सत्यमेव जयते
Ministry of Earth Sciences
Government of India

14th INDIAN ARCTIC EXPEDITION REPORT

2023-2024

राष्ट्रीय ध्रुवीय एवं समुद्री अनुसंधान केन्द्र

NATIONAL CENTRE FOR POLAR AND OCEAN RESEARCH

Ministry of Earth Sciences, Government of India
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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, 27 July 2024 (MoES Foundation Day)

सत्यमेव जयते
डॉ. एम. रविचंद्रन
Dr. M. Ravichandran

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Foreword

The Arctic is a barometer for global climate health, a repository of unique biodiversity, a region of significant scientific interest, and a focal point for geopolitical and economic activity. Recent studies have shown that it plays a vital role in influencing Indian monsoon precipitation as well. Therefore, studying it is essential for understanding and addressing some of the most pressing challenges of our time. Since 2007, the Ministry of Earth Sciences through the National Centre for Polar and Ocean Research (NCPOR) has been launching annual expeditions to the Svalbard, Arctic. India also has established a station, Himadri, in Ny-Ålesund that supports our scientific activities observational network in Svalbard.

The 14th Indian Expedition to the Arctic during 2023-24 is a major milestone. A new beginning was made by launching a regular winter expedition to the Arctic during polar nights, which provides us with a year-long presence in the Arctic. The first Arctic Winter Expedition was flagged off by the then Hon'ble Minister of Earth Sciences, Shri Kiren Rijiju, on 18 December 2023 at a solemn function in MoES, New Delhi.

As part of India's Arctic Policy 2022, India wishes to have a pan-Arctic presence for a better understanding of the Arctic and its impact on global systems. Towards this, we also had an expedition to the Canadian High Arctic Research Station (CHARS) in Cambridge Bay, Canada during the summer of 2023.

Through the report, you will find detailed accounts of India's research activities. Each chapter is a testament to the dedication and resilience of our researchers, who faced extreme weather and challenges towards the Arctic exploration. My compliments to NCPOR for planning and coordinating the Arctic expeditions for such remarkable achievements.

(M. Ravichandran)

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डॉ. तम्बान मेलत
निदेशक
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 synthesizes the scientific field activities and logistics accomplishments of the 14th Indian Scientific Expedition to the Arctic during 2023-2024. A total of 29 projects were implemented under the summer component and 15 projects were implemented under the winter component of the 14th Indian Arctic Expedition during 2023-24. These projects were selected after a nationwide call for proposals and a rigorous peer review by external expert committees.

During 2023-24, we made a new beginning by initiating winter expeditions to the Ny-Ålesund, in Svalbard during dark and cold polar nights. It provided an opportunity to address the knowledge gap and data deficiency during the winter and early spring seasons. The Hon'ble Minister, Shri Kiren Rijiju, launched the 1st Indian Winter Expedition to the Arctic at the Ministry of Earth Sciences, New Delhi, on 18 December 2023. He also visited the Indian Arctic Research Station – Himadri in June 2023. He interacted with the Indian researchers and inaugurated the Indian Arctic Atmospheric Observatory in Gruvebadet.

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, we also launched an expedition to the Canadian High Arctic in Cambridge Bay, Canada during August-September 2023.

I would like to thank Dr. Manish Tiwari, Dr. Rohit Srivastava and the Arctic Operations Group team for the commendable work for all scientific planning and logistics arrangements during the expedition. I sincerely thank all the team coordinators and team members of the 14th Indian Arctic Expedition for participating in different batches and for providing their inputs for the on-field activities used in the report.

Thamban M 24/7/2024

(Thamban Meloth)

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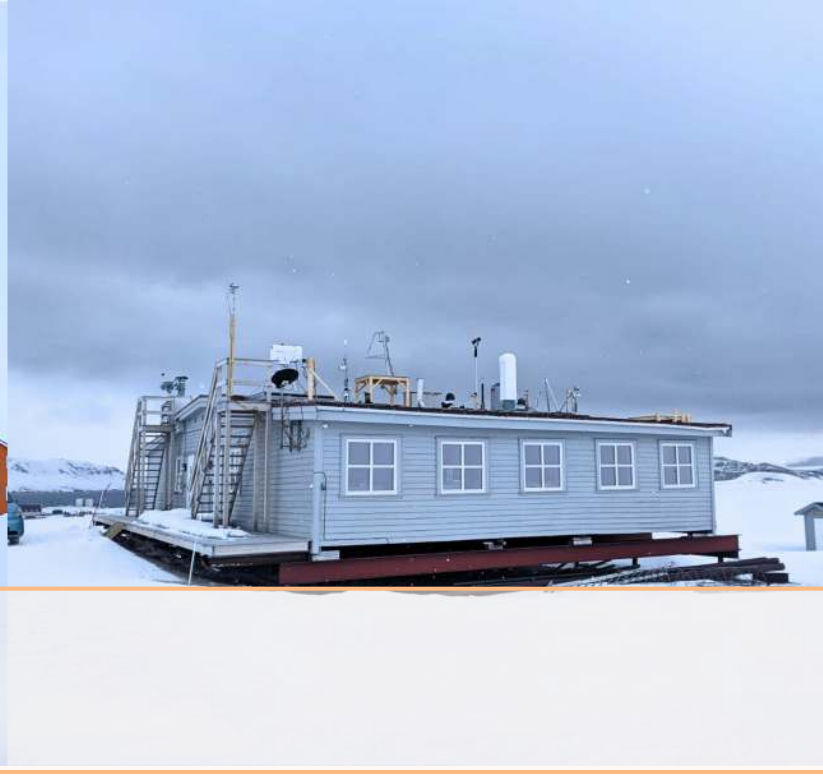


Contents

1. 14th Indian Arctic Expedition: 2023 - 2024

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 Component

To concretize the scientific and logistics aspects of the Indian scientific endeavors in the Arctic during the year 2023-24, ESSO-NCPOR had floated an advertisement during December 2022 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 2023-24 were restricted to the following focus areas:

- Atmospheric Science with special reference to study of aerosols, trace gases and precipitation over the Arctic
- 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.

A total of Thirty-Eight (38) proposals were received by NCPOR against the advertisement. Twenty-Five (24) proposals were new and the remaining fourteen were related to continuing projects. Based on peer review by subject experts and the detailed deliberations at the meetings and taking into account the scientific objectives of the various projects vis-à-vis the work being carried out by the scientists from other nations in the Arctic, the group of experts recommended total 30 projects (in which 13 were ongoing and 16 were new projects) for further consideration by NCPOR, MoES.

1.2.1 Implemented projects in summer

A total 29 projects were implemented under summer component of 14th Indian Arctic Expedition - 2023-2024. The theme wise distribution of the projects are shown in Figure 1.1.

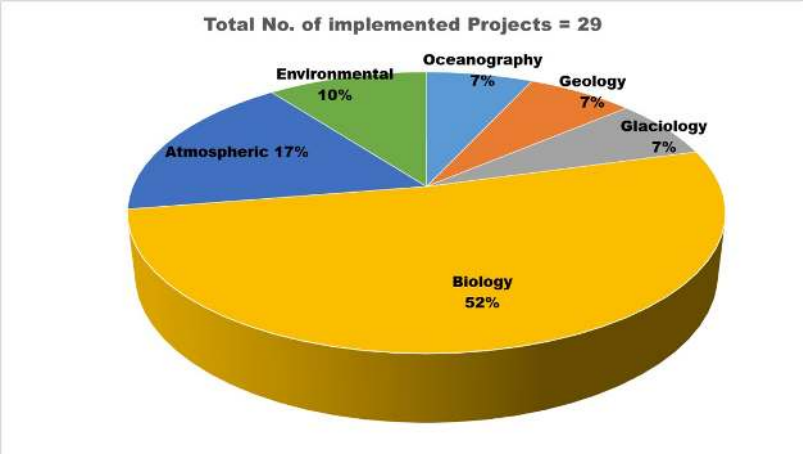


Figure 1.1: Distribution of projects under different themes for summer component of 14th Indian Arctic Expedition 2023-2024

The list of implemented projects with the leading institutes are mentioned in the Table 1.

Table 1: List of implemented projects for 14^{th} Indian Arctic Expedition - 2023-2024 during summer session (May - October 2023.)

Sr. No.	Name of the scientific project/ tasks (Institutes)
Ongoing Projects	
1	Monitoring of Arctic clouds precipitation (Lead: ESSO-NCPOR)
2	Study of characteristics of atmospheric aerosols and their climatic implications over the Arctic (Lead: ESSO-NCPOR)
3	Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies (Lead: ESSO-NCPOR)
4	Ice dynamics of the glaciers from Broggerbreen Peninsula based on the glaciological studies on Vestre Broggerbreen Glaciers, Svalbard, Arctic (Lead: GSI)
5	Monitoring of Cryospheric Processes and Dynamics using space borne and in-situ data (Lead: SAC, Ahmedabad)
6	Tropical Transfer Of Essential And Non-Essential Metals In The Arctic Food Webs - A Comprehensive Analysis Of Kongsfjorden And Krossfjorden Ecosystems (Lead: Bharathidasan Univ.)
7	Selected emerging contaminants and toxic metals in the environmental matrices of Ny-Alesund, Arctic (Lead: M. G. Univ.)
8	Microbiome of the Glaciomarine system of Svalbard: Diversity, its variability and bioprospecting potential (Lead: CUSAT, Kochi)
9	In-situ and satellite based primary productivity and bio-optical studies for understanding dynamics of Kongsfjorden and Krossfjorden twin ecosystem (Lead: ESSO-NCPOR)
10	Time scale changes in the spatiotemporal variations in the community structure of meiofauna in the Arctic Kongsfjord (Lead: CUCAT, Kochi)

11	Microbial biodiversity of Arctic fjords and bioprospecting for novel metabolites with bioactive potentials (Lead: CUSAT, Kochi)
12	Microbial community dynamics and responses to naturogenic perturbations in the high Arctic ecosystems (Lead: ESSO-NCPOR)
13	Does global warming and glacial melting affect the vertical migration and population dynamics of zooplankton in the Arctic ecosystem? A study utilizing morphological and molecular approaches (Lead: ZSI, Kolkata)
New Projects	
14	To study variations in the gamma ray counts using BGO/NaI(Tl) scintillation detector in the low geomagnetic rigidity region (Lead: IIG-Navi Mumbai)
15	Long term observations of halogen oxides in the Arctic Boundary Layer (Lead: IITM, Pune)
16	Fingerprinting the sources of organic aerosols at High Arctic: Formation Processes and Removal Mechanisms (Lead: SPL, Trivandrum)
17	Deployment of Ambience Noise System for Polar region measurements (Lead ESSO-NIOT)
18	Investigating Past Teleconnections between Arctic and Indian Monsoon through Sediment Biogeochemical Proxies at Kongsfjorden (Lead: ESSO-NCPOR)
19	Chemical weathering and glacial oxidation in Arctic environments: Constraints from water chemistry and sulfur isotopes. (Lead: IISER, Pune)
20	Polycyclic aromatic hydrocarbons in Arctic soils and sediments: Contamination and association with black carbon and total organic carbon (Lead ISI, Assam)
21	Impact of rapid warming on heterotrophic bacterial metabolic rates, zooplankton assemblages, and their contributory role in the carbon cycle in Arctic Kongsfjorden-Svalbard (Lead: Goa Univ.)
22	Unveiling the Viral Realms of Kongsfjorden and Krossfjorden: An Investigation of Diversity and Activity (Lead: CUSAT, Kochi)

23	Evolutionary History and Phylogeography of the micrometazoan phylum Tardigrada of Arctic terrestrial ecosystem (Lead: ZSI, Kolkata)
24	Systematic study on vascular plant rhizosphere soil microbiota from arctic ecosystem for iron bio-fortification (Lead: Sathyabama Institute of Science & Technology, Chennai)
25	Benthic-pelagic linking approach to decode the benthic population of Arctic fjord (Lead: Presidency Univ., Kolkata)
26	Investigation on contribution of thraustochytrid protists to the microbial carbon pump functioning during summer diatom blooms at the Kongsfjorden (Lead: Goa Univ.)
27	Biodiversity assessment and documentation of the Polar habitat employing Fire Hawk honey badger optimization enabled deep learning (Lead: JAIN Deemed to be University, Bengaluru)
28	Arctic warming and methane release controlled by methanogens / methanotrophs - A case study of Arctic Fjords and Lakes (Lead: KUFOS, Kochi)
29	Metagenomic study of bacterial diversity associated with microplastics deployed at selected sites in Arctic water bodies (Lead: Goa Univ.)

