

Appendix I: Indian Arctic Programme

India's Arctic program aims to contribute to developing, consolidating, and disseminating the current understanding of climate change, its impacts, and adaptations in the Norwegian Arctic through its scientific activities based in Svalbard. The Indian scientific endeavours in the Arctic commenced when a five-member scientific team visited Ny-Ålesund, Svalbard archipelago of Norway, during the summer of 2007.

Appendix II: Study area:

Svalbard: Ny-Ålesund, Brøggerhalvøya, Kongsfjorden, and Krossfjorden

Background

As the Arctic is warming four times as fast as the global average, and the Svalbard region is warming fastest within the Arctic, Ny-Ålesund Research Station in the north-western part of Spitsbergen, Svalbard, is a unique platform for climate change studies and is a key location for natural science research and environmental monitoring in the high Arctic. Though remote, it is accessible and offers extensive research infrastructure.

Svalbard: Svalbard (meaning "Cold Coast") archipelago, part of Norway, is located in the Arctic Ocean well north of the Arctic Circle. The islands lie between longitude 10° and 35° E and latitude 74° and 81° N, about 930 km north of Tromsø, Norway. The archipelago is composed of nine main islands: Spitsbergen (formerly West Spitsbergen), North East Land, Edge Island, Barents Island, Prins Karls Foreland, Kvit Island (Gilles Land), Kong Karls Land (Wiche Islands), Bjørn (Bear) Island, and Hopen. The total area of Svalbard is 62,700 square km. Spitsbergen, with an area of 39,044 square km, is the largest island of Svalbard.

Ny-Ålesund: Ny-Ålesund located at 79°N, is the world's northernmost year-round research base providing unique access to a natural polar laboratory. India has a research station in Ny-Ålesund named 'Himadri'

Brøggerhalvøya: Brøggerhalvøya is a peninsula in Oscar II Land on the west coast of the island of Spitsbergen in Svalbard. It is 20 kilometres long and 10 kilometres wide and borders Kongsfjorden to the north and Forlandsundet to the west. Ny-Ålesund, the world's northernmost permanent settlement, is located on the peninsula.

Kongsfjorden: Kongsfjorden is an Arctic fjord located in the Svalbard archipelago. Its hydrography is influenced by the warm and saline Atlantic Water (AW) from the West Spitsbergen Current and the cold and fresh Polar Water circulating on the shelf. Ny-Ålesund, the research base, is located on the southern shore of Kongsfjorden.

Krossfjorden: Krossfjorden is a fjord adjacent to Kongsfjorden. Both the fjords share a common mouth.



- 1- Himadri
- 2- Gruvabadat Atmospheric Laboratory
- 3- Marine Lab

Ny-Ålesund is situated on the southern shore of Kongsfjorden, one of the many deep and wide fjords on Spitsbergen's west coast. Its geographic position, varied topography, and prolific representation of bird, animal, and plant life, make it ideal for research. The ice-capped interior is dotted with the pointed nunataks which gave the island its name. The steep mountains along the coastal fringe are interspersed with glaciers, some of which terminate in the sea. The coastline (45 km around Broggerhalvøya) is snow-free from mid-June to September with tundra, alluvial plane, and braided streams. Kongsfjorden is approximately 28 kilometres long.

Climate

A northern branch of the Gulf Stream produces a climate on Spitsbergen's west coast, which is unusually "warm" for its extreme northerly position. The west is mostly free of sea ice during

the summer months, and the north and east have colder temperatures and are choked with fast or pack ice for most of the year.

Ny-Ålesund	78° 55'N 11° 56'E
Period of midnight sun	21 April to 21 August
Period of polar night	28 October to 14 February
Mean July temperature	+5.0°C
Mean February temp.	-14.0°C
Annual precipitation	371 mm

Reference: Ny-Ålesund Safety Guide, 2nd Edition

Appendix III: Himadri and Gruvabadet Atmospheric Laboratory

HIMADRI - 'the abode of snow' - is India's first research station at the International Arctic Research base at Ny-Ålesund, Svalbard. The station was inaugurated on the 1st July 2008. The station caters to the sustained interest of Indian researchers in pursuing scientific studies in the Arctic. The 'Himadri' consists of office space, a preparatory laboratory, and accommodation for 8 researchers. The office space has computer systems and an internet facility. Bedding in the bedrooms is provided by Kings Bay AS.

