOR scientists to collect deep permafrost cores for biological and biogeochemical studies around the Canadian High Arctic Research Station (CHARS), Cambridge Bay, Canada (Figure 5.1). The scientists have also collected tundra samples and active layer soil samples as part of the project objective across different geographical locations around Cambridge Bay.

Figure 5.1: Map showing the locations of permafrost samples collected around the Canadian High Arctic Research Station (CHARS), Cambridge Bay, Canada.

5.1 Field activities undertaken by members of Canadian Arctic Expedition

5.1.1 Evaluation of multidrug-resistant bacteria in the tundra soil, active layer, and permafrost regions of the Canadian High Arctic

Permafrost is permanently frozen soil mainly found in the alpine and polar regions and acts as a massive carbon reservoir, storing ∼1700 petagrams of carbon. As the climate in the polar region is continuously warming, it leads to the thawing of permafrost, which leads to the release of greenhouse gases, buried organic carbon, and reactivation of ancient microbial communities into the surrounding environments, causing significant implications to the functioning of ecosystems. The major aim of the expedition is to investigate the prevalence of antibiotic-resistant genes (ARGs) and antibiotic-resistant bacteria (ARBs) from the permafrost, Active layer, and Tundra soil samples collected around the Canadian High Arctic region near Cambridge Bay, Canada. As a part of the project objective, field activities were conducted by NCPOR scientists around the Canadian High Arctic Research Station (CHARS), Cambridge Bay, Canada. During fieldwork, about 2.3 m deep permafrost cores (No = 8) were collected from different geographical locations within a radius of 40 km around Cambridge Bay located in the Nunavut province (see Figure 5.1). In the laboratory, back at NCPOR, DNA sequencing and culturing will be carried out on the collected permafrost samples to study antibiotic-resistant microbes. By studying the microbial communities locked in Arctic permafrost, scientists hope to better predict the potential release of harmful pathogens and greenhouse gases as the region continues to warm at an unprecedented rate.

5.2 Participants Details

Table 6: Participants of Indian Expedition to Canadian Arctic summer Batch

Sl. No.	Name	Designation/Affiliation
1	Dr. Venkatachalam Siddarthan	Project Scientist-II, NCPOR, Goa

2	Dr. Jabir Thajudeen	Project Scientist-I, NCPOR, Goa

Figure 5.2: Field photo showing preparations for the drilling of Permafrost core samples [left]. Field photo showing the drilled permafrost core samples from the Canadian High Arctic Region. [right]

6. Summer Batch -5 (02 Sep to 30 Sep 2024)

The fifth batch studied the fjords Kongsfjorden and Krossfjorden for various scientific aspects. The locations of the sampling are given in the Figure 6.1.

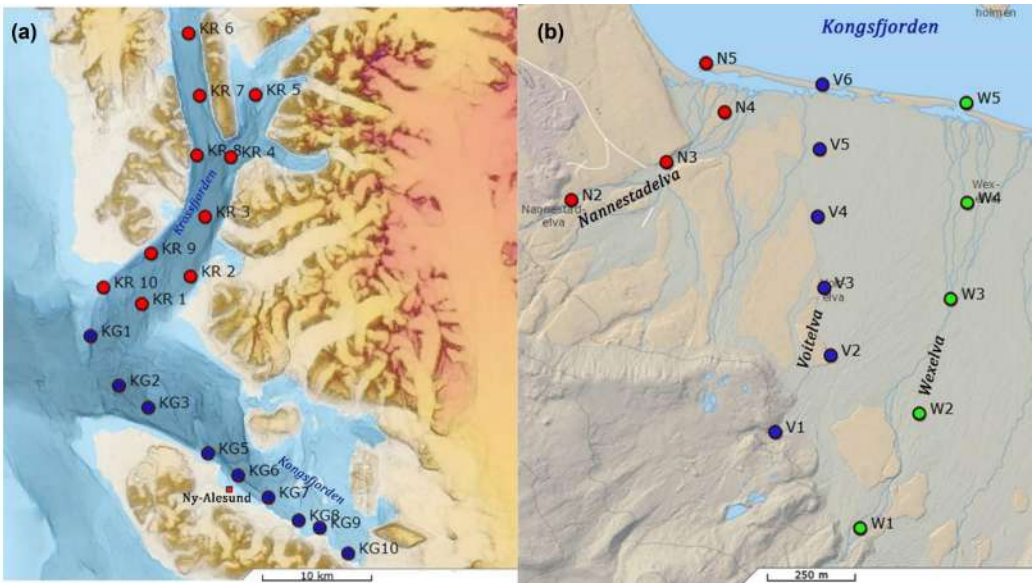

Figure 6.1: (a) Map showing the sampling locations and (b) map showing the sampling locations for sediments from the three glacial runoff streams: Nannestadelva (red dots), Voitelva (blue dots), and Wexelva (green dots).

6.1 Field activities undertaken by summer batch-5

6.1.1 Detection and measurement of rare events and LET spectra of cosmic rays at north pole

Under the project entitled Detection and Measurement of rare events and LET spectra of cosmic rays at North Pole under Space Science project gamma ray dose level at Himadri station using RADEYE-G electronic pocket dosimeter was measured during Sept 2-29, 2024. Further, another RADEYE-G dosimeter was taken during field visit along with other members and measured at two locations of Vestre Broggerbreen and Austre Broggerbreen and radiation levels were found to be around 10-15 μR/h which is considered to be normal background considering the fluctuation of the radiation level. Further RADEY-G dosimeter was taken to Zeppelin laboratory (Atmospheric laboratory of Norway) on Brøggerhalvøya mountain lab which is two km from Himadri situated at about 472 meters above sea level. Gamma radiation level on the rock of the mountain and at 1 m above the rock were also found to be about 10-12 μR/h. Tissue Equivalent Proportional counter (TEPC) has also been operate 24x7 during Sept 2-29, 2024 and the data of low and high LET radiation dose, spectra etc. were recorded and processed to convert them into text file/excel file. The data needs to be analysed using different statistical tools at BARC to get information on the variation on different components of cosmic ray to correlate with solar weather. One set of two CR-39 detector sheets deployed during the winter expedition has been replaced with a fresh set of CR-39 detector towards detection and measurement of rare events at Gruvebadet Atmospheric laboratory. The CR-39 sheet which have been removed from Gruvebadet lab will be chemically processed at BARC.