1.3 Winter Component

NCPOR, MoES made a new beginning by initiating Expeditions in the Arctic (Ny-Ålesund, Svalbard) during winter and spring that constitute polar nights. It provided an opportunity to address the knowledge gap and data deficiency during the winter and early spring season. To concretize the scientific and logistical aspects of the Indian scientific endeavors in the Arctic during November 2023 – March 2024, NCPOR had floated an advertisement during August 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, the call for proposals

for November 2023 – March 2024 was restricted to the following focus areas:

- Atmospheric Science with special reference to the 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

A new research theme *Space sciences, Astronomy and astrophysics* had been introduced to winter component of 14th Indian Arctic Expedition - 2023-2024. A total of Thirty-Eight (41) proposals were received by ESSO-NCPOR against the advertisement. Thirty (30) proposals were new, and the remaining eleven (11) were related to ongoing projects.

1.3.1 Implemented projects in Winter

Based on peer- review and the detailed deliberations at the meetings and taking into account the scientific objectives of the various projects vis-à-vis the work being carried out by the scientists from other nations in the Arctic, the group of experts recommended 15 projects (in which 7 ongoing projects and 8 new projects) for further consideration by NCPOR, MoES.

The theme wise distribution of the projects are shown in Figure 1.2.

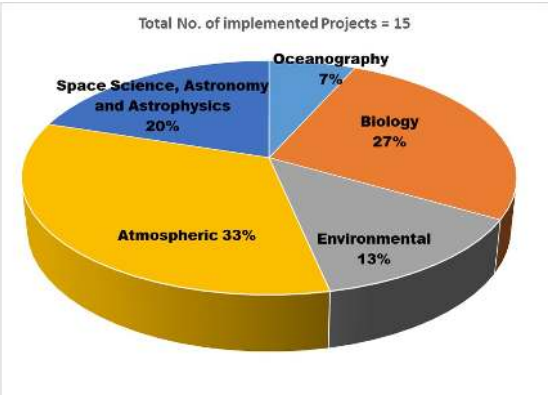


Figure 1.2: Distribution of projects under different themes for winter component of 14th Indian Arctic Expedition 2023-2024

The list of implemented projects with the leading institutes are mentioned in the Table 2.

Table 2: List of implemented projects of winter component

Ongoing Projects	
Sl. No.	Name of the scientific project/ tasks (Institutes)
1	Monitoring of Arctic clouds precipitation (Lead: ESSO-NCPOR)
2	Study of characteristics of atmospheric aerosols and their climatic implications over the Arctic (Lead: ESSO-NCPOR)
3	Fingerprinting the sources of organic aerosols at high Arctic (Lead: SPL)
4	Long-term monitoring of Kongsfjorden-Krossfjorden for climate change studies (Lead: ESSO-NCPOR)
5	Selected Emerging Contaminants and Toxic Metals in the Environmental Matrices, Ny-Ålesund, Arctic (Lead: MGU)
6	Microbial community dynamics and responses to naturogenic perturbations in the high Arctic ecosystems (Lead: ESSO-NCPOR)
7	Automated framework for detection and documentation of finfish biodiversity change of the Polar habitat using AI based deep learning models (Lead: JAIN (Deemed to be University)
New Projects	
8	Environmental Microbiology Investigation of alteration of Airborne Microbial Diversity by long-range transport of continental aerosols over Arctic (Lead: Bose Institute)
9	Study of lightning and global Electric circuit over Artic in Climate change scenario (Lead: ESSO-IITM)
10	Detection and measurement of rare events and LET spectra of cosmic rays at North Pole (Lead: BARC)
11	Upper-Lower atmosphere Coupling and Radio Astronomy at Low Frequency (Lead: IIT Indore)

12	Characterization of radio frequency environment for cosmology experiments (Lead: RRI)
13	Microplastic pollution in the Arctic environment: Vertical distribution profile along the fjord ecosystems of Svalbard (Lead: IISER Kolkata)
14	Diversity and distribution of actinobacteria in Arctic during polar nights and their adaptation properties (Lead: Satyabhama IS&T)
15	Siderophores, EPS, and sea-ice microbial community in Kongsfjorden role in sustaining microbial loop in underlying waters (Lead: ESSO-NCPOR)

1.4 Launching of First Indian Winter Expedition to Arctic

Hon'ble Minister of Earth Sciences, Govt. of India, Shri Kiren Rijiju, launched the 1st Indian Winter Expedition to Arctic in New Delhi on 18 December 2023 in the presence of Dr. M. Ravichandran, Secretary, MoES and Dr. Thamban Meloth, Director, NCPOR. It will help increase our scientific understanding and India's stake in the Arctic.

Figure 1.3: Members of 1st winter Arctic expedition batch and MoES and NCPOR members with Hon'ble Minister of Earth Sciences, Government of India, Shri Kiren Rijiju.

2. Summer Batch -01 (20 May–27 Jun 2023)

The first summer batch reached to the Indian Arctic Research Station - Himadri on 22 May 2023. A team of nine members participated in the first summer batch. The project wise field activities undertaken at Arctic are described.

2.1 Field activities undertaken by summer batch-01

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

Hydrographic sampling of the two adjacent fjords Kongsfjorden and Krossfjorden was conducted at a biweekly interval. The locations of the hydrography profiling are shown in Figure 2.1. Besides the water temperature, salinity, and depth, dissolved oxygen (DO), Photosynthetically Active Radiation (PAR), turbidity, and fluorescence of chlorophyll a were also measured, using the corresponding sensors attached to the portable SBE19plus V2 Seacat CTD profiler. The wet and dry bulb temperatures, humidity, wind speed, and direction metkit was used for wet and dry bulb temperatures, humidity, wind speed and direction,were measured using the metkit; and the euphotic depth was measured using a secchi disk. In addition to the biweekly measurements, profiles of temperature and salinity have been collected from the near Kronebreen glacier locations in Kongsfjorden on a 3-day interval to understand high frequency T-S variations and freshwater dynamics near glaciers

during the summer.

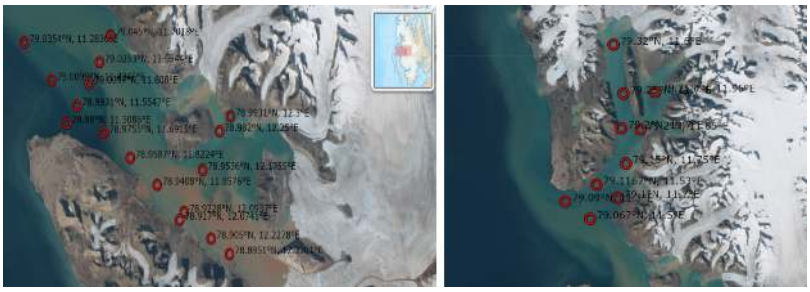


Figure 2.1: Sampling locations (red circles) in Kongsfjorden (left) and Krossfjorden (right). Projects executed mostly rely on these predetermined locations for sample collection.

2.1.2 Does global warming and glacial melting affect the vertical migration and population dynamics of zooplankton in the Arctic ecosystem? A study utilizing morphological and molecular approaches

Biological samples (for mesozooplankton and microzooplankton analysis) and water samples (for the analysis of nutrients and other physico-chemical parameters) were collected from all the demarcated stations of the proposed project. The samples were later analysed in the laboratory.

2.1.3 Arctic warming and methane release controlled by methanogens / methanotrophs - A case study of Arctic Fjords and Lakes

Six stations from the Kongsfjorden fjord and four stations from Krossfjorden fjord of Ny-Alesund for methane analysis were selected for the present study. Surface and bottom water and sediment samples were collected from the selected stations. The water samples for methane were collected in glass bottle and capped using a Teflon faced septum and a crimp cap of the appropriate size to fit the bottle. The samples were preserved with 3.5% $HgCl_2$ solution to inhibit methane oxidation. The sample bottles were purged with nitrogen before the sampling and transported back in the laboratory for analysis.

2.1.4 Unveiling the Viral Realms of Kongsfjorden and Krossfjorden: An Investigation of Diversity and Activity

Water samples were collected from 6 locations in the Kongsfjorden and 4 stations in the Krossfjorden for the analysis of various parameters such as viral abundance, prokaryotic abundance, viral morphology, viral production, viral lysogeny and viral diversity. The main objectives of the study were 1) to study the horizontal and vertical distribution of virioplankton and viral activity in both Kongsfjorden and Krossfjorden, 2) to perform metagenomic analysis for deciphering the diversity of marine viruses and possible functional gene mining, and 3) to understand the viral interactions with host microbes, and possible links to other biomes.

2.1.5 Automatic framework for migration studies of the fish species using AI based deep learning models: Application to Arctic Ecosystem

The ultimate goal of this research is to design and develop an automatic framework for migration studies of the fish species using AI based deep learning methods. At first, over the period of time with respect to the location, fish images were collected from Kongsfjorden and Krossfjoden fjords. Further analysis will be conducted using various deep learning and AI techniques.

2.1.6 Impact of rapid warming on heterotrophic bacterial metabolic rates and the trophic link to zooplanktons and their contributory role in the carbon cycle in Arctic Kongsfjorden-Svalbard

Water samples were collected from eight different stations in Kongsfjorden from three different depths and will be analysed for the parameters like bacterial abundance, Dissolved Organic Carbon(DOC), Particulate Organic Carbon(POC), and samples have been analysed for the dissolved oxygen. Zooplankton samples were collected from all six stations from surface to 50 m. The experiment was set up at three different temperatures (ambient, 6^0C, and 13^0C). Initial samples were collected for the measurements of Dissolved Oxygen, viral particles, bacterial abundance, DOC, POC, metagenomic analysis, and zooplankton

abundance. Samples were collected at an interval of 72 hours for 16 days to measure Dissolved Oxygen, viral particles, bacterial abundance, bacterial respiration, and DOC. Samples for metagenomic analysis and zooplankton abundance were collected at the beginning, mid, and end of the experiment. Zooplankton-associated bacteria were isolated from the experimental as well as in situ zooplankton samples on Zobell Marine Agar. Zooplankton samples were collected at three stations in Krossfjorden.