Gruvebadet Atmospheric Laboratory is an atmosphere laboratory and observatory located midway between Ny-Ålesund, the Zeppelin observatory, and the Climate Change Tower. India has a dedicated portion of the lab to install its own instruments. At present, the lab has a microwave radiometer profiler, micro rain radar, ceilometer, nephelometer, aethalometer, aerodynamic particle sizer, net radiometer, and sun photometer operational.



Himadri During winter



Gruvebadet Atmospheric Laboratory.

It may be noted that no equipment can be installed in Himadri. Atmospheric equipment can only be installed in the Gruvebadet observatory. It is not advised to mount equipment outside as it may be difficult to provide a power supply.

Appendix IV: Facilities provided by Kings Bay AS

1. Marine Laboratory

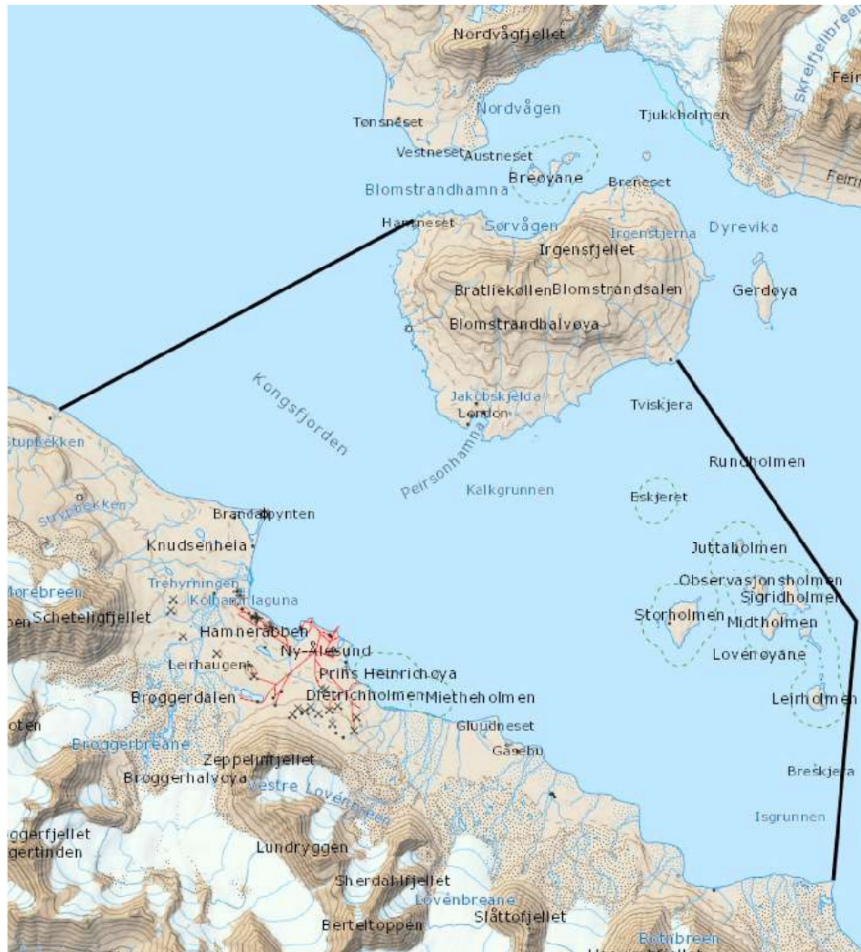
The Kings Bay Marine Laboratory in Ny-Ålesund, owned and managed by Kings Bay AS, is a common research infrastructure in Ny-Ålesund. It was officially opened on 1 June 2005. It is an experimental laboratory for research in marine ecology, physiology, and biochemistry, as well as physical sciences like oceanography, marine geology, and ice physics. The laboratory is located right on a beach with easy access to boats. It contains smaller rooms with system-controlled experimental variables like air and seawater temperature. It is also appropriate for experiments under ambient conditions.

2. Veksthuset Laboratory

The terrestrial laboratory Veksthuset is in the middle of Ny-Ålesund and includes dry and semi-wet lab facilities.

3. MS Teisten

MS Teisten is a small workboat operated by Kings Bay AS. The boat is 31 feet long and equipped to do smaller scientific operations, transportation, and surveys in Kongsfjorden and Krossfjorden during *summer*. Safety equipment is available on board (life raft, life belts, and survival suits). The maximum number of passengers on board for scientific work is restricted to four.



In *winter*, the MS Teisten availability is limited, and the boat can only cover the restricted area in Kongsfjorden near the Ny-Ålesund coast. The area demarcated in the map shows the region that can be covered by the boat during the polar winter.

Please go through the website <https://kingsbay.no/marine-lab-veksthuset/> for more details.

