Arctic: why India should pursue the North Pole from a science and technology perspective?

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The Arctic has been receiving a lot of attention recently due to environmental and economic reasons. The continuing reduction of sea ice and sheet ice is likely to affect global climate significantly. It is expected that these changes will affect monsoon as well as inundate our coasts. India has a modest presence in the Arctic, mainly for scientific purposes. The changing Arctic is likely to offer many economic opportunities, especially for ensuring energy security and access to rare earths. India needs to enhance its presence for launching scientific projects to study the interactions between cryosphere, atmosphere and ocean in order to understand long-term impacts on the country. It is essential that India defines its strategy as well as a policy for the Arctic in the near future and contributes towards generating strategic knowledge for the region. Such knowledge will help ensure food, energy and resource security for the country.

The polar regions or the cryosphere, the Arctic, the Antarctica and the Himalaya, the third pole, collectively form one of the important components of the earth system. These regions modulate the global weather and climate through an exchange of mass and energy within themselves as well as across other components of the earth system, viz. ocean, atmosphere, geosphere and biosphere, and thus impact ecosystems. The changes occurring in the Arctic are yet to be fully understood. Hence, the changing Arctic has become a focus of scientific, geopolitical and economic interests. The physical linkages of the coupled ice–ocean–atmosphere system in the Arctic, including permafrost and its relation to the global system, need to be further explored. The critical areas of research include impacts of the changes in the Arctic on ocean circulation, weather and climate as well as the availability of petroleum and mineral resources, and subsequently their implication on economy and society.

It is expected that these changes in the Arctic will affect the Indian monsoon as well as provide access to petroleum and mineral resources, especially rare earths. Hence, it is necessary for India to define its strategy and policy to increase its engagements in the Arctic and contribute towards generating knowledge on the region and protect its long-term interests.

What is happening in the Arctic?

The Arctic has been changing rapidly due to global warming. The following changes are critical as they are likely to significantly influence global climate and weather.

(i) The sea ice, both in winter and summer, has been decreasing since the 1980s. This decrease in sea ice has resulted in diminished surface albedo and affected the energy budget of the region. The diminishing albedo further contributes to an increased warming of the Arctic Sea and further loss of sea ice. Hence the continuing reduction in albedo needs to be taken into account for future forecasts of ice loss[1].

(ii) The sea-ice loss has also influenced marine and terrestrial ecological dynamics, influencing productivity, species interaction, population mixing, development of new fishing grounds, etc.[2].

(iii) The melting of ice sheets of Greenland and ice caps in other Arctic regions significantly introduced a large amount of freshwater in the Arctic, and also contributed to global sea-level rise. This process will continue. The estimate of ice-loss from the shrinking Greenland ice sheet is of the order of 227 Gt/y and contributes about 0.7 mm/y to the average sea-level rise[3]. These changes in ice-sheet mass balance further affect thermo-hyaline ocean circulation in the North Atlantic[4,5], and ultimately global climate.

(iv) The deep ocean circulation, governed by temperature and salinity, from the tropics to the poles and back to the tropics, exchanges mass and energy. This process also redistributes heat, and drives weather and climate of the earth. It could slow down the Atlantic current system, and temperatures in North America and Europe may plunge[4] and affect precipitation patterns in the tropics[6]. This circulation is considered as a possible tipping point in the earth system[7]. Hence, it could impact bio-geophysical and socio-economic systems at the regional and global scale.

(v) Melting of ice sheets is further enhanced by surface darkening by algae. Such darkening will result in net albedo reduction[8].

(vi) The release of methane from the permafrost region is another critical issue. The East Siberian Arctic Shelf is venting at least 17 Tg (17 million tonnes) of methane into the atmosphere each year[9]. Global research has indicated that the warming will continue to release more methane, which in turn will further warm the planet.

The Arctic environment should be managed based on the best available scientific knowledge, and following best practices on conservation and protection of the environment. Hence, it is vital to observe the Arctic in a sustainable manner to predict changes and develop adaptation strategies. For this, increased and sustained observations need to be carried out and integrated with new and innovative modelling approaches. The integration of ice-shelf dynamics, permafrost, ecology and economics into a modelling framework should be the priority.