2.1.7 In-situ & satellite-based phytoplankton biomass and bio-optical studies for understanding dynamics of Kongsfjorden-Krossfjorden twin ecosystem

Water sampling were carried out twice in the Kongsfjorden-Krossfjorden system within 15 days. Fjord samples were collected from 10 m and 30 m using Niskin samplers by hydrocast while surface water was collected using bucket sampling. Simultaneous measurements of SST and SSS were carried out using a bucket thermometer and hand-held refractometer.

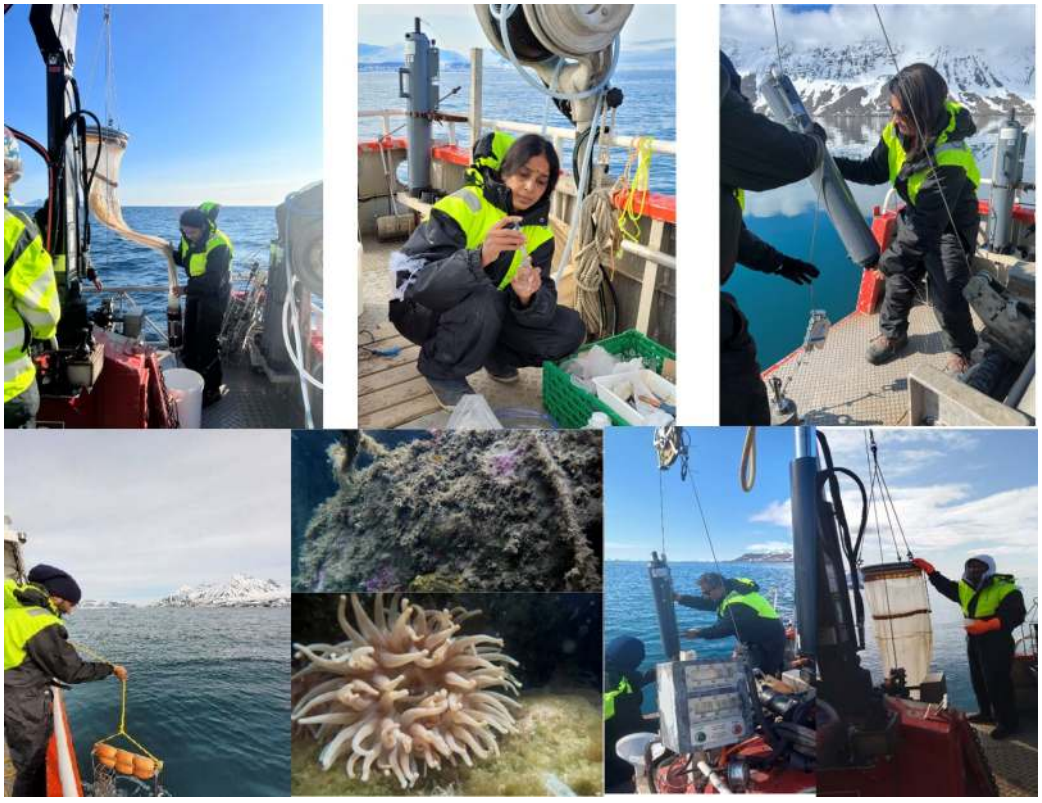


Figure 2.2: Field activities for fjord observation and sample collection.

2.2 Participants Details

Table 3: Participants of 14^{th} Indian Arctic Expedition - 2023-24 summer Batch -01

Sl. No.	Name	Designation/Affiliation
1	Dr. Sarat Chandra Tripathy	Scientist-F, NCPOR, Goa (Team Leader)
2	Dr. Vankara Venkataramana	Project Scientist II, NCPOR, Goa
3	Dr. Sudarsana Rao Pandi	Project Scientist II, NCPOR, Goa
4	Mr. Shereef Ahammed	JRF, NCPOR, Goa
5	Dr. Lata Gawade Velip	Asst. Professor, Goa University, Goa
6	Dr. Parvathi Ammini	Professor, CUSAT, Kochi
7	Mr. Felix Mattathil Philip	Assistant. Professor,JAIN University, Kochi
8	Dr. Resmi Panikkaveettil	Post Doctoral Fellow, KUFOS, Kochi
9	Ms. Haritha Prasad	SRF, ZSI, Kolkata

2.3 Other Activities

2.3.1 Ministerial Visit to Arctic

On 14 June 2023, Hon'ble Union Minister of Earth Sciences, Shri. Kiren Rijiju visited "Himadri"- the Indian Research station in Ny-Ålesund, Svalbard, Arctic and interacted with the Indian researchers. The Hon'ble Minister also inaugurated the Indian Atmospheric Observatory at Gruvebadet besides interacting with researchers from other stations and visiting some key facilities in Ny-Ålesund (Figure 2.3).

2.3.2 International Yoga Day - 2023

On 21 June 2023, celebration of International Yoga Day was organized by Himadri. Researchers/staff from other research stations and Kings Bay joined the rare occasion at Kongsfjordhallen. A total of 20 participants were present during the celebration (Figure 2.4).

Figure 2.3: Hon'ble Union Minister of Earth Sciences, Shri. Kiren Rijiju formally inaugurated Indian Atmospheric Observatory in Gruvebadet, Ny-Ålesund, Svalbard, Arctic.

Figure 2.4: Hon'ble Union Minister of Earth Sciences, Shri. Kiren Rijiju formally inaugurated Indian Atmospheric Observatory in Gruvebadet, Ny-Ålesund, Svalbard, Arctic.

- **World Environment Day:** On 5th June 2023, World Environment Day was celebrated at Himadri.
- Dr. Sarat Chandra Tripathy delivered two invited talks in webinars for the Ocean Society of India Delhi-NCR Chapter and the Department of Geography, University of Delhi on 7 and 8 (on the occasion of Word Ocean's Day) of June 2023, respectively.

- Online interaction from the Arctic with the students of Sree Navdurga Vidyalaya School, Madkai Goa and Pragati High School – Pilerne, Goa was conducted by Dr. Lata Gawade on 19th June 2023.

3. Summer Batch -02 (24 Jun–26 Jul 2023)

The Arctic Ocean is a remarkable and diverse ecosystem and has long been a subject of fascination for scientists and researchers. The Indian Arctic expedition sought to gain a comprehensive understanding of the Arctic ecosystem's diversity, especially the Kongsfjorden- Krossfjorden system and the factors influencing it by bringing together experts from various projects. The second batch of this expedition comprises researchers from diverse projects, encompassing disciplines such as Atmospheric physics, Atmospheric Chemistry, Microbiology, Biotechnology, Benthic ecology, and Physical oceanography. By focusing on the Kongsfjorden- Krossfjorden system, oceanographers conducted extensive sampling at predetermined stations in the fjords (Figure 3.1).

3.1 Field activities undertaken by summer batch-02

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

Hydrography survey from the first batch was continued with the extensive CTD measurements in the Kongsfjorden-Krossfjorden system. The depth profiles of water temperature, salinity, depth, DO, PAR, turbidity, and fluorescence of Chlorophyll$_a$ were measured in both the fjords at a biweekly interval. The 3-day hydrography survey near the Kronebreen glacier was also continued investigate high-frequency variability and freshwater dynamics near the

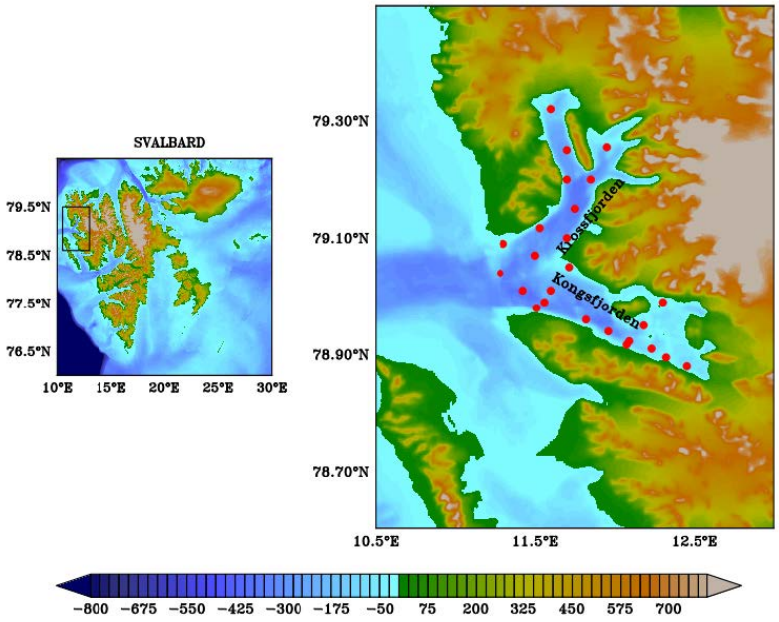


Figure 3.1: Sampling locations (red circles) in the Kongsfjorden-Krossfjorden system in Svalbard. Projects executed mostly rely on these predetermined locations for sample collection

glacier in the summer. Selected stations in Kongsfjorden were chosen for water sample collection to analyze oxygen isotopes.

Extensive sampling in the Kongsfjorden-Krossfjorden system was conducted using CTD (Conductivity, Temperature, and Depth) measurements. The parameters measured included Temperature, Salinity, Dissolved Oxygen (DO), Photosynthetically Active Radiation (PAR), turbidity, and fluorescence of Chlorophyll$_a$. Sampling at all stations in both fjords occurred biweekly. Additionally, stations near the Kronebreen glacier were sampled every 3 days to investigate high-frequency variability near glaciers during the summer. Selected stations in both fjords were also chosen for water sample collection to analyze oxygen isotopes.

3.1.2 Fingerprinting the sources of organic aerosols at High Arctic: Formation processes and removal Mechanisms

A high-volume sampler (HVS; PM_{10}) was installed at the roof-top of the Atmospheric Science building, Gruvebadet, Ny-Alesund of Svalbard. The HVS was calibrated and fixed for each sampling period of 72 hours (3 days). During the expedition period, 6

PM10 samples were collected and were properly stored under low temperatures. The sampling should be continued by following batches. Field personal also collected a few different Glaciers, Lake waters, Glacier-sediment, and rhizosphere soil samples around the Gruvebadet Lab. These samples will be studied for various chemical and molecular species. Moreover, Sea-surface water samples and marine sediments over Kongfjorden and Krossfjorden were also collected to understand the trace elements and their distributions in the different Arctic Environments. All the samples are stored at -20^{0}C room in the Marine Biology Lab.

3.1.3 Monitoring of Arctic clouds precipitation

GNSS receiver, Lightning detector, and electric field mill are successfully installed and data collection started at Gruvabet lab. Though some technical issues were faced at the beginning due to the compatibility with the computer, which was finally sorted out. Necessary maintenance of the other instruments at the Atmospheric lab also has been made. Moreover, the old data from OTT Parsivel has been successfully retrieved.