Annexure V: Resource websites and links to know the study area and ongoing research

Research in Svalbard (RiS): <https://www.researchinsvalbard.no/>

The Research in Svalbard database (RiS) contains information about research and monitoring projects in Svalbard and its surrounding waters by different research groups. The portal is used by registered users to submit applications and reports for research activity to the Governor of Svalbard and to book services at Ny-Ålesund Research Station.

The portal contains the research strategy of Svalbard and Ny-Ålesund, which will help you to make our proposal appropriate to the study area. The portal also contains guidelines for researchers coming to Svalbard and Ny-Ålesund Research Station, which will be useful for both before and after the proposal is approved.

Svalbard Integrated Arctic Earth Observing System: <https://www.sios-svalbard.org/>

SIOS is a regional observing system for long-term measurements in and around Svalbard addressing Earth System Science questions. SIOS integrates the existing distributed observational infrastructure and generates added value for all partners beyond what their individual capacities can provide.

SIOS brings observations together into a coherent and integrated observational programme that will be sustained over a long period. Within SIOS, researchers can cooperate to access instruments, acquire data, and address questions that would not be practical or cost-effective for a single institution or nation alone.

NCPOR is a member institution of SIOS.

Appendix VI: Ongoing long-term projects in the Arctic

May write the Ris IDs for further reference.

1. Long-term monitoring of Kongsfjorden for climate change studies (Ris ID - 12260)

The pace and magnitude of environmental change in the warming Arctic Ocean is greater than at any other location on Earth. Most importantly, these implications of climate change are not limited to the Arctic region but also influence the rest of the world. Even though numerous scientific programs have been mounted in the Arctic over the last several decades to study the changes and implications, critical knowledge gaps still exist that need to be addressed on priority considering the fast pace of events that happen far north.

The Arctic fjords are vital systems that serve as pulse points to measure the cause and effect of environmental change, may it be fuelled by local disturbances or global processes. NCPOR has been conducting systematic hydrography measurements in Kongsfjorden and Krossfjorden, the twin fjord system in west Svalbard in the Norwegian Arctic, since 2011. The fjord system that is directly influenced by the intrusion of waters from the Arctic and Atlantic along with glacial melt sets an ideal locale to study climate change and its implications.

Assessment of the collected hydrographical data shows an increase in the glacial melt-induced surface freshening and an increased Atlantic water inflow in the fjords having implications for the fjord biogeochemistry. These changes embedded with strong interannual and multiannual variabilities thereby warrant the continuation of more high-resolution monitoring to understand the physical and biogeochemical processes and their changes.

The identified objectives of the project are

1. Mechanistic understanding of the interaction between the Atlantic and Arctic waters in terms of formation of water mass, subglacial melting and circulation within the Kongsfjorden-Krossfjorden fjord system.
2. Quantification of the role of freshwater discharge into the fjord in altering the dynamics and hydrographic characteristics of the fjord.
3. Estimating the changes in mixing and stratification due to the increased intrusion of Atlantic water and freshwater discharge from the glaciers.

4. Understanding the role of changing stratification and mixing impacts on the timing, magnitude, and composition of the phytoplankton blooms in Kongsfjorden

For more details on the project, locations of data collection, and other related projects by various research groups, please check the RiS ID 12260 in the Research in Svalbard website described above.

2. Monitoring Arctic Precipitation (Ris ID - 12263)

Arctic precipitation undergoes profound changes and is governed by local and remote drivers. These are intricately linked to large scale circulation variability to local environmental factors. However, the extent of these is relatively less known in defining precipitation at smaller time scales. The precipitation structure can be directly linked to the latent heat profile of the atmosphere. This will, in turn, affect the global radiation budget and climate. Hence, a better understanding of the same will help NWP model forecasts. Considering these aspects the following objectives are drawn.

1. How temperature, circulation and the oceanic region off Svalbard impact the Arctic Precipitation particularly extremes at sub-daily time scales. Which precipitation type mostly follows the Clausius-Clapeyron relationship.
2. Characterize the precipitation microphysics, particularly rain-on-snow events and the vertical evolution of the precipitation.
3. To understand the thunderstorms in such environments.
4. to understand water vapour characteristics and its retrieval using GNSS measurements.
5. Numerical Modeling of Arctic precipitation.

Expected deliverables are publications in peer-reviewed journals, interpreting observations obtained from Ny Alesund in the context of pan-Arctic changes. This will strengthen our knowledge base about the Arctic environment which will be important as Arctic changes are expected to impact the globe. As a part of the program PhD candidates will be trained in Arctic climate and weather. A numerical model will be set up to study the Arctic weather and climate.