6.1.2 Trophical transfer of essential and non-essential metals in the Arctic food webs - A comprehensive analysis of Kongsfjorden and Krossfjorden ecosystems

This research aims to explore the trophic transfer of essential and non-essential metals within the Arctic food webs of Kongsfjorden and Krossfjorden ecosystems. Despite existing studies on heavy metal contamination, there is a significant knowledge gap in understanding how these metals move through Arctic ecosystems and the sources contributing to their

accumulation. Specifically, the glacial runoff from the Brøggerhalvøya Peninsula has been underexplored as a potential source of metals. The primary objectives of this study are to assess the distribution of metals from glacial runoff streams and analyze their biomagnification within marine organisms, sediments, and water in the fjords. Fieldwork included collecting surface and bottom water, phytoplankton, zooplankton, and sediments from Krossfjorden (10 sites) and Kongsfjorden (9 sites), as well as sediments samples from three glacial runoff streams including Nannestadelva, Voitelva, and Wexelva. Biological samples, including five macroalgal species from the intertidal zones of beaches and bird feathers, were also collected for metal analysis. Methodologically, the study will utilize multivariate statistical techniques and metal pollution indices to assess contamination levels. The findings are expected to provide critical data on the movement of metals through Arctic food webs and identify key sources. This research has the potential to inform environmental policies and conservation strategies in Arctic ecosystems impacted by both natural and anthropogenic influences.

6.1.3 Comparing Arctic-Himalayan permafrost dynamics: Investigating thaw processes from remote sensing and advanced inversion techniques

This study focused on monitoring mountain permafrost in Ny-Ålesund, marking the first Indian-led research of its kind in the region. The target site was the Rock Glacier 11^o 53' 35.28557" E, 78^o 54' 43.85779" N in the Zeppelin Mountains, situated around 200 meters above sea level. Conducting fieldwork presented significant challenges, particularly due to the unavailability of a polar bear guard. Despite official support from Kings Bay being unavailable, a staff member kindly assisted with his pet dog, allowing us to access the glacier safely. During the expedition, we successfully mapped the geolocation using GPS, especially the boundary of the glacier. Also, we have identified water sources from the permafrost layer beneath the rock glacier. Additionally, we observed that the cable car route near the Zeppelin Mountains provided an additional insights to survey the glacier. With assistance from the Norwegian Polar Institute (NPI), we obtained access to the cable car, which enabled us to capture valuable aerial imagery of the glacier using a GoPro camera. The expedition

concluded successfully with the completion of the survey, contributing new insights into the mountain permafrost in Svalbard. In addition to the above-mentioned project, Dr. Remya had the opportunity to tag along with a team from the Alfred Wegener Institute (AWI) to visit Astre Brøggerbreen Glacier (11^o 49' 56.20307" E, 78^o 54' 15.74302" N. During this expedition, we collected geolocation data and monitored the glacier extensively. Using satellite remote sensing techniques, we calculated changes in the glacier velocity and volume between 2000 and 2024. GSI has been maintaining field observatory data for Brøggerbreen Glacier since 2012, providing a valuable dataset for validation. This will be the first-ever observation of rock glaciers in this region.

6.1.4 Analyzing ocean-atmosphere-sea ice-snow dynamics and growth patterns in the Ny-Ålesund, Svalbard region using advanced neural network models

The process of plankton bloom in the Arctic region is a highly non-stationary and non-linear process. The existing plankton bloom prediction method using various techniques cannot effectively explain the plankton bloom generation process, and the prediction accuracy is not high. Therefore, a new technique named as Proposed Xception-Long Short-Term memory (X-LSTM) approach will be introduced for predicting plankton bloom. Initially, the atmospheric and oceanographic parameters, such as pressure, temperature, conductivity, turbidity (NTU), Dissolved Oxygen (DO) (ml/L), fluorescence, Depth (m), Salinity, Density (sigma-t, kg m^{-3}), wind speed, wind direction, perception, short wave, long wave, cloud height, and plankton count and time, will be considered as input. After that, the input data will be passed to data normalization, where the data will be normalized using Z-score normalization. Following this, the data will be augmented by utilizing the Synthetic Minority Oversampling Technique (SMOTE). After this, plankton growth prediction will be carried out by employing the proposed X-LSTM, which will be obtained by the integration of the Xception model and Deep Long Short-Term Memory (DLSTM). Finally, an analytic study of plankton growth prediction will be performed. Moreover, the implementation of the proposed method will be executed in Python. The performance of X-LSTM will be evaluated under the metrics of Root Mean Square Error (RMSE), Mean Square Error (MSE),

and Mean Absolute Percentage Error (MAPE). The dataset used for this research will be a real-time dataset. Furthermore, the proposed method, X-LSTM will be compared with the existing works in order to reveal its performance.