3.1.4 Microbiome of the glaciomarine system of Svalbard: Diversity its variability and bioprospecting potential

A comprehensive investigation into the microbial diversity and ecological parameters of the Arctic marine system was carried out through the collection of water and sediment samples from Krosfjorden and Krossfjorden. These samples played a crucial role in deepening our understanding of the intricate relationships within this delicate ecosystem. Another significant aspect of the expedition involved the study of glaciers, as they are integral features of the Arctic landscape. To accomplish this, samples from various glaciers were collected, seeking to unravel the geological and environmental processes shaping these awe-inspiring formations. In addition, samples from migratory birds, namely the Arctic tern and barnacle goose were gathered. By analyzing these samples, the main aim was to uncover their potential role in the dissemination of antibiotic-resistant bacteria within the polar environment.

3.1.5 Timescale changes in the spatiotemporal variations in the community structure of meiofauna in the Arctic Kongsfjord

Eight stations from the Kongsfjorden and five from the Krossfjorden were selected for the field sampling. Water, sediment, and benthic samples were collected from both the fjords. The water samples from the surface and bottom were collected. 100ml each from both were collected in bottles and 2 liters of surface water was filtered using glass microfiber filters (47 mm) for the collection of chlorophyll. 100 g of sediment each for studies like metagenomics of benthic fauna and sediment characteristics was collected in zip lock covers. The sediment and water samples and the filter papers were kept at -20^{0}C. At each station, macro and meiobenthic samples were collected by a van Veen grab (KC Denmark A/S) of a 0.1 m^2 catching area. Immediately after grab hauling, ascertaining that the sediment was undisturbed, core samples for meiobenthic studies were taken from the middle of each grab sample to a depth of 5 cm using a corer with a cross-section area of 10 cm^2. Samples for the quantitative analysis of macrobenthos were also collected separately. Separation of benthic fauna from the sediment sample was completed by sieving with a 500 μm mesh for macrobenthos and 63 μm meshes for meiobenthos. Both the samples were fixed in 4% buffered formalin and kept at room temperature.

3.1.6 Microbial biodiversity of Arctic fjords and bioprospecting for novel metabolites with bioactive potentials

Water samples from ten stations at Kongsfjorden, focusing on three distinct layers: Bottom Mixed Layer, Deep Chlorophyll Maxima, and Surface Water were collected. Each 10ml water sample was designated for culturable study, while 2 liters of water were filtered from each collection for the metagenomic study. Sediment samples were gathered from the same areas and stored in ziplock covers for culturable analysis, while 50 ml tubes were used for metagenomic studies. Additionally, water samples from Bottom Mixed Layer, Deep Chlorophyll Maxima, and Surface Water, in 10 ml vial culturable bacterial studies, along with sediment samples from 5 stations across Krossfjorden were collected. The sediment samples were collected in ziplock covers for culturable analysis and 50 ml tubes

for metagenomic studies. Lastly, soil samples were collected from the Tundra region, as well as permafrost from two glaciers, Vestre Lovenbreen and Vestrebrogenbreen glaciers.

3.1.7 Systematic study on vascular plant rhizosphere soil microbiota from Arctic ecosystem for iron bio-fortification

Around 25 rhizosphere soil samples from 15 vascular plants were collected exploring 5 different areas in and around Ny-Alesund, Arctic. Among them each 25 rhizosphere soil samples were separated as two batches and were preserved in -20^{0}C and 2^{0}C. Apart from these this soil samples, 2 liters of marine waters from 12 surface samples of the Kongsfjorden region have also been collected and were filtered in 0.2 μm filter paper. One batch of filter papers were immerged in distilled water and kept 2^{0}C. And another batch of filter paper were preserved in -20^{0}C to carryout metagenomics analysis. Similarly, the water samples from different depth of the Kongsfjorden and Krossfjorden region collected and filtered as mentioned above and preserved in 2^{0}C and -20^{0}C to analysis culturable and unculturable diversity. Also, sediment samples from both 14 stations of Kongsfjorden and Krossfjorden regions and preserved in 2^{0}C and -20^{0}C to study the microbial diversity. Apart from that other samples such as glacier ice, seaweed and sponge samples were collected and preserved in -20^{0}C to analysis culturable and unculturable diversity.

3.1.8 Benthic-Pelagic linking approach to decode the benthic population of Arctic fjord

A total of 13 stations were sampled taking 5 stations in Krossfjorden and 8 stations at Kongfjorden. In all stations, triplicate macrobenthos, meiobenthos samples (Statistically it is must for community ecology study) were taken along with secondary data water quality parameters and texture/OC sediments. This sampling strategy is standard protocol for benthic studies. In all those stations, zooplankton samples were also collected to decipher the contribution of meroplankton in dictating the benthic community. After collecting the samples macro, meiobenthos samples were sorted and processed and preserved. This was done to reduce the sample weight significantly. As Arctic benthic samples are precious

samples are sorted individually in 70% ethanol for possible DNA barcoding work.

The team also gathered critical data on both physical and biological aspects of the atmosphere, ocean, and terrestrial sectors of the region (Figure 3.2).

Figure 3.2: Different field observations and samplings conducted during Arctic expedition (Summer batch-02)

3.2 Participants Details

Table 4: Participants of 14^{th} Indian Arctic Expedition - 2023-24 summer Batch -02

Sl. No.	Name	Designation/Affiliation
1	Dr. Teesha Mathew	Project Scientist-I, NCPOR, Goa (Team Leader)

2	Dr. Rohit Srivastava	Scientist E, NCPOR, Goa
3	Dr. Saurabh Das	Associate Professor, IIT, Indore
4	Dr. Suresh Kumar Reddy Boreddy	Sci / Eng D, SPL, Trivandrum
5	Dr. K Manigundan	Scientist, Sathyabama Institute of Science and Technology
6	Ms. Krishnapriya P.P.	Senior Research Scholar, CUSAT, Kochi
7	Dr. Sumit Mandal	Assistant Professor, Presidency University, Kolkata
8	Mr. Akhil Prakash	Senior Research Fellow, CUSAT, Kochi
9	Mr. Mohammad Umar	Ph.D. Scholar, CUSAT, Kochi

4. Summer Batch -03 (25 Jul–26 Aug 2023)

The third summer batch studied the fjords Kongsfjorden and Krossfjorden for various scientific aspects. The location of the sampling is given in Figure 2.1.

4.1 Field activities undertaken by summer batch-03

4.1.1 Monitoring Arctic Precipitation

Under this project the Artic precipitation as observed from Ny Alesunsd is being studied. The field visit was for the maintenance and calibration of equipments and for data transfer.

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

The high resolution hydrography survey in Kongsfjorden and Krossfjorden from the first and second batches was continued during the period.

4.1.3 Polycyclic aromatic hydrocarbons in Arctic soils and sediments: Contamination and association with black carbon and total organic carbon

In this project, surface soil and sediment samples from lakes and fjords were collected, with measurements and analyses conducted on a range of physiochemical parameters (EC, pH etc.)

4.1.4 Long term observations of halogen oxides in the Arctic boundary layer

Installation of a multi axis differential optical absorption spectrometer was done at the Gruvebadet atmospheric laboratory. The instrument will collect continuous observations of halogen oxides, OVOCs, NO_2 etc.

4.1.5 Evolutionary history and Phylogeography of the micrometazoan Phylum Tardigrada of Arctic Terrestrial Ecosystem

The project aims to study the diversity, evolutionary history and phylogeography of arctic tardigrades. For checking the presence of tardigrades, water samples were collected from different locations from the fjord and moss samples were collected from Ny- Alesund and nearby areas.

4.1.6 Investigation on contribution of thraustochytrid protists to the microbial carbon pump functioning during summer diatom blooms at the Kongsfjorden

Water samples from various stations across Kongsfjorden and Krossfjorden were collected and processed for different parameters. (i) Pine pollen baiting of all the seawater samples and a few sediments from a few locations in Kongsfjorden was carried out to isolate thraustochytrids. (ii) Chlorophyll a analysis was carried out. (iii) Seawater was filtered to study non-culturable diversity of protists (metagenomic analysis) (iv) Seawater was fixed with 4% formalin to study the abundance (total count) of thraustochytrids.

4.1.7 Study of aerosol optical and physical properties and their climatic impact over the Arctic

Calibration and maintenance of pre-installed Particle Sizer and Aethalometer has done as well as Balack Carbon data has been collected form Aethalometer. Aerosol sample has collected from High Volume Sampler (HVS) and maintenance of HVS has done.

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

Water and sediment samples from Kongsfjorden and Krossfjorden has been collected from 18 selected locations. All samples are extracted and kept for analysis. Phytoplankton samples were collected from two locations in Kongs fjordedn and Krossfjorden. Also sediment samples are collected from terrestrial location for source identification.

4.1.9 Chemical weathering and glacial oxidation in Arctic environments: Constraints from water chemistry and sulfur isotopes

Under this project, chemical weathering is being studied. Sediment, water and ice samples were collected for this purpose.

4.2 Participants Details

Table 5: Participants of 14^{th} Indian Arctic Expedition - 2023-24 summer Batch -03

Sl. No.	Name	Designation/Affiliation
1	Dr. Nuncio Murukesh	Scientist-E, NCPOR, Goa (Team Leader)
2	Dr. Anoop Mahajan	Scientist-F, Indian Institute of Tropical Meteorology, Pune
3	Prof. Raja Ram	Professor, Bharathidasan University
4	Dr. Varada Samir Damare	Assistant Professor, Goa University

5	Mr.Praveen Raj	Senior Research Fellow, Zoological Survey of India
6	Ms. Kruttika Mohapatra	Junior Research Fellow, Indian Institute of Science Education and Research, Pune
7	Mr. Ritesh Kumar	Junior Research Fellow, NCPOR, Goa
8	Mr. Tanojit Paul	Junior Research Fellow, Indian Statistical Institute, Tezpur

Figure 4.1: Different field observations and samplings conducted during Arctic expedition (Summer batch-03)

5. Summer Batch -04 (26 Aug–27 Sep 2023)

The summer batch- 4 of the 14^{th} Indian Arctic Expedition 2023-24 carried out sampling and measurements in Kongsfjorden, terrestrial areas near Ny-Ålesund and Vestre Brogerbreen glacier for various scientific aspects. Locations of the studies under various projectsare given in the Figure 5.1

5.1 Field activities undertaken by summer batch-04

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

Hydrographic sampling of Kongsfjorden and Krossfjorden was conducted on biweekly interval. Sensor-based measurements of water temperature, salinity, depth, dissolved oxygen DO, PAR, turbidity, and fluorescence of Chlorophyll$_a$ were collected twice in a month from both the fjords. Samples for temperature, salinity and δ^{18}O collected from the near Kronebreen glacier location in the head of Kongsfjorden to understand high frequency variabilities water mass transformation and freshwater dynamics in the inner fjord during the summer.