Arctic and India

India's association with the Arctic is 100 years old. The Svalbard treaty in 1920 allowed India (as British Overseas Dominion) to engage in commercial activities, mainly exploiting coal resources in

this region. India's main interest in the Arctic is to understand its role in modulating global climate, and specifically to India. The first Indian expedition to the Arctic was undertaken in 2007 and India established the Himadri station at Ny-Alesand, Svalbard in 2008. It is worthwhile to remember late Mahendra Nath Bose who set foot on the Arctic in 1962 to collect plant fossils in collaboration with Norwegian scientists. That was the beginning of India's scientific engagement with the Arctic.

In the current scenario, the Arctic has provided an opportunity to the global scientific community to build strategic knowledge on changes in the region and their consequences. India, having extensive experience in carrying out research activities in the Antarctica and the Himalaya, can contribute significantly towards global efforts in building strategic knowledge about the Arctic. Many national laboratories and universities, viz. Earth System Science Organization-National Centre for Polar and Ocean Research, Geological Survey of India, Wadia Institute of Himalayan Geology, CSIR-Centre for Cellular and Molecular Biology, Jawaharlal Nehru University, etc. have been involved in the cryospheric research programmes. Their expertise on the cryosphere should be channelized to understand the Arctic and its environment.

For India, the prediction of monsoon in the changing climate scenario is essential for food security, infrastructure development and thus for sustainable economic development. There is a teleconnection between the Arctic and the Indian monsoon (https:www.ncdc.noaa.gov/teleconnections/ao/). A link between cold episodes in the North Atlantic and weakened monsoon during 40,000 to 11,000 BCE[10] and the Holocene[11] has been suggested. The physical mechanism between the North Atlantic sea surface temperature and Indian monsoon was explained by Goswami *et al.*[12].

Recently, it has been shown that there is a positive correlation between the Greenland sea-ice area in October with the Indian summer monsoon[13]. It has also found that the changes in glacial and sea-ice melting contribute towards year-to-year variability of the Indian monsoon causing droughts and floods[14]. The changes in the monsoon pattern will have an impact on long-term viability of agriculture and water resources, leading to food and water security issues.

Similarly, changes in the monsoon in India have been affecting the Arctic. The heavy rainfall events in the Northwest Himalaya cause increased melting in the Canadian Arctic[15]. Understanding the teleconnection between changes in the Arctic and monsoon will further enhance our understanding of the global climate.

The Arctic has abundant petroleum and mineral resources. According to an estimate by USGS in 2008, the Arctic had about 30% and 13% of the world's undiscovered gas and oil reserves respectively[16]. India may need to explore the possibility of collaborating with Russia and Norway for accessing these resources. At the same time, the advantage is that this region has low geopolitical risks compared to Africa or the Middle East. This is critical to ensure long-term energy security of the country.

India needs to have access to critical metals and rare earth elements – niobium, platinum group of minerals, tantalum, molybdenum, vanadium, etc. These minerals are widely used in various products ranging from electric motors, electronics and aerospace industry. The access to these minerals is critical for ensuring resource security.

The possibility of opening of a sea route and its likely impact on India also need critical examination as it will reduce time, cost and CO_2 emission. It has been reported that by 2050, open-water ships and polar class vessels will be able to navigate along the Northern Sea Route and over the North Pole respectively[17]. It is expected that in future Indian ships may carry cargo throughout the world, and hence the Northern Sea Route will be of interest to the country. There will be opportunities for Indian companies to sign contracts for carrying out seabed survey, especially for bathymetry and identifying shipping lanes. Arctic tourism is another area which will need our attention.

The investment in developmental activities in the Arctic is likely to increase in future, leading to degradation of the environment. The cost of environmental damage also needs to be recognized, such as hazards of oil spill, methane release, ecosystem loss, etc. According to an estimate, the release of methane from thawing permafrost alone could be of order of US$ 60 trillion, if no mitigating actions are initiated[18]. Much of the cost will be borne by the developing countries, especially India, which may face extreme weather, lower agricultural production, etc. India needs to undertake economic modelling to understand its vulnerability to the changing Arctic and its consequences.