6.1.5 Biodiversity assessment and documentation of the Polar habitat employing Fire Hawk honey badger optimization enabled deep learning

The proposed project consists of phases such as fish image collection, pre-processing, frame extraction, annotation (labeling), training and validation of the AI model, fish detection, fish type classification, addition of fish information into databases and climate migration and correlation study. Underwater images of finfishes shall be collected from the Arctic ecosystem during Summer and polar night - using Norwegian fish pots (also known as fish traps) fitted with underwater action cameras (GoPro HERO11 Black Waterproof Action Camera). The study will be specifically, targeting Atlantic cod (Gadus morhua) and Polar cod/Arctic cod (Boreogadus saida). These species were selected as many studies reported that pole-ward expansion of the Atlantic cod (Gadus morhua) populations and it is threatening the native Polar cod (Boreogadus saida) and the unique polar ecosystem

6.1.6 Investigating the characteristics and the Fate of terrestrial organic matter in the marine realms of high Arctic fjords

The project aimed to investigate the sources and fate of terrestrial organic matter in the Kongsfjorden. Sampling was conducted in Kongfjorden collecting seawater samples and CTD measurements. Water was filtered through 0.7 μm GF/F filters to collect particulate organic matter for further chemical analysis and through 0.2µm polycarbonate filters for bacterial DNA. Sub-samples were also collected for nutrients, and TOC analysis. All samples were stored in frozen conditions to be shipped to India for further analysis. Bayelva River sediments were collected to trace the fate of terrestrial organic matter down the riverine transport of sediments into the fjord water. This research not only promises to shed light on the sources contributing to the particulate fraction of the organic matter but also holds implications understanding the fate associated with organic matter through the water

column.

6.1.7 Microbial community dynamics and responses to climate-change-induced variations in the high Arctic fjord ecosystems

In collaboration with other Flagship institutes, the project is monitoring the site KB3 (Figure 6.1) in a weekly time series. During the present batch, the site was sampled in the Week 4, Week6 and Week 7 along with a monthly (time series) sampling at the same site. In addition, a coastal (macroalgal) site was sampled for a monthly time series. At all the locations, water samples were collected and processed in the Marine lab. Sub-sampling was done for i. bacterial RNA and DNA by filtering seawater through 0.2 μm polycarbonate filters,
ii. POM by filtering through pre-combusted GF/F filters.
iii. TOC and DOM
iv. Measurements were carried out for bacterial respiration and production

The project aims to understand the seasonal variability and dynamics of prokaryotic community and organic matter in Kongsfjorden using this Kongsfjorden Flagship time-series.

6.1.8 Long term monitoring of Kongsfjorden-Krossfjorden for climate change studies

This project continued the sensor-based monitoring of the hydrography and biogeochemistry of Kongsfjorden and Krossfjorden to study high to low frequency changes the fjord undergoes. CTD casts were carried out on a nearly biweekly interval, i.e., twice in September at different locations covering both Kongsfjorden (19 stations) and Krossfjorden (10 stations). This data collection was also used to understand the environmental setting of Kongsfjorden water column during the period by the AI-based monitoring project for the fish community changes.

6.2 Participants Details

Table 7: Participants of 15^{th} Indian Arctic Expedition - 2024-25 summer Batch -05

Sl. No.	Name	Designation/Affiliation
1	Ms. Archana Singh	Scientist-D, NCPOR, Goa (Team Coordinator)
2	Dr Ashok Kumar Bakshi	Scientific Officer-H, Bhabha Atomic Research Centre (BARC), Mumbai
3	Dr. Remya S N	Assistant Professor, Amrita Vishwa Vidyapeetham, Kerala
4	Ms Anupama Jims	Assistant Professor, Chinmaya Vishwa Vidyapeeth (Deemed-to-be University), Kerala
5	Dr Felix M Philip	Associate Professor, JAIN (Deemed to be University), Bengaluru
6	Dr. Biswajit Roy	DST-Inspire Faculty, NCPOR, Goa
7	Mr. Emmanuel Charles Partheeban	PhD Research Scholar, Bharathidasan University Tiruchirappalli

Figure 6.2: Field activities by the members of summer batch 5

6.3 Other Activities

6.3.1 Ny-Ålesund Science Talks

The following two members delivered science talk Figure 6.3:

1. Dr. Remya delivered a science talk on “Cryosphere Hazards in the Third Pole” in Kongsfjordhallen, on 3 Sep 2024.

2. Ms. Anupama and Dr. Felix M Philip delivered a science talk on “AI for Arctic Biodiversity Monitoring” in Zepplin hall, on 24 Sep 2024.

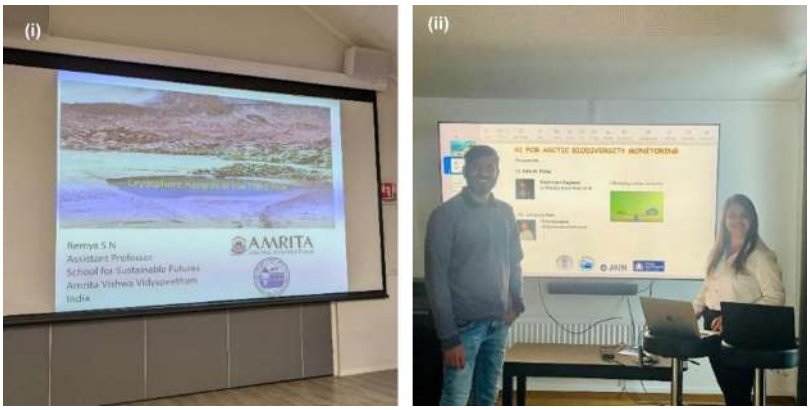

Figure 6.3: Ny-Ålesund Science Talks by (i) Dr. Remya S. N. and (ii) Ms. Anupama Jims and Dr. Felix M Philip

6.3.2 Swachhata hi Sewa 4.0: India’s Swachh Bharat Mission

As part of India’s Swachh Bharat Mission, we conducted a cleanliness drive at the Himadri Station in Ny-Ålesund and its surrounding areas. This initiative aimed to preserve the pristine Arctic environment while promoting sustainable practices among researchers. Every participant pledged to uphold cleanliness standards and contribute to maintaining the ecological integrity of the region. Through these efforts, we not only reinforced the importance of keeping the Arctic clean but also underscored India’s commitment to environmental stewardship, aligning with global efforts to protect and conserve fragile ecosystems Figure 6.4.