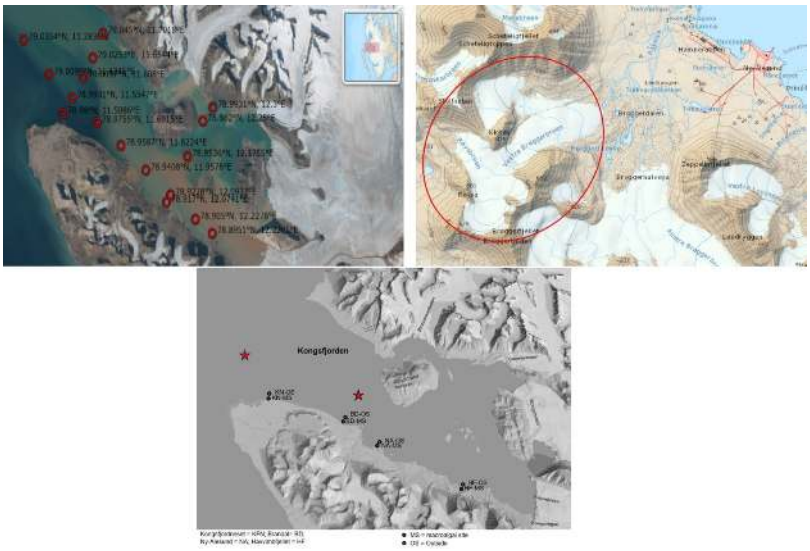


Figure 5.1: Sampling locations for (a) Project 1 and Project 6 (red circles) in Kongsfjorden; (b) Project 2 (red and green circles) and 3 (coring locations as star) in Kongsfjorden; and (c) Project 4 and 5 (Red circle) in Vestre Brogerbreen glacier area

5.1.2 Microbial community dynamics and responses to naturogenic perturbations in the High Arctic Ecosystems

Water samples collected and processed by sequential filtering to collect particle associated and free-living microbial biomass. Samples were also collected for nutrient, total organic carbon, and particulate organic matter characterization. Measurements carried out marine lab for bacterial production, respiration and evaluating extracellular enzymatic activity. The samples will be used to expand our knowledge of microbial community dynamics and their responses to warminginduced changes, such as increased macroalgal biomass, and Atlantic water intrusion to understand the consequences of such changes on the cycling of carbon and climatic-feedback mechanisms.

5.1.3 Paleoclimatic Reconstructions of the Kongsfjorden employing Sediment Biogeochemical proxies: Implications on Global Climate teleconnectivity

Conducted two significant sediment coring expeditions in Kongfjorden, each retrieving sediment cores measuring 1 meter in length. These coring efforts were part of a groundbreaking project aimed at unraveling the paleoclimatic history of the Kongsfjorden region, employing

advanced sediment biogeochemical proxies. This research not only promises to shed light on the local climate history but also holds implications for understanding global climate teleconnectivity. What makes this endeavor even more remarkable is the unprecedented collaboration between NCPOR and the Italian team from ISMAR, marking the first-ever joint effort of its kind in this remote polar region.

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

The major objective was to collect in-situ data for technique development and validation of remote sensing derived geophysical products over Svalbard. Following sub-objectives were addressed during the expedition: 1. To collect spectral measurements using spectro-radiometer instrument over various types of snow/ice surfaces over Vestre-Broggerbreen (VB) glacier near Ny-Alesund 2. To collect in-situ measurements of dielectric constant (relative permeability), wetness, depth and density of snow over Vestre-Broggerbreen (VB) glacier

5.1.5 Ice dynamics of the glaciers from Broggerbreen Peninsula based on the glaciological studies on Vestre Broggerbreen Glaciers, Svalbard, Arctic

Glacial stakes were installed over the Vestrebroggerbreen glaciers (VB-I and II) in the zone of ablation along with snout measurements. Snouts of nearby glaciers in Brogger peninsula was recorded to assess and relate the climatic condition for large recession in VB-II. Melt-water channel sections were sampled for dating with their sedimentological measures. The work will help in generating baseline for mass balance and ice dynamics for VB glaciers.

5.1.6 Selected Emerging Contaminants and Toxic Metals in the Environmental Matrices, Ny-Ålesund, Arctic

To assess concentration of selected emerging contaminants (esp. Per- and polyfluoroalkyl substances (PFAS)), mercury, and other toxic metals in the environmental matrices of Ny Ålesund, water and sediment samples were collected from Kongsfjorden. PFAS were

extracted from the collected water samples using Solid phase extractor on field. Terrestrial soil and lake sediment samples were collected from the Eastern and western spans of the Ny-Ålseund along the coastal line of Kongsfjorden.

5.2 Participants Details

Table 6: Participants of 14^{th} Indian Arctic Expedition - 2023-24 summer Batch -04

Sl. No.	Name	Designation/Affiliation
1	Ms. Archana Singh	Scientist-D, NCPOR, Goa (Team Leader)
2	Dr. Anand Jain	Project Scientist III, NCPOR, Goa
3	Dr. Biswajit Roy	DST-INSPIRE Faculty, NCPOR, Goa
4	Mr. Naveen Kumar Tripathi	Scientist, SAC-ISRO, Ahmedabad
5	Mr. Abhishek Verma	Senior Geologist, GSI, Faridabad
6	Mr. Deepak Y. Gajbhiye	Senior Geologist, GSI, Faridabad
7	Ms. Saritha V K	Research scholar, MG University, Kottayam

5.3 Other Activities

Embassy visit: Ms. Archana Singh and Dr. Biswajit Roy visited the Indian Embassy in Norway and interacted with Ambassador Dr. Acquino Vimal on 26 August 2023 and discussed about Indian Arctic Expeditions in Ny-Ålesund

Cleaning Drive at Himadri: Batch 4 carried out a cleaning drive at Himadri by removing old stuff/ junk and rearranging the station in a meticulous format.

6. Summer Batch -05 (26 Sep–25 Oct 2023)

The fifth batch studied the fjords Kongsfjorden and Krossfjorden for various scientific aspects. The location of the sampling is given in the Figure 2.1.

6.1 Field activities undertaken by summer batch-04

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

The hydrography and sensor based biogeochemistry measurements were done in Kongsfjorden and Krossfjorden as was done in the earlier batches The locations shown in Figure 2.1.

6.1.2 To study variations in the gamma ray counts using NaI(Tl) scintillation detector in the low geomagnetic rigidity region

The auroral and polar regions are strategically important as charged energetic particles of solar wind origin and galactic origin can have direct entry. They are abundant in the polar region mainly due to low geomagnetic rigidity. The observations of these particles facilitate the study of their energetics and dynamics in detail, and hence helps in understanding the solar wind magnetosphere-ionosphere coupling during space weather events, and other transient radiation events like Gamma-ray burst (GRB), terrestrial gamma-ray flash (TGF) etc. NaI(Tl) scintillation detector is installed on the roof top of Gruvebadet Atmospheric

Laboratory and is covered by wooden box to protect it from rain/snow. rain/snow. The NaI(Tl) scintillation detector installed at Ny-Ålesund collects gamma ray counts with different energies, enabling the study of the dynamics of energetic particles at low geomagnetic rigidity regions.

6.1.3 Metagenomic study of bacterial diversity associated with microplastics deployed at selected sites in Arctic water bodies

Sediment and water samples without Microplastic pieces (MPs) will be collected from the selected sites and processed to compare the bacterial diversity. This will give an idea about the bacterial species that attach and those which do not attach to plastic/MPs.

6.2 Visit of Joint Secretary to the Ministry of Earth Sciences

Joint Secretary to the Ministry of Earth Sciences Government of India, Shri D. Senthil Pandian visited Indian Arctic station 'Himadri' in Ny-Ålesund, Svalbard during 16th- 20th October, 2023. During his visit, Shri Pandian took an extensive overview of ongoing scientific activities, interacted with Norwegian Polar Institute (NPI) and several other international institutes and explored areas of potential collaborations to expand Indian scientific activities.

6.3 Participants Details

Table 7: Participants of 14^{th} Indian Arctic Expedition - 2023-24 summer Batch -05

Sl. No.	Name	Designation/Affiliation
1	Mr. Sourav Chatterjee	Scientist-D, NCPOR, Goa (Team Leader)
2	Dr. Geeta Vichare	Professor-F, IIG Mumbai
3	Ms. Veda Manriker	Research Fellow, Goa University, Goa

6.3.1 Other Activities

Dr. Geeta Vichare gave a science talk at NyAlesund Arctic Research Center on “Space Weather Studies” on 10 October 2023.

Dr. Geeta Vichare visited the University Centre in Svalbard (UNIS), Longyearbyen, and interacted with Prof. Noora Partamies and Prof. Stein Haaland, Department leader of Arctic Geophysics.

7. Mooring deployment (11 – 22 Sep 23)

The members studied the fjord of Kongsfjorden with acoustical sensor and installed -deployed an Ambient noise system (Acoustic Monitoring) to study the ice dynamics, anthropogenic and biphonic activities at the location given at Figure 1a. The location of the acoustic survey and deployment of system is 78^0 57’ 44.21” N and 12^0 20’ 52.78” E which is shown in Figure 7.1