Currently impact of warming on Arctic precipitation, rain on snow events and the vertical evolution of precipitation using observations from Ny Alesund is being pursued. Please refer the Ris Portal mentioned above for more details or talk to us if you need further information.

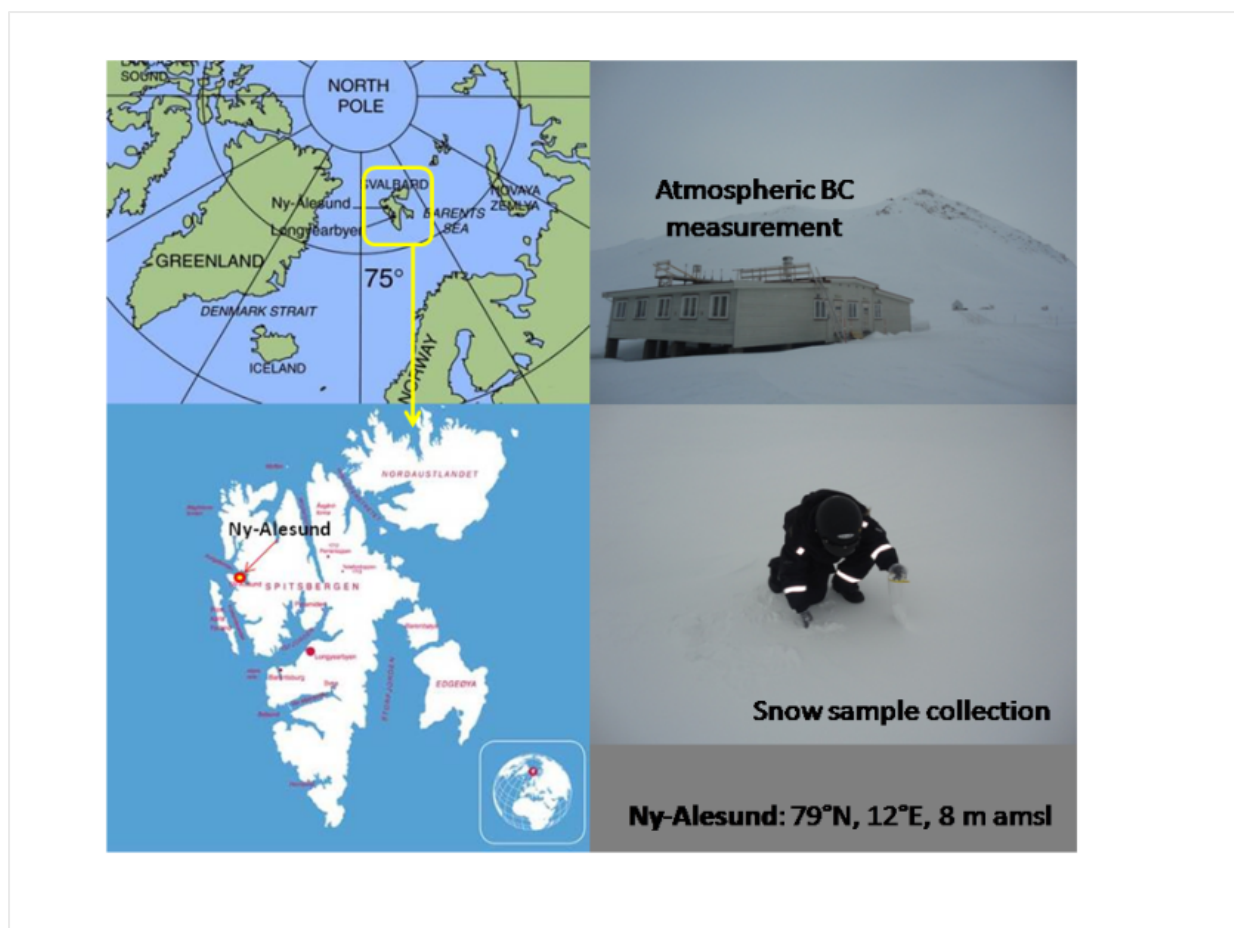


Fig.1: The geographic position of Ny- Ålesund (79°N, 12°E, 8 m amsl) in the Arctic (left panels), along with the atmospheric BC observatory at Gruvebadet (top-right) in Ny- Ålesund and the surrounding snow sampling locations at the bottom.