Figure 6.4: Cleaning activities under Swachhata hi Sewa

6.3.3 Onam Celebration

Onam, the vibrant harvest festival of Kerala, symbolizes unity, prosperity, and the return of King Mahabali. At Ny-Ålesund, the team celebrated Onam on 14th September 2024 by preparing the traditional Indian dessert, Payasam Figure 6.5. The team served it to all the researchers and Kings Bay staff, sharing a taste of India in the Arctic. This celebration brought warmth and cultural exchange, fostering a sense of togetherness far from home. The festive spirit of Onam was truly felt, even in the remote polar region.

Figure 6.5: Onam celebration on 14th September 2024 by Indian team members in Arctic

7. Summer Batch -6 (07 Oct to 27 Oct 2024)

The sixth batch studied investigate the nitrogen cycle and its associated microbial communities within the glacio-marine environment of the Arctic.

7.1 Field activities undertaken by summer batch-6

7.1.1 Nitrogen cycle and associated microbiome in the glacio-marine ecosystem of Svalbard

Nitrogen (N) is a vital nutrient regulating marine primary production. Understanding the processes of nitrogen fixation, assimilation, and removal is essential for elucidating the N cycle in marine ecosystems. Due to ongoing global warming, the fjord systems of Svalbard are experiencing significant variability in physico-chemical conditions. These changes are considered early indicators of broader environmental shifts that may occur across the Arctic region. The dynamics of sea ice and glacial melt strongly influence primary production and biogeochemical cycles in the coastal Arctic Ocean. Since the 1970s, Arctic sea ice has declined by approximately 9% per decade, coinciding with a 25% increase in primary productivity. To sustain this rising productivity, an additional nitrogen source is likely required; however, the origin of this nitrogen remains unclear. Fjord systems are expected to be key contributors.

This study adopts an integrated approach to investigate the nitrogen cycle and its associated microbial communities within the glacio-marine environment of Svalbard. It aims to characterize the diversity, abundance, distribution, and ecological roles of these microbial communities. By estimating rates of nitrogen transformation processes—such as nitrogen fixation and assimilation—the study will also explore the functional significance of microbial taxa involved in Arctic nitrogen cycling.

7.1.2 Polar Space Electric and Magnetic Sensor (SEAMS) for studying RFI in the polar region and very low frequency radio astronomy

Radio frequency interference (RFI) is mostly created by human activities and directly interferes with our exploration of the Cosmic Universe. The radio astronomy spectrum has been well explored in the frequencies above 20/30 MHz and has given rise to numerous astronomical discoveries of importance like Quasars, Pulsars, active galaxies and dark matter and dark energy. However, frequency range from a few hundred KHz to about 15 MHz remains largely unexplored, due to ionospheric opacity to radio waves of extra- terrestrial origin. This frequency range is a very important range where red- shifted hydrogen line may be discovered which can produce transformative science on the Epoch of Reionization and the origin of the Universe. With the advances in technology and computing, today it is possible to design and realize such a low frequency radio telescope named SEAMS (Space Electric and Magnetic Sensor) in space. To check the performance of the SEAMS system at the very cold arctic ambiance and study the performance of electronics. Map the Low Frequency Radio Frequency Interference (RFI) below 16 MHz in the polar region for the first time with a short active antenna. Explore the possibility of observing sky signals of AKR and the galactic spectrum in the very low-frequency (<16 MHz). Radio emission from the Sun by studying the solar radio bursts in the deca and hectometric region.

7.2 Participants Details

Table 8: Participants of 15^{th} Indian Arctic Expedition - 2024-25 summer Batch -06

Sl. No.	Name	Designation/Affiliation
1	Dr. Vipindas Puthiya Veetil	Project Scientist II, NCPOR, Goa (Team Coordinator)
2	Mr. Niketan Pawar	Project Engineer, Savitribai Phule Pune University. Pune

Figure 7.1: Field Activities undertaken by members of summer batch 6

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8. Winter Batch -1 (11 Nov 2024 - 30 Jan 2025)

The members of Winter batch -01 calibrated Atmospheric instruments and collected aerosol samples. CTD observations were made in Kongsfjorden at 10 locations twice during the expedition. In addition, the members collected fjord water samples for microbiological study.

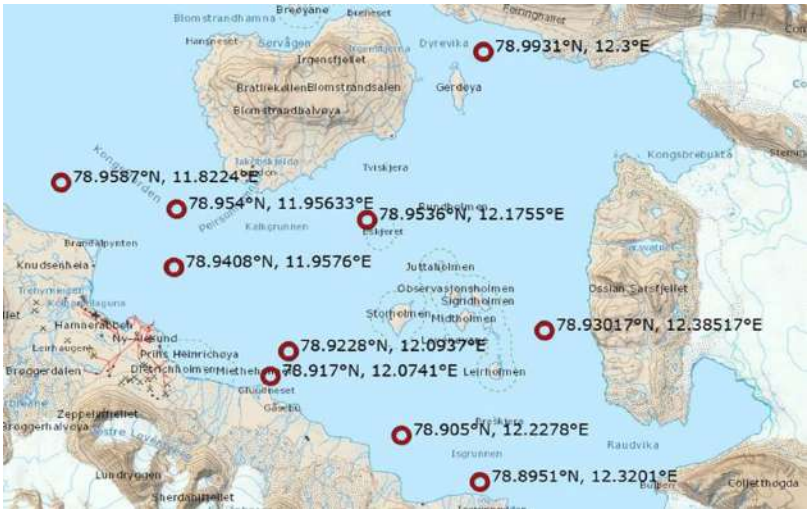

Figure 8.1: Sampling locations for CTD and water sampling. KB3 and KB6 are part of Year round Ecosystem monitoring Studies(YES) plan by Kongsfjorden flagship program. KB3 was occupied every week for microbial studies while rest of the locations were sampled once in two weeks. Fjord observations were carried out in the boat Tiesten. Atmospheric observations were carried out from the Gruvebadet Atmospheric Observatory.