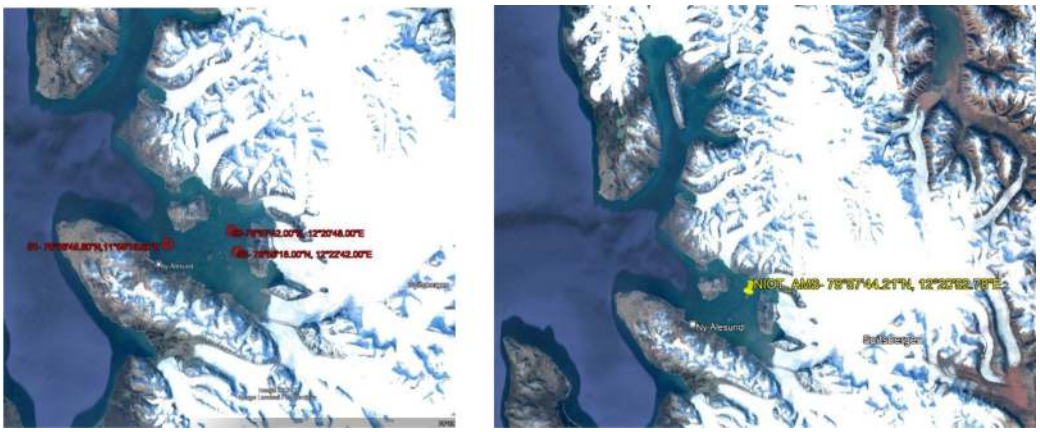


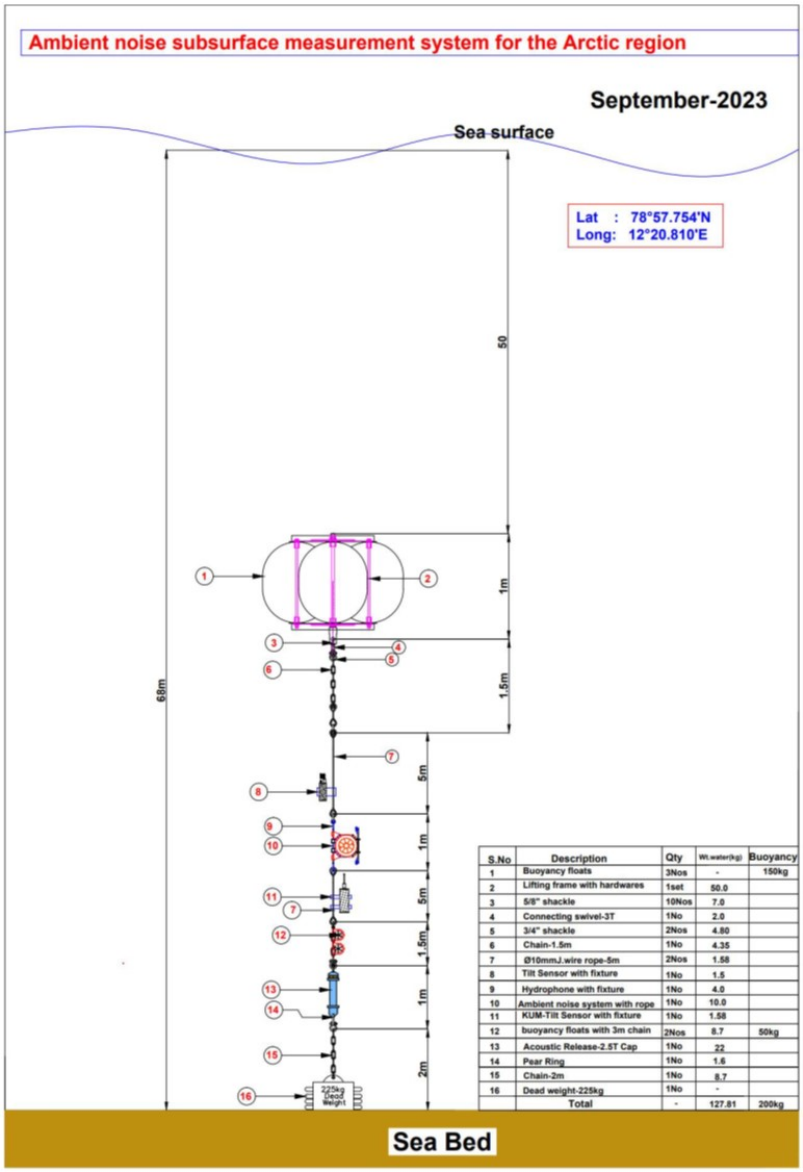
Figure 7.1: (a) Acoustic survey locations are marked in red circles in Kongsfjorden and (b) installation-deployment (location 78^0 57’ 44.21” N and 12^0 20’ 52.78” E) of ambient noise system in yellow color (right).

Underwater acoustical survey with digital hydrophone and portable CTD sensor was conducted prior and post installation (deployment) of Ambient Noise System (Acoustic Monitoring) at the Kongsfjorden. The ambient noise system consists of data acquisition system and power pack enclosed in an instrumentation glass sphere. The two numbers of hydrophones are used as acoustical sensor and connected with data acquisition system with suitable underwater connectors. Mooring components like buoyancy floats, acoustic release and sinker weight are connected with proper mooring ropes with hard wares. The suitable Tilt and CTD sensor are also used in the ambient noise mooring system. The proposed depth was 40 m based on hydrographic chart data, however, during the field experiment, the depth at proposed location was found to be 68 m. Therefore, the system was deployed at ocean depth of 68 m and the location is situated 10.0 km from North East of Ny-Ålesund harbor and 2.5 km radius from the Glacier. Mooring diagram is attached in the below Figure 7.2.

7.1 Participants Details

Table 8: Participants of 14^{th} Indian Arctic Expedition - 2023-24 mooring deployment batch

Sl. No.	Name	Designation/Affiliation
1	Dr. Latha Baskar	Scientist-G, NIOT, Chennai (Team Leader)
2	Mr. Thirunavukkarasu Ayyadurai	Scientific Officer, NIOT, Chennai
3	Mr. G. Raguraman	Scientific Officer, NIOT, Chennai
4	Mr. C. Dhanaraj	Technician, NIOT, Chennai



S.No	Description	Qty	Wt.water(kg)	Buoyancy
1	Buoyancy floats	3Nos	-	150kg
2	Lifting frame with hardwares	1set	50.0	
3	5/8" shackle	10Nos	7.0	
4	Connecting swivel-3T	1No	2.0	
5	3/4" shackle	2Nos	4.80	
6	Chain-1.5m	1No	4.35	
7	Ø10mmJ.wire rope-5m	2Nos	1.58	
8	Tilt Sensor with fixture	1No	1.5	
9	Hydrophone with fixture	1No	4.0	
10	Ambient noise system with rope	1No	10.0	
11	KUM-Tilt Sensor with fixture	1No	1.58	
12	buoyancy floats with 3m chain	2Nos	8.7	50kg
13	Acoustic Release-2.5T Cap	1No	22	
14	Pear Ring	1No	1.6	
15	Chain-2m	1No	8.7	
16	Dead weight-225kg	1No	-	
	Total	-	127.81	200kg

Figure 7.2: Mooring Diagram of Ambient Noise System

8. Canadian Arctic Expedition (12 Aug – 12 Sep 23)

The first Indian Expedition to Canadian Arctic Expedition was launched on 11 August 2023 by Secretary to Government of India, Ministry of Earth Sciences (MoES) and H.E. Cameron MacKay, High Commissioner for Canada in India at New Delhi (Figure 8.1).

Figure 8.1: Members of Indian Expedition to Canadian Arctic with Hon'ble Secretary to Government of India, Ministry of Earth Sciences and H.E. Cameron MacKay High Commissioner for Canada in India at New Delhi on 11 August 2023

8.1 Interaction with members of local community regarding changes in Canadian Arctic climate

In line with India's interest in the Arctic regions and toward pan-Arctic vision, NCPOR explored research facilities and logistic support at Cambridge Bay, Canada, through the Canadian High Arctic Research Station (CHARS) in 2019. Subsequently, an MoC was signed between NCPOR and the Canadian High Arctic Research Station (CHARS) on 26 Feb 2020 to facilitate Indian researchers' access to CHARS for research activities. The the visit the logistic requirements and challenges were discussed. The implementation of the projects requires the local indigenous community's consent. Therefore, meetings with the local community of Ekaluktutiak Hunters and Trappers Association (EHTO) and the Kitikmeot Inuit Association (KIA) were organized, and in the meetings, highlights of the Indian Arctic Program and projects were discussed (Figure 8.2). Dr. Rohit Srivastava (team leader of Indian Expedition to Canadian Arctic) delivered public lecture on "Understanding the Arctic aerosols and their climatic impacts", and Dr. Jabir T. and Dr. S. Venkatachalam delivered public lecture on "Permafrost thaw and the role of microorganisms in a warming Arctic". These lectures were organized under the POLAR Speaker Series by Polar Knowledge Canada at CHARS, Cambridge Bay.

Figure 8.2: Meeting with Local community people of Canadian Arctic in Cambridge Bay, Canada

8.2 Field activities undertaken during Canadian Expedition

8.2.1 Atmospheric monitoring observatory in Canadian Arctic

The logistic arrangements regarding the setup of the Atmospheric Observatory in Cambridge Bay (Canadian Arctic) were discussed. In addition, the two atmospheric instruments (i) Micro Wave Radiometer (MWR) and (ii) PM10 (Particulate Matter 10) High Volume Sampler were planned to be installed in the Canadian High Arctic Research Station (CHARS) campus. However, due to technical and logistic issues, members may try to install the instruments in the forthcoming Canadian expedition. A suitable location outside of the town's local contamination was also identified; however, the procedure for utilization of the site will be discussed with CHARS administration.

The visit was successful in terms of understanding the logistic and technical requirements and convincing the local community regarding the scientific research projects of NCPOR India. The understanding will open the opportunity to establish the first Indian Atmospheric observatory in the Canadian Arctic.

8.2.2 Evaluation of multi drug resistant bacteria in the thawing Permafrost regions of the Canadian High Arctic

Field personal carried out in-field sampling survey in the Canadian high Arctic during from 13^{th} August to 10^{th} September 2023 and implemented project on Evaluation of microbiome and multi drug resistant bacteria in the Active soil layer and Permafrost regions of Canadian high Arctic. The project aims to study the microorganism in the thawing of permafrost of Arctic regions. Arctic warming impacts the thawing of permafrost- –which could potentially reactivate many of the dormant microorganisms that are preserved in the permafrost soils for centuries. Some of these microorganisms may be pathogenic and/or drug-resistant bacteria that can lead to the resurgence of zoonotic diseases. In this project, we intend to perform a comprehensive survey of the microbiome in the tundra soil, active layer, and permafrost and evaluate the presence of potential pathogenic and drug resistant using a culture-dependent and independent approach but also to delineate potential sources-anthropogenic and/or ancient origins in the Canadian high Arctic region. The project will generate baseline data

of Antibiotic-resistant genes (ARGs) and antibiotic-resistant bacteria (ARB) in the Canadian High Arctic. Major questions address in this project are 1. How does Arctic warming impact the permafrost thawing and associated microbial communities? Do permafrost samples contain different community structures? and 2. Evaluation of Antibiotic-resistant genes (ARGs), virulence-related genes, and antibiotic-resistant bacteria (ARB) in the tundra, Active soil layer, and Permafrost?

Figure 8.3: Field activities for collecting permafrost samples in Canadian Arctic

8.3 Participants Details

Table 8: Participants of Indian Arctic Expedition to Canadian Arctic - 2023-24

Sl. No.	Name	Designation/Affiliation
1	Dr. Rohit Srivastava	Scientist-F, NCPOR, Goa (Team Leader)
2	Dr. Charan Teja Tejavath	Project Scientist I, NCPOR, Goa
3	Dr. Jabir Thajudeen	Project Scientist I, NCPOR, Goa
4	Dr. Venkatachalam Siddarthan	Project Scientist II, NCPOR, Goa

9. Winter Batch -01 (19 Dec 23 – 17 Jan 24)

The members of Winter batch -01 installed the space science and Astronomical observations instrument, calibrated Atmospheric instruments and collected aerosol samples.

9.1 Field activities undertaken by Winter batch-01

9.1.1 Characterization of radio frequency environment for cosmology experiments

The Universe, from the Big Bang to its current stage, has undergone a series of crucial transformations over the last 14 billion years. The emergence of the first stars and galaxies, referred to as cosmic dawn, and the subsequent ionization of the Universe, called the epoch of reionization, constitute a crucial period in cosmic history. These periods led to the formation of further structures that evolved into the Universe we see today. Unfortunately, we know very little about such a significant period.