In order to effectively participate in Arctic research, India needs to build scientific infrastructure. Apart from the existing station in Svalbard, it needs to set up research stations in Greenland, Canada, Russia and Alaska. India has set up one moored multi-sensor observatory in Svalbard to collect real-time data on seawater temperature, salinity, current, etc. at discrete depths. Such observatories are critical to improving our understanding of the response of the Arctic to climatic variability, the Arctic processes and their influence on the Indian monsoon system. India has a plan to deploy many such observatories at appropriate locations. Satellite data are also critical input in Arctic research. We need to set up a satellite data-receiving station to collect data in real-time for the Arctic environment. This will also facilitate global coverage of Indian satellite data and complement similar stations in the Antarctica.

At present, there is no university in India that provides formal education related to the cryosphere. Currently, Norway and India are jointly funding doctoral research at the University Centre in Svalbard, Norway. We need to build infrastructure to provide education at postgraduate and doctoral levels, if we want to effectively participate in Arctic research. India also needs to collaborate with universities in the Arctic countries, including the Arctic University. Capacity building at various levels among all stakeholders should be a priority.

Need for an Arctic policy

India needs to devise an Arctic policy and a set of strategies to achieve it, with an objective to effectively participate as well as engage with various stakeholders in the Arctic. One of India's primary strategies has to be based on scientific research, as it is key to economic activity. Besides the emphasis on science and technology (S&T), India will also have to pursue a strong foreign policy approach towards achieving its Arctic objectives. Such an approach should not be aimed only at those countries in the Arctic region, but also the ones outside it.

S&T strategy for India in the Arctic

India's S&T strategies for its Arctic policy could be based on the following:

(i) Understanding of cryospheric processes and their interaction with other earth processes (water, atmosphere, ecosystem, soil and anthropogenic activities), and connecting the Antarctica and Himalayan research to Arctic research.
(ii) Preservation and conservation of the Arctic environment, and addressing issues related to climate change.
(iii) Development and utilization of the Arctic energy resources, direct investments in oil and gas, and the role of Indian companies.
(iv) Exploration of rare earths (Greenland) and other critical minerals, development of tourism, new shipping routes, etc. and participation of the Indian private sector.
(v) To address issues related to the Arctic infrastructure.

Foreign policy strategy for India in the Arctic

India's foreign policy strategy towards the Arctic should be as follows:

(1) Arctic cooperation and governance: One of India's primary strategies should address issues relating to Arctic cooperation and governance as well. Since India has an 'Observer' status in the Arctic Council, New Delhi can influence through participation in various working groups. Active and effective participation in the International Arctic Science Committee, Arctic Circle (policy makers, scholars, business leaders, people), Asian Forum on Polar Sciences and Intergovernmental Panel on Climate Change, International Maritime Organisation, United Nations Environment Programme is crucial[19,20], and the necessary mechanism has to be worked out.
(2) Bilateral strategies with the big Arctic powers: Russia, USA and Canada are three big Arctic powers. While India has established strategic partnerships with USA and Russia on various other issues, the Arctic has not been a primary focus of these strategic partnerships. India should consider an exclusive dialogue at bilateral level with these countries. An exclusive Arctic strategic dialogue needs to take place at two levels – dialogue at the state level, as track-I and at the non-State level between the academic and scientific institutions as track-II.

In USA, Canada and Russia, there are multiple organizations – academic and scientific, that have a special focus on the Arctic. Direct contacts need to be established with these institution by the Indian institutions. These institutional linkages are essential for India to develop a comprehensive understanding of developments in the Arctic, and also to build capacity among various actors.
(3) Bilateral strategies with smaller Arctic powers: In the Arctic, the smaller countries play a more significant role. For example, Norway, Denmark and Iceland, though geographically smaller, strategically have a larger role to play.

India's foreign policy engagement with the smaller states is at different levels and stages. While it has a better equation with Norway, the same cannot be said about Denmark. India has to be proactive and engage with these smaller countries much more intensely.