8.1 Field activities undertaken by Winter batch-01

8.1.1 Monitoring of Arctic clouds precipitation

Precipitation over the Arctic is studied using a suite of equipment mounted atop Gruvebadet. The field visit was to carry out maintenance of the instrument. As of now, all the equipment is functioning, except that the calibration of the microwave radiometer could not be performed due to a lack of Liquid N_2. During the past two months, nearly 31 precipitation events were recorded by at Gruvebadet by the Parsivel Disdrometer. These events were significantly higher than during Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies (21 events) (Figure 8.2). At the same time, 2024 was characterized by more low-intensity events than during Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies. It may also be noted that 2024 was also characterized by more rain events than during Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies (more by 3.5 hours). Also, the number of days with hail seems to be higher as well in 2024 (Figure 8.3).

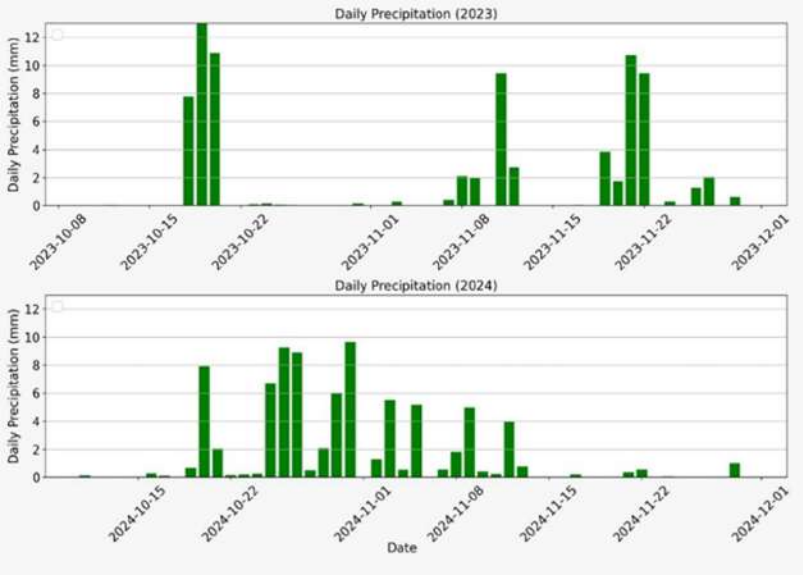

Figure 8.2: Daily precipitation intensity Gruvebadet in Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies 2023 (top) and 2024(below), October-November. The number of precipitation events was significantly higher in 2024

This difference between the two years needs to be understood in the context of recent

changes happening in the Arctic that lead to increased liquid precipitation. It is during September-November that Ny Ålesund receives maximum snowfall. Change of precipitation phase during this time may have profound consequences for the environment here

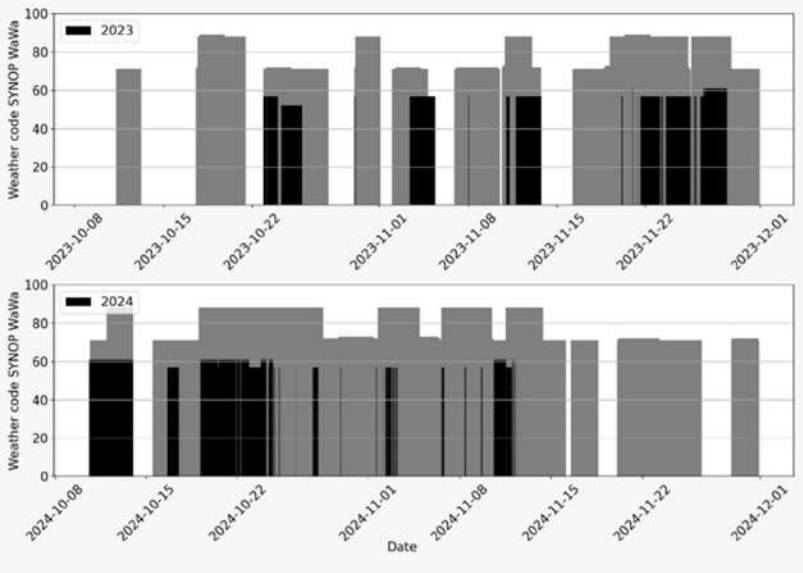

Figure 8.3: Precipitation type recorded at Gruvebadet in Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies(top) and 2024(below). Darker colour represents Rain(code at yaxis 61-68). Hails are represented with code 88-89.

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8.1.2 Microbial community dynamics and responses to naturogenic perturbations in the high Arctic ecosystems

This is a Flagship project for Year Ecosystem Study of Svalbard particularly Kongsfjorden fjord, seawater was conducted from the KB3 weekly for the Bacterial community composition (BCC), Dissolved organic matter (DOM), Total organic carbon (TOC), bacterial respiration (BR) and bacterial production (BP) analysis. Also, monthly samples were collected from KB3 and ML stations. The experiment to observe if there is any changes in bacterial community during dark nights in presence of various carbon sources of phtoplankton, macroalgal biomass and alginate a polysaccharide of brown macroalgae. The samples will be further processed in Arctic Ecology and Biogeochemistry Division at NCPOR.

8.1.3 Study of Characteristics of atmospheric aerosol and their climatic implications over the Arctic

This project involves the integration of a High-Volume Sampler (HVS) and an Aethalometer to monitor and analyze air quality with a focus on particulate matter (PM) and black carbon (BC) concentrations. The HVS is employed to collect suspended particulate matter (SPM) over a specified sampling period, enabling mass-based measurements. Simultaneously, the Aethalometer provides real-time quantification of BC mass concentration based on the optical absorption of aerosol particles at different wavelengths. The PM2.5 aerosol samples were collected on quartz filter paper using HVS at interval of 7 days, and nephelometer was calibrated for zero and span using air and CO_2 respectively.

The combined use of these instruments allows for a comprehensive assessment of air quality, aiding in the identification of pollution sources and temporal variation analysis. The collected data will be useful in understanding the Arctic aerosols and their climatic impacts.