Detection of the faint cosmological signal from hydrogen, referred to as the 21-cm signal, from the early Universe is considered to be the final frontier in cosmology. This signal was emitted from the era when first stars and galaxies were formed, a period called as cosmic dawn. Detecting this elusive signal will, for the first time, shed light on the properties of the very first sources that lit up the Universe. Several experiments across the globe are aiming to detect the signal. SARAS experiment, designed at Raman Research

Institute, is a world leading experiment in this field. Its past results have made significant contributions to the physics of cosmic dawn. Astronomical observations from the radio quiet location of Svalbard will offer a significant advantage in uncovering the faint 21-cm signal

Figure 9.1: (L) Discone antenna placed on rooftop of Gruvebadet laboratory to sense electromagnetic signal in the frequency range 5 to 500 MHz; (R) Radio frequency interference recording system set up inside the Gruvebadet laboratory, Ny-Ålesund.

Using the set up shown in the Figure 9.1, radio frequency interference scenario in Ny-Ålesund was sampled at different times of the day. Our initial analysis suggests that the site is promising for 100-200 MHz (SARAS 4), and is worthy of proposal to do a science deployment given the radio quietness. A detailed analysis of 50 -200 MHz frequency range will help us in thoroughly evaluating the suitability of the site.

9.1.2 Study of lightning and global Electric circuit over Artic in Climate change scenario

To study the difference in electric field characteristics during winter and summer in Arctic region. Experiment that is begun during this winter season will continue for three years for comparing data from summer and winter season. Observation of electric field and atmospheric electric current during lightning period over Arctic would provide an opportunity to understand the electrical properties of thunderstorms over Arctic, especially in winter season.

An Electric Field Mill (EFM) and a Maxwell antenna have been successfully installed on rooftop of the Gruvebadet laboratory. They have been operationalized for the continuous

measurement of Atmospheric electricity and lightning strikes over arctic. The instruments were installed on 06 January 2024 and calibration of the EFM and Maxwell antenna have been carried out till 09 January 2024. From 09 January onwards both instruments are working on a continuous basis (24 $\times$ 7) and logging data to a USB Data card through a laptop connected to the set up.

9.1.3 Monitoring of Arctic Clouds and Precipitation

Calibration and maintenance of the instruments to monitor clouds and precipitation installed by NCPOR in Gruvebadet observatory. The first Indian Winter Arctic expedition ensured all the instruments were working fine. The data backup was also completed for the atmospheric instruments.

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

Aerosol High Volume sampler was installed in the Gruvebadet lab in Ny-Alesund. This a high-volume sampler which has a flowrate of 1 m^3 min^{-1} and collects PM10 (Particulate matter of diameter less than 10 µm) over a 8$\times$10 inch filter paper. Samples are being collected over daily basis over a Quartz micro fibre filter paper which then will be shipped to India for further chemical analysis. These aerosol samples will be used to analysed for BrC, BC, HULIS and their respective optical properties. In addition, snow samples were collected over the period from three pristine locations in Ny-Ålesund for the period of December 2023-January 2024. While collecting the snow samples, it was made sure that locations should be away from local emission sources so we get samples depicting the picture on both local and long-range transport of aerosols.

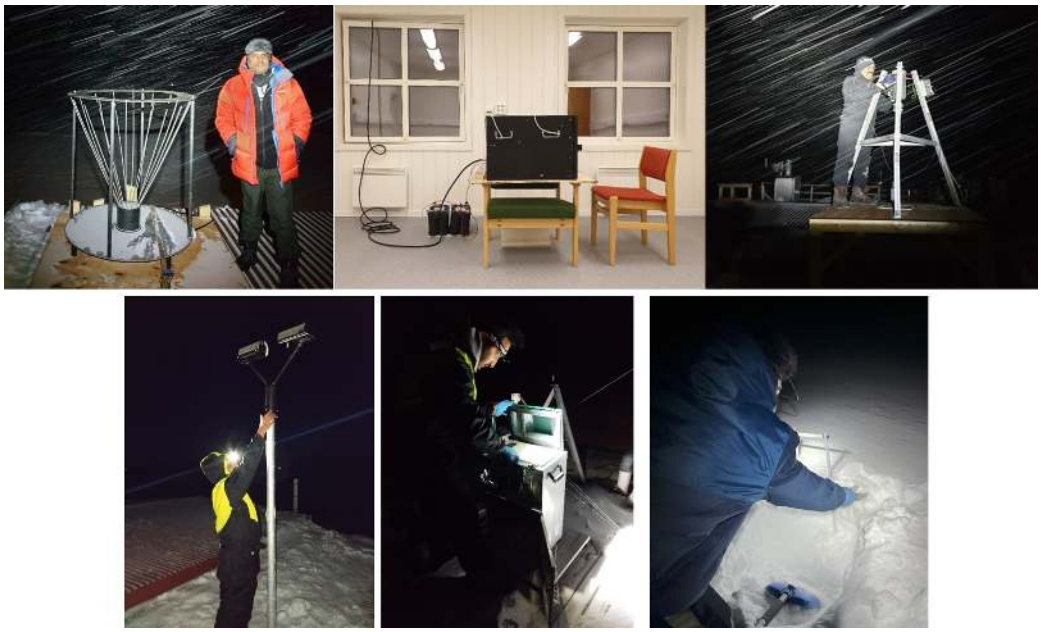


Figure 9.2: Installation of instruments and field activities od winter Batch -01 at Gruvebadet laboratory, Ny-Ålesund.

9.2 Participants Details

Table 9: Participants of 14^{th} Indian Arctic Expedition - 2023-24 Winter batch -01

Sl. No.	Name	Designation/Affiliation
1	Mr. Girish Baragur Seshagiriyappa	Research Scientist E, Raman Research Institute, Bengaluru (Team Leader)
2	Mr. Surendra Singh	Senior Project Associate, Indian Institute of Tropical Meteorology, Pune
3	Ms. Athulya Radhakrishnan	Research Scholar, NCPOR, Goa
4	Mr. Prashant Rawat	Research Scholar, Indian Institute of Technology, Mandi

10. Winter Batch -02 (10 Jan–14 Feb 2024)

Due to the limited access to the fjord during winter the various scientific aspects were studied in the Kongsfjorden fjord. The location of the sampling is given in Figure 10.1.

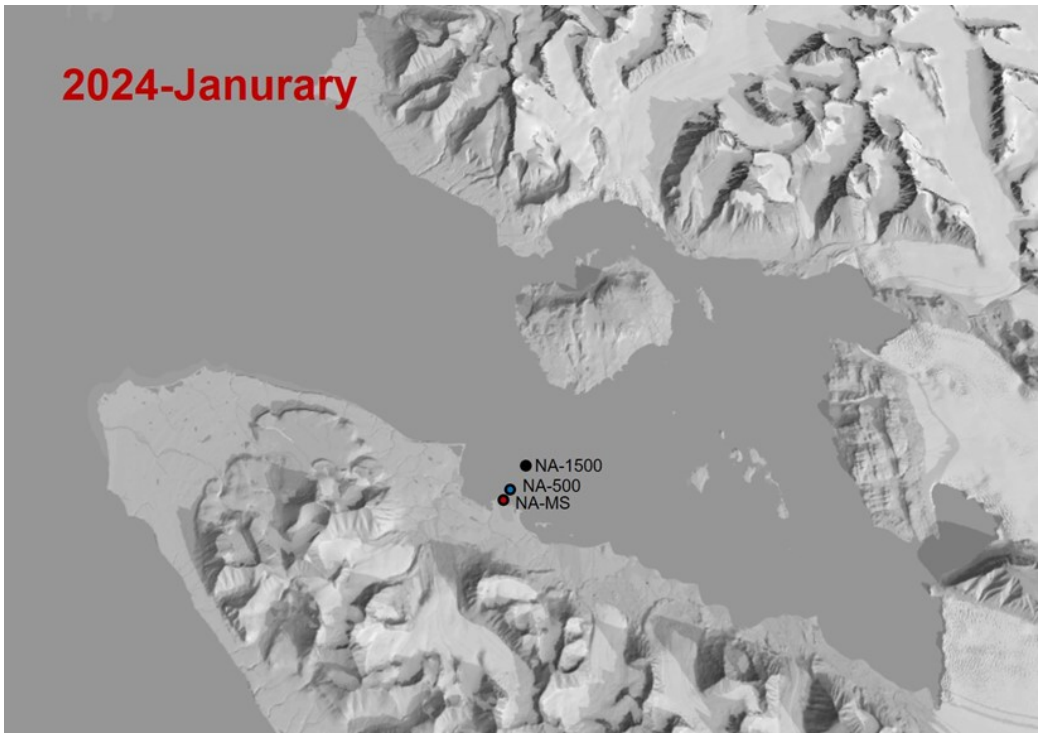


Figure 10.1: Sampling locations in Kongsfjorden fjord restricted in winter due to the ice cover and accessibility

Table 10: Sampling locations in Kongsfjorden fjord restricted in winter due to the ice cover and accessibility

NA-MDS	NA500	NA1500
Surface 40L	Surface 40L	Surface 40L
	Bottom (70m) 25L	Mid (150m) 25L
		Bottom (300m) 25L

10.1 Field activities undertaken by Winter batch-02

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

The hydrography and sensor based biogeochemistry measurements were done in six locations in the inner Kongsfjorden, once a month.

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

Under this project, seawater sampling was conducted at three locations with different depth in Kongsfjorden fjords. Dissolved oxygen (DO), bacterial respiration and bacterial production (BP) were measured in the marine laboratory. The samples were collected for particulate organic carbon (POC), Dissolved carbohydrates (D-CHO), Total organic carbon (TOC), Total bacterial count (TBC) Nutrients, and community structure of bacteria from free living and particle associated samples, which will be processed at Arctic Ecology and Biogeochemistry Laboratory, NCPOR.

10.1.3 Detection and measurements of rare events and LET spectra of cosmic rays at North Pole

Under this project, a Gas-Filled Tissue Equivalent Proportional Counter has been installed in the Gruvebadet Atmosphere Laboratory. The instrument records energy deposition events within the detector, which is being subsequently deconvoluted to assess the individual contributions of gamma rays, electrons, and heavy charged particles. Atmospheric data

sourced from AWIPEV and CNR have been employed for comprehensive correlation studies. The project is currently ongoing, with a scheduled completion date of March 25th, 2024. In addition to the proportional counters, Poly-Allyl Diglycol Carbonate CR-39 track detectors have been strategically deployed to capture tracks indicative of potential rare events and high-energy cosmic rays. Post-deployment, these detectors will undergo thorough analysis upon their return to the Bhabha Atomic Research Center.

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

Consecutively eleven (11) air-sample filter papers and aerosol high-volume samples were collected round-the-clock at the roof-top of Gruvebadet observatory using simultaneously two identical bio-aerosol samplers, and PM10 sampler at an interval of 48 hours under the Arctic dark nights at Ny Alesund from 19 Jan to 12 Feb 2024. Immediately after the collection of each air sample filter paper were transferred to Marine laboratory, Ny Alesund to preserve into two different medias for further metagenomic and cultural analysis, which will be carried out at Bose Institute. PM10 samples were weighted properly and kept in zip-locked bag for further chemical analysis at Bose Institute.