3. Aerosols projects (POLar AERosol NETwork (POLAERNET))

Atmospheric aerosols influence regional and global climate through direct and indirect processes. While polluted continental locations are more prone to drastic changes in anthropogenic activities, the far remote Arctic, Antarctic, and high altitude Himalayas are also not free from the dramatic influence of these suspended particulates, primarily through long-range transport from source regions outside these regions. The transport of aerosols from low latitude regions to the Arctic atmosphere and subsequent deposition in Arctic snow/ glaciers and ice sheets has been a major scientific concern in recent years. In addition, the Arctic is considered as a net sink for black carbon (deposition > emission). This process contributes to the Arctic amplification, where warming in the Arctic occurs at nearly four times the global average rate. Therefore, long-term and continuous aerosol observations over the Arctic region are required to improve our understanding of Arctic aerosols and their climatic impacts. To address this, NCPOR, India, is developing the POLar AERosol NETwork (POLAERNET) to provide continuous monitoring of aerosol levels in the Arctic, Antarctic, and Himalayan regions. Consistent monitoring of Arctic aerosols is crucial for improving our understanding of their effects on the region. The main objective of the POLAERNET is to investigate spatio-temporal variations in aerosols and their optical, physical, chemical and vertical properties over the polar region and their climatic impacts over Polar Regions in particular and on a global

scale in general. The atmospheric aerosol measurements have been carried out at the Norwegian Arctic location Ny-Ålesund since 2010, emphasizing the scattering and absorption properties of aerosols, their physical dimensions (e.g., mass concentration, size distributions, etc.), in addition to the columnar optical properties.

Long-term and continuous observations of aerosols, black carbon (BC) mass concentrations, and the physical and optical properties of aerosols in the Arctic are essential for building a comprehensive dataset. This data will help quantify BC mass and aerosol characteristics in the region, providing insights into anthropogenic influences on the Arctic. Additionally, it will allow for the analysis of trends and behaviors, as well as the validation of model simulations and satellite-derived aerosol data. Improved models, based on this validated data, will enhance the accuracy of climate change predictions. These refined regional climate models will be valuable for studying the effects of anthropogenic climate change in the Arctic.

Microbial Community dynamics and RespOnses to Climate-Change-Induced variations in the High Arctic Ecosystems (MICROCAR).

The Arctic is warming at an alarming rate, causing glacier melting as well as a decline in the sea ice cover. The pronounced seasonal variations in sunlight, glacier melting, Atlantic water intrusion, and sea ice cover influence the primary production (by microalgae and macroalgae) and inputs of terrigenous organic matter into the Kongsfjorden, thereby complicating the biogeochemical cycling of carbon and nitrogen. Microbes (bacteria, archaea, and viruses) play an essential role in the processing of organic matter, thereby influencing carbon and nitrogen cycling and climatic feedback mechanisms. Despite the importance of microbes in various biogeochemical processes and climatic feedback mechanisms not much is known about how ongoing climate-change-induced alterations, including Atlantic water intrusion, Glacier melting, and production and supply of organic matter, are affecting microbes and their processes in the high Arctic fjord. Given the above, the project has been running since 2015.

Keywords: Microbiology, microbial ecology, diversity, metagenomics, transcriptomics, enzyme activity, microbial metabolism, carbon and nitrogen cycling.

Research questions:-

- 1) How climate-change-induced variations in the sources and supply of organic matter are impacting the microbial diversity, community composition, and metabolic potential in Kongsfjorden.
- 2) How changes in microbial diversity, community composition, and metabolic potential would alter the biogeochemical cycling of carbon and nitrogen and climatic feedback mechanisms.

General Objectives:-

- 1) Census of microbial diversity using high throughput and novel microbial culturing techniques.
- 2) Microbial community studies using metabarcoding, metagenomics, metagenome-assembled genomes (MAGs), and metatranscriptomics.

- 3) Evaluation of microbial abundance (including viruses), respiration, biomass production, carbon demand, and extracellular and intracellular enzymatic activities.
- 4) Marine and terrestrial organic matter source identification and characterization using IR-MS, HPLC, and HPAEC.

Specific objectives:-

- 1) Evaluate the impact of macroalgal forests/detritus on the pelagic-benthic prokaryotic community structure and metabolism in Kongsfjorden.
- 2) Fate, fluxes, and degradation of macroalgal POM in Kongsfjorden.
- 3) Role of particle-attached and free-living microbes in vertical organic matter fluxes in Kongsfjorden.
- 4) Evaluate the diversity and community dynamics of nitrogen-fixing and denitrifying microbes in Kongsfjorden.
- 5) Evaluate the influence of heavy metal contamination on microbial community structure and functions.