8.1.4 Stable isotopic study of atmospheric water vapor and snow over Ny-Ålesund, Svalbard

Stable isotopes, deuterium (D) and oxygen-18 (18O), are key tracers of natural hydrological processes. Isotope variations in precipitation arise from isotopic fractionation during phase changes and slower diffusion of heavy isotopes. Studies show that isotopic signals in coastal ice or firn cores often poorly correlate with surface temperatures, highlighting the need to consider atmospheric dynamics and local processes alongside classical thermodynamics. This work aims to understand isotopic changes in water vapour and precipitation, equilibrium between snow and vapour, and meteorological effects on isotopes. Atmospheric vapour were collected at 15 days interval.

8.1.5 Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies

Even though the locations to conduct hydrography monitoring was quite limited compared to summer-fall, CTD observations were continued in the logistically accessible central Kongsfjorden region during the batch. Kongsfjorden, influenced by both Atlantic and Arctic

waters as well as glacial melt, is a key site for studying ongoing environmental changes. Hydrographic measurements are carried out every 14 days using the research vessel Teisten, covering 10 predefined stations within a single day—an approach necessitated by winter field constraints. Core parameters monitored include conductivity, temperature, depth, and dissolved oxygen, all of which help assess hydrographic variability. During the current expedition phase, three sampling events were completed on 13 and 26 November 2024, 3 and 18 December 2024, 05 and 23 January 2025. The corresponding sampling locations are shown in Figure 8.1. The long-term goal of this study is to understand the variability of the Arctic–Atlantic climate signal by examining the interactions between freshwater input from glacial runoff and the Atlantic water transported by the West Spitsbergen Current.

8.1.6 Upper-Lower atmosphere coupling and radio astronomy at low frequency

In continuation with the previous campaign there were following field work that where carried out- 1. Calibration and maintenance of GNSS, Electric Field mill, Wide band frequency observation system and All Sky Imager 2. Repeat RFI survey to assess the seasonal and year-to-year variability. Moreover, it was observed that due to extreme weather conditions one of the instrument deployed for continuous monitoring for the L-Band Spectrum malfunctioned and needs parts replacement.

Figure 8.4: Image of an Auroral event captured by All Sky Camera

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Additionally, post calibration there were several space weather event of auroral activity were captured by All sky camera (Figure 8.4) and other instruments needing further analysis to

ascertain the accuracy. Additionally, the RFI monitoring revealed that there was a significant variation compared to Summer expedition thus, during the winter campaign the lower frequency band is continuously monitored.

8.2 Participants Details

Table 9: Participants of 15^{th} Indian Arctic Expedition - 2024-25 Winter batch -01

Sl. No.	Name	Designation/Affiliation
1	Dr Nuncio Murukesh	Scientist E, NCPOR, Goa (Team Coordinator)
2	Dr. Ashok Jagtap Shivaji	Project Scientist, NCPOR, Goa
3	Mr. Nimil Konkoth Paulson	Project Scientist, NCPOR, Goa
4	Mr. Harsha Avinash Tanti	PhD Researcher, Indian Institute of Technology (IIT), Indore
5	Dr. Emilia Chamberlain	Post doctoral researcher, Leheigh University, USA
6	Ms. Noemi Schollmeyer	PhD Researcher, Leheigh University, USA

Figure 8.5: Field Activities undertaken by members of winter batch 1

.

8.3 Other Activities

8.3.1 Republic Day celebration on 26 January 2025

The team members celebrated National republic day in Arctic on 26 January 2025 Figure 8.6.

Figure 8.6: Celebration of Republic Day on 26 January in the Arctic

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9. Winter Batch -2 (03 Feb to 28 Mar 2025)

Atmospheric aerosol samples and Oceanographic observations were undertaken by the members of Winter batch 03.

9.1 Field activities undertaken by Winter batch-03

9.1.1 Microbial community dynamics and responses to naturogenic perturbations in the high Arctic ecosystems

This is a flagship project under the Year-Round Ecosystem Study of Svalbard, with a particular focus on the Kongsfjorden fjord. Weekly seawater samples were collected from the KB3 station to analyze bacterial community composition (BCC), dissolved organic matter (DOM), total organic carbon (TOC), bacterial respiration (BR), and bacterial production (BP). In addition, monthly samples were collected from both KB3 and ML stations. An experiment was conducted to investigate changes in the bacterial community during the polar night, in the presence of different carbon sources—specifically, phytoplankton, macroalgal biomass, and alginate (a polysaccharide derived from brown macroalgae). All collected samples will be further processed and analyzed at the Arctic Ecology and Biogeochemistry

Division of NCPOR.

9.1.2 Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies

This project monitors hydrographic parameters in Kongsfjorden—an Arctic fjord near Ny-Ålesund, Svalbard in winter season during the month. The Arctic is undergoing unprecedented warming and plays a vital role in regulating global climate. Kongsfjorden, influenced by both Atlantic and Arctic waters as well as glacial melt, is a key location for observing environmental changes in this sensitive region. Hydrographic measurements are carried out every 14 days using the research vessel Teisten, covering 10 predefined stations within a single day—an approach necessary due to logistical constraints during the winter season. Core parameters such as conductivity, temperature, depth, and dissolved oxygen are recorded to evaluate hydrographic variability. During the current expedition phase, five sampling events were conducted on 13, 14 and 28 in February, and 14 and 26 March 2025. The corresponding sampling locations are illustrated in Figure 8.1. The long-term goal of this project is to better understand Arctic–Atlantic climate variability by examining the interactions between glacial freshwater input and the Atlantic water transported by the West Spitsbergen Current.

9.1.3 Study of Characteristics of atmospheric aerosol and their climatic implications over the Arctic

This project integrates a High-Volume Sampler (HVS) and an Aethalometer to monitor air quality, with a focus on particulate matter (PM) and black carbon (BC) concentrations. The HVS collects suspended particulate matter (SPM) over defined sampling periods, allowing for mass-based analysis. Simultaneously, the Aethalometer provides real-time measurements of BC concentrations by analyzing the optical absorption of aerosol particles at multiple wavelengths.