Table 11: Participants of 14^{th} Indian Arctic Expedition - 2023-24 Winter batch -02

Sl. No.	Name	Designation/Affiliation
1	Dr. Jagtap Ashok Shivaji	Project Scientist, NCPOR, Goa (Team Leader)
2	Mr. Sandipan Dawn	Bhabha Atomic Research Centre (BARC), Mumbai
3	Dr. Sanat Kumar Das	Associate Professor, Bose Institute, Kolkata
4	Md Abu Mushtaque	Research Scholar, Bose Institute, Kolkata

10.2 Other Activities

Republic day celebration The Republic day was celebrated on 26th January, 2024 at "Himadri"- the Indian Research station in Ny-Ålesund, Svalbard, Arctic. Researchers/staff from other research stations and Kings Bay joined the republic day celebration.

Figure 10.2: Republic Day celebration by members of winter batch -02

11. Winter Batch -03 (03 Feb–28 Feb 2024)

Some members of third batch could not conduct the scheduled sampling as planned, as the necessary instruments and scientific materials did not arrive on time due to unforeseen circumstances during transportation. Additionally, extreme weather conditions and restrictions on maneuvering the boat in the semi-frozen fjord posed further challenges. Despite these logistical constraints, some sampling activities were still undertaken.

11.1 Field activities undertaken by Winter batch-03

11.1.1 Upper-Lower atmosphere Coupling and Radio Astronomy at Low Frequency

Snow depth samples from 5 location in Ny-Alesund successfully collected and maintained the atmospheric instruments in Gruvebadet Lab. The close observation of Arctic weather conditions provides valuable insights into the region's environment, aiding in better understanding. Analysis of the data gathered during the visit is underway, revealing exciting phenomena such as heavy snowfall, the mesmerizing Northern Lights, high winds, and extreme low temperatures. These observations contribute to our understanding of Arctic dynamics and will likely lead to valuable scientific discoveries and insights.

11.1.2 Diversity and distribution of actinobacteria in the Arctic during polar nights and their adaptation properties

During the Arctic Winter expedition in the month of February 2024, around 35 samples were collected from the Ny Alesund – the High Arctic region (79^0N) as summarized below:

1. Snow from the terrestrial region around Ny-Alesund
2. Frozen soil from the terrestrial region around Ny-Alesund
3. Surface water from Kongsfjorden Pier
4. Sea Ice from Kongsfjorden Pier

Figure 11.1: Collection of (A) snow sample and (B) frozen soil sample from Ny Alesund for actinobacterial research

The PI has received the collected samples, and analysis is being conducted at Sathyabama Institute of Science and Technology. The following outcomes can be expected from the collected samples:

- Baseline data on diversity (cultural and uncultured) of actinobacteria at the Ny Alesund during polar nights.
- Culturable actinobacteria (psychrophilic, psychrotolerant) from the Ny Alesund.
- Taxonomically novel actinobacteria, if any.
- Knowledge on EPS, AFP, Siderophores and cold active enzymes by actinobacteria and its role in cold adaptive properties of actinobacteria during polar nights at Ny

Alesund.

- Ex situ conservation of actinobacteria from the Arctic region and its sustainable utilization for bioprospecting applications

11.1.3 Siderophores, EPS, and sea-ice microbial community in Kongsfjorden role in sustaining microbial loop in underlying waters

Although sea-ice sampling was not possible due to inclement weather conditions and the non-arrival of cargo, some surface water samples were collected from the pier. Parameters such as DOC, TOC, DOM, and nutrients will be measured from the collected samples to get a preliminary idea of the variation of these parameters in boreal winter.

Table 12: Participants of 14^{th} Indian Arctic Expedition - 2023-24 Winter batch -03

Sl. No.	Name	Designation/Affiliation
1	Dr. Sarat Chandra Tripathy	Scientist-F, NCPOR, Goa (Team Leader)
2	Dr. M. Radhakrishnan	Professor (Research), Sathyabama Institute of Science & Technology
3	Mr. Lekhraj Saini	Senior Research Fellow, IIT Indore
4	Mr. Sandipan Dawn	Bhabha Atomic Research Centre (BARC), Mumbai

11.2 Other Activities

Online interaction from the Arctic with the students of Government Ambedkar 10+2 Residential School, Champaran, Bihar was conducted on 17th Feb and explained the Arctic's Role in Climate change study and How Indian's Scientists doing research in Arctic.

12. Winter Batch -04 (28 Feb–27 Mar 2024)

The fourth batch of winter Arctic Expedition aimed at various studies in the fjords and from the land. Due to the adverse climatic conditions, the batch only got one day in the field in Kongsfjorden. Snow samples were collected from various locations in the land at Ny-Alesund within the town limit. The location of the sampling at Kongsfjorden is given in Figure 12.1.

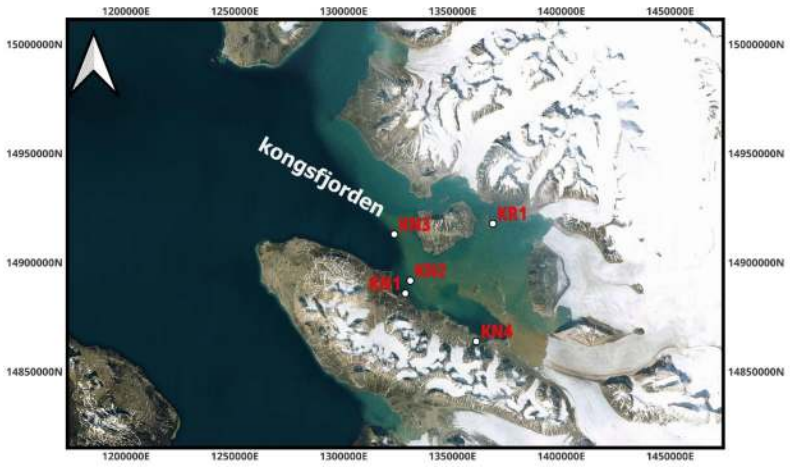


Figure 12.1: Sampling locations in Kongsfjorden at which the water samples were collected by members of winter batch -02

12.1 Field activities undertaken by Winter batch-04

12.1.1 Selected Emerging Contaminants and Toxic Metals in the Environmental Matrices, Ny-Ålesund, Arctic

The major aims of the proposed study were to assess the concentration of selected emerging contaminants (PFCs and PPCPs), mercury and other toxic metals in the environmental matrices of Fjords, terrestrial soils and freshwater lakes of Ny Ålesund and in the aquatic organisms and also the isolation and Characterisation of perfluorinated resistant strains of bacteria from the sedimentary environment. As the first phase of the study, we collected water and sediment samples from various environmental systems in Ny Alesund during the summer expedition. The samples are being processed to evaluate the contaminants present. The second phase of the study was aimed at the quantification and characterization of emerging contaminants in the Arctic during the winter season. The expedition was done from 1-25 March 2024. The 4th batch of the Winter Arctic expedition Expedition arrived at the Indian Research Station - Himadri on the 1st of March 2024 (Friday) afternoon. The first two days remained holidays in the town and the major field work started 4th March 2024 in the Kongsfjorden. Water samples were collected from two locations in the fjord during the day. More sampling was not possible due to adverse weather conditions. During the following days, snow and ice samples were collected from 15 locations in and around Ny-Ålesund city, three of which were taken from the fjord shoreline of Kongsfjorden. These samples were allowed to melt at room temperature and filtered in the terrestrial laboratory. The filter papers are retained for detailed analysis of microplastics and other contaminants. The filtered water underwent further processing through a solid-phase extraction unit, with the cartridges subsequently eluted using methanol. The eluate containing extracted compounds will be analysed in India.

12.1.2 Automated framework for detection and documentation of finfish biodiversity change of the Polar habitat using AI based deep learning models

The 4^{th} batch of the Winter Expedition team arrived at the Himadri Research Station of India at Ny-Ålesund on 01 March 2024 (Friday) afternoon. The average air temperature was

-5.2^{0}C at Ny-Ålesund on that day. Data collection started from 04 March 2024 (Monday) onwards. Station KN1 (near the Harbour) (Figure 12.1) was surveyed using underwater cameras (using GoPro HERO11 Black cameras) and custom-made fish traps. The fish trap could capture 3 Shorthorn sculpin/Ulke (Myoxocephalus scorpius) fish from the fjord (Figure 12.2). The data collection continued till 15-March-2024. By that time, the surface of the fjord was completely frozen, with the air temperature dropping below -29^{0}C and the windchill temperature dropping below -44^{0}C.

Figure 12.2: Shorthorn sculpin/Ulke (Myoxocephalus scorpius) fish captured from the Kongsfjorden using custom-made fish traps

Went onboard MS Teisten boat on 06 March 2024 (Wednesday) inside the Kongsfjorden. The fjord was having some floating ice sheets; however, the boat could go to three stations. The boat couldn't go any further in to the fjord as there were more ice on the surface and the Harbour Master decided to go any further in to the fjord. We could capture underwater images from the above three stations in the fjord. The water parameters were recorded using the CTD onboard. The boat could not be operated further as the Harbour Master found it is not safe to operate the boat considering then prevailing weather conditions.

12.1.3 Understanding the contribution of microplastics and its associated contaminants from anthropogenic, aerial, and ocean currents at Ny-Alesund

Snow and ice samples were collected from 15 locations in and around Ny-Ålesund city, four of which were taken from the fjord shoreline of Kongsfjorden. These samples were allowed to melt at room temperature and subsequently filtered in the terrestrial laboratory. The filter papers, containing the retained particles, will be transported back to India for detailed analysis, focusing on microplastics and associated contaminants such as metals and polycyclic aromatic hydrocarbons (PAHs). The filtered water underwent further processing through a solid-phase extraction unit, with the cartridges subsequently eluted using dichloromethane. The eluate, containing extracted compounds, is being shipped back to IISER Kolkata for additional investigation, particularly concerning background levels of polycyclic aromatic hydrocarbons. In addition to these, filtered water samples were collected from each location and are currently in transit for analysis of heavy metal concentrations. Overall, this comprehensive sampling and analysis approach will provide valuable insights into the presence and distribution of microplastics and microplastic-associated metals and PAHs in the Arctic environment around Ny-Ålesund in winter. These pollutants could potentially contribute to the contamination load in soil and the fjord when the ice melts, thereby enhancing our understanding of the microplastic-driven transport of associated contaminants in this region.

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

Water samples were collected from the fjord at multiple locations and depths. Incubation experiments were carried out to estimate rates of dinitrogen fixation. Water samples were collected and preserved to measure dissolved CH_4, CO_2 and N_2O along with DOC, DIC, and DIN. Particulate matter was filtered on GF/F filters to analyse particulate organic carbon, particulate nitrogen and particulate black carbon.

Figure 12.3: Field work carried out onboard MS Teisten boat in the Kongsfjorden Arctic Fjord. Underwater image captured using under-water camera during the field work

Sl. No.	Name	Designation/Affiliation
1	Dr. Baiju K.R.	Professor, Mahatma Gandhi University, Kottayam, Kerala (Team Leader)
2	Dr. Gipson Edappazham	Associate Professor, JAIN (Deemed to be University), Kochi
3	Mr. Abhishek Mandal	Research Scholar IISER Kolkata
4	Dr Siddhartha Sarkar	Postdoctoral Fellow, Physical Research Laboratory, Ahmedabad
5	Mr. Sandipan Dawn	Bhabha Atomic Research Centre (BARC), Mumbai

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