$PM_{2.5}$ samples were collected on quartz filter paper using the HVS at 7-day intervals. The combined use of these instruments enables a comprehensive assessment of air quality, supports source identification, and facilitates the analysis of temporal variations. The

resulting data will contribute to understanding Arctic aerosol characteristics and their climatic impacts.

Table 10: Participants of 15^{th} Indian Arctic Expedition - 2024-25 Winter batch -02

Sl. No.	Name	Designation/Affiliation
1	Mr. Sarabjeet Singh Chhabra	Project Scientist, NCPOR, Goa (Team Coordinator)
2	Dr. Venkatachalam Siddarthan	Project Scientist, NCPOR, Goa
3	Ms. Holly Stapelfeldt	PhD Researcher, Leheigh University, USA

Figure 9.1: Field activities undertaken by the members of winter batch -03

10. Winter Batch -3 (03 Mar to 28 Mar 2025)

Atmospheric aerosol samples and Oceanographic observations were undertaken by the members of Winter batch 03.

10.1 Field activities undertaken by Winter batch-03

10.1.1 Microbial community dynamics and responses to naturogenic perturbations in the high Arctic ecosystems

This is a flagship project under the Year-Round Ecosystem Study of Svalbard, with a specific focus on Kongsfjorden fjord. Weekly seawater samples were collected from the KB3 station to analyze bacterial community composition (BCC), dissolved organic matter (DOM), total organic carbon (TOC), bacterial respiration (BR), and bacterial production (BP). In addition, monthly samples were collected from both KB3 and ML stations. The study aims to investigate potential changes in bacterial communities during the polar night, particularly in response to different carbon sources derived from phytoplankton, macroalgal biomass, and alginate—a polysaccharide found in brown macroalgae. All collected samples will be further processed and analyzed at the Arctic Ecology and Biogeochemistry Division

of NCPOR.

10.1.2 Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies

This project aims to monitor hydrographic parameters in Kongsfjorden, an Arctic fjord near Ny-Ålesund, Svalbard, to investigate the effects of climate change. As the Arctic undergoes rapid and unprecedented warming, it plays a key role in influencing global climate systems. Kongsfjorden, shaped by the interplay of Atlantic and Arctic waters along with glacial melt, is a critical site for studying ongoing environmental changes. Hydrographic measurements are carried out every 14 days using the research vessel Teisten, covering 10 predefined sampling stations within a single day—an approach necessitated by harsh winter conditions. The study focuses on key parameters such as conductivity, temperature, depth, and dissolved oxygen to track variations in the fjord's water column. During the batch 03 of Arctic expedition, five sampling campaigns were conducted on 13/02/2025, 14/02/2025, 28/02/2025, 14/03/2025, and 26/03/2025 at the locations shown in Figure 8.1. The long-term goal is to understand the variability of Arctic and Atlantic climate signals by examining the interaction between freshwater inputs from glacial runoff and Atlantic water carried by the West Spitsbergen Current.

10.1.3 Study of characteristics of atmospheric aerosol and their climatic implications over the Arctic

This project integrates a High-Volume Sampler (HVS) and an Aethalometer to monitor air quality, with a focus on particulate matter (PM) and black carbon (BC) concentrations. The HVS collects suspended particulate matter (SPM) over defined sampling periods, allowing for mass-based analysis. Simultaneously, the Aethalometer provides real-time measurements of BC concentrations by analyzing the optical absorption of aerosol particles at multiple wavelengths.

$PM_{2.5}$ samples were collected on quartz filter paper using the HVS at 7-day intervals. The combined use of these instruments enables a comprehensive assessment of air quality, supports source identification, and facilitates the analysis of temporal variations. The

resulting data will contribute to understanding Arctic aerosol characteristics and their climatic impacts.

10.1.4 Siderophores, Eps, and sea-ice microbial community in Kongsfjorden- Role in sustaining microbial loop in underlying waters

Comprehensive sampling operations were conducted in Kongsfjorden to investigate siderophore-producing microbial communities and their role in sustaining microbial loops. Field sampling was carried out at six stations (Stn-09, Kf-08, Kf-07, Kf-06, Kf-05, and Kf-04) using CTD and hydrocast systems aboard the research vessel Teisten. Water samples were collected from multiple depths (5m, 10m, and 30m) at each station for analysis of nutrients, total organic carbon, phytoplankton, picoplankton, bacterial abundance, dissolved and particulate organic matter, siderophore genes, and metagenomic diversity. Sea-ice sampling operations included collection of platelet ice from Ny-Ålesund harbour using shovels and plastic crates, followed by systematic collection of a 27cm long sea-ice core using a KOVACS sea-ice corer at coordinates 78^o 58.3241' N, 12^o 12.7469' E. All ice samples were transported to Kings Bay Marine Laboratory for controlled thawing and sub-sampling. Additional opportunistic sampling included snow collection from locations near the Marine Laboratory and Gruvebadet using clean plastic containers. Microplastics sampling was conducted by filtering 40 L of seawater through specialized mesh systems. All samples were appropriately preserved at -20^oC or -80^oC depending on analysis requirements and transported to India for detailed laboratory investigations of microbial community structure and organic ligand production.

10.1.5 Monitoring Of cryosphere processes and dynamics using space-borne and in-situ data

Field investigations were conducted on Vestre Broggerbreen glacier to support cryospheric monitoring and validate remote sensing products. Two field visits were carried out using snowmobile transport to access sampling locations across the glacier surface. Snow fork measurements were systematically collected at multiple locations to determine snow

wetness, density, and dielectric properties. These readings provided ground-truth data for validating satellite-derived glacier facies and understanding snow characteristics across different elevations and aspects of the glacier. Field observations included documentation of glacier surface conditions and general glaciological characteristics. All measurements were recorded with GPS coordinates for accurate correlation with satellite observations. The collected data contributes to improved understanding of Arctic glacier dynamics and provides validation datasets for space-based monitoring techniques. The snow fork measurements support ongoing research into glacier surface properties and their seasonal variations, which are essential for developing and improving remote sensing algorithms for Arctic glacier monitoring.

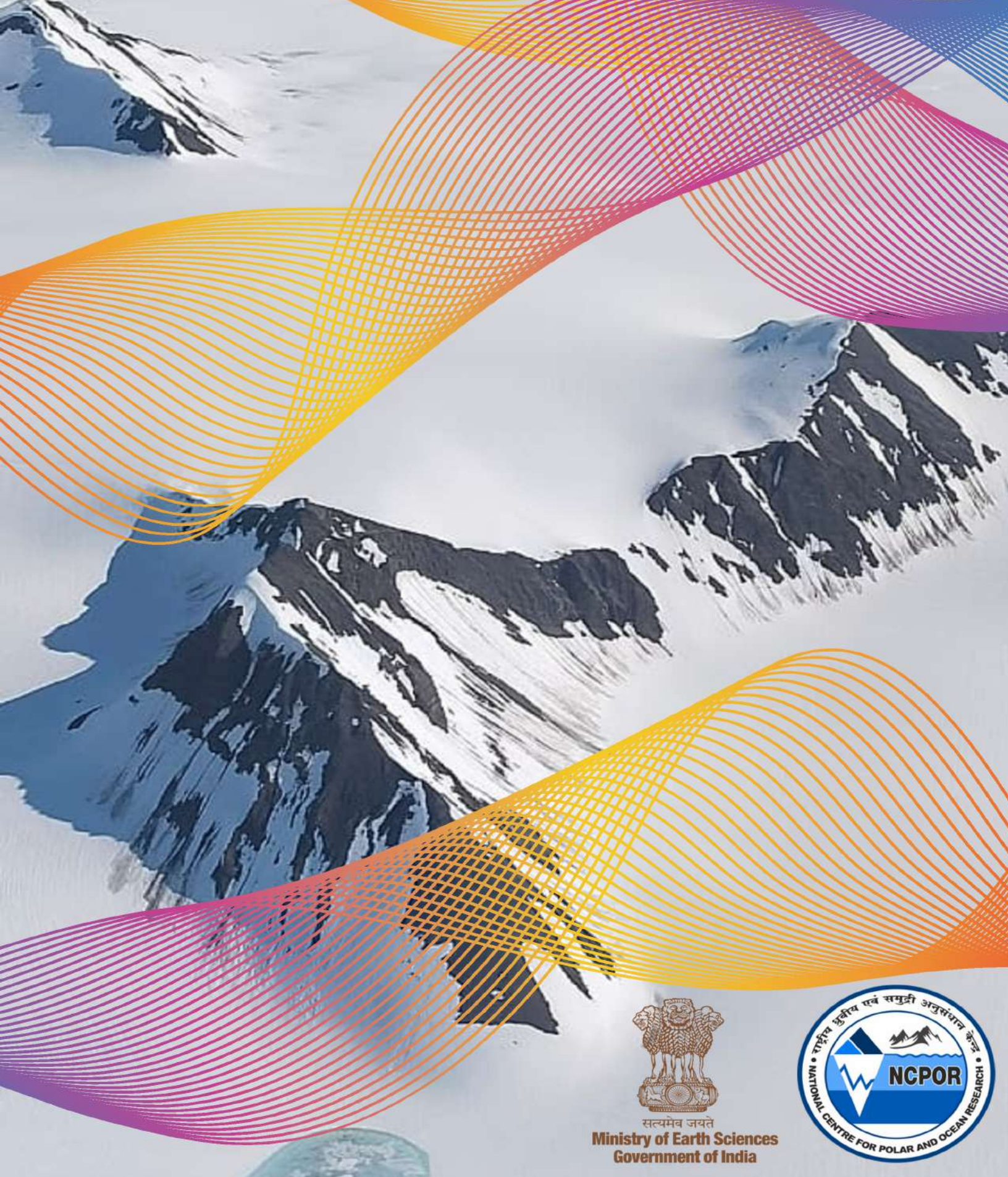
10.1.6 Airborne invaders: Unveiling the menace of airborne microplastics transporting a toxic cocktail of chemicals to the Arctic frontier

Systematic atmospheric sampling was conducted across multiple locations in the Ny-Ålesund region to investigate microplastic contamination in Arctic precipitation. Weekly collection of wet and dry atmospheric depositions was carried out using clean glass containers positioned at sampling sites in Ny-Ålesund, Kongsfjorden, and Krossfjorden areas. Snow samples were systematically gathered to assess microplastic accumulation during precipitation events. The sampling protocol focused on maintaining contamination-free collection procedures to ensure accurate detection of airborne microplastics, particularly tire wear particles and other atmospheric pollutants. Collection jars were positioned to maximize capture of both wet precipitation and dry deposition while minimizing local contamination. Meteorological conditions were recorded during each collection event to correlate microplastic concentrations with atmospheric transport patterns. All samples were properly labeled with collection details and weather conditions before preservation for laboratory transport. The collected samples will undergo comprehensive analysis for microplastic identification, quantification, and associated chemical contaminants to understand the role of microplastics as vectors for pollutant transport to Arctic environments.

Table 11: Participants of 15^{th} Indian Arctic Expedition - 2024-25 Winter batch -03

Sl. No.	Name	Designation/Affiliation
1	Mr. Sarabjeet Singh Chhabra	Project Scientist, NCPOR, Goa (Team Coordinator)
2	Dr. Venkatachalam Siddarthan	Project Scientist, NCPOR, Goa
3	Dr. Parli V. Bhaskar	Scientist E, NCPOR, Goa
4	Dr. Vaibhav Garg	Scientist/Engineer – SF, Indian Institute of Remote Sensing, Dehradun
5	Mr. Vishnu Sreejith M.	PhD Scholar, M G University, Kottayam

Figure 10.1: Field activities undertaken by the members of winter batch -03



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