India's foreign policy strategies vis-à-vis these three countries, obviously cannot be Arctic specific. It should be a part of a broader approach.
(4) An Arctic coalition in the South and looking east to look North: India has been developing a 'Look East' (now Act) approach as a part of its foreign policy approach towards Southeast Asia and East Asia. Within these two regions – Singapore, South Korea and Japan are three Arctic 'Observer' countries in Asia.

India should engage with these three Asian countries and build an Arctic coalition in the South. South Korea and Japan have already invested in the Arctic on S&T and polar shipping. India could use this Asian coalition on the Arctic to strengthen its case in the region.

Both South Korea and Japan are already engaged in an annual dialogue with China. These two countries along with Singapore could be a part of the 'Arctic South' approach for India.
(5) Building bridges with the Arctic indigenous communities: In no other regional groupings do the indigenous communities play a role as in the Arctic. There are multiple indigenous communities that play a strong role in the Arctic – individually and collectively.

India has to establish a link with these indigenous communities, perhaps at the track-II level. One could also facilitate a dialogue with the indigenous communities of the Himalaya.
(6) Building further on the INSTC and the Vladivostok–Chennai Corridor: Last year, India's Prime Minister announced the launching of a new maritime corridor linking Russia's east and India's south, viz. the Vladivostok–Chennai corridor. This could provide a physical passage for India to reach the Arctic.

Much before the launching of the above corridor in the east, India has launched the INSTC – International North–South Corridor linking St Petersburg in Russia with Mumbai in western India via Iran and the Central Asian countries. If the Vladivostok–Chennai corridor is predominantly maritime, the INSTC from Iran is a road corridor. The INSTC could have a link in the west into Siberia and then the Arctic.

India has to take an active interest especially, for developing a common agenda for global good and an appropriate environmental policy for the Arctic.

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Preprint submissions by Indian scientists in arXiv

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This note analyses the preprint submission patterns of Indian scientists to the popular preprint server arXiv. We analysed research papers published during a five-year period (2014–18) as indexed in the Web of Science and identified how many of these were deposited in arXiv. The discipline-wise distribution of research papers deposited in the repository was also analysed. Results show that overall, only about 3.5% of research papers were deposited in arXiv. The deposits, however, vary across disciplines, ranging from a high of about 23% for physics to a low of 0.4% for agricultural science and biology. We present the overall submission and download statistics for arXiv, and highlight the need for promoting the use of such repositories by the Indian scientific community.

The open-access archive arXiv.org was established in 1991 through collaborative funding as a community-supported resource. It was founded by Paul Ginsparg and is maintained and operated by Cornell University, USA. The server is maintained by a team with guidance from the arXiv Scientific Advisory Board and the arXiv Member Advisory Board. The arXiv repository is funded by Cornell University, the Simons Foundation (https://www.simonsfoundation.org/), member institutions (https://arxiv.org/about/ourmembers) and donors (https://arxiv.org/about/give).

Over a period of time, it has grown to become a 'free distribution service' and an 'open-access archive' for more than 1.5 million scholarly articles (https://arxiv.org). The main subject areas that arXiv covers are: physics, mathematics, computer science, quantitative biology, quantitative finance, statistics, electrical engineering and systems science and economics (https://arxiv.org/about). A registered user in arXiv may submit articles that are announced by the server after certain checks. All submissions to arXiv are subject to a moderation process that classifies materials as topical to the subject area and having scholarly value. The submissions can be downloaded free of charge by anyone across the world.

As on 13 July 2020, arXiv has a total of 1,731,310 submissions (https://arxiv.org/stats/monthly_submissions). Figure 1 shows a plot of the number of new submissions per month to arXiv starting from 1991 till 2020. It can be observed that from about 2000 new submissions per month in 1997, arXiv has grown to receive about 17,000 new submissions per month as in 2020. Ginsparg[1] examined the status of arXiv at the age of 20 years in 2011, and a few years later Van Noorden[2] pointed out that 'arXiv preprint server has hit 1 million articles'. Figure 2 shows the disciplinary distribution of new submissions, indicating that physics, astrophysics, mathematics and computer science constitute majority of these submissions.

Lin *et al.*[3] analysed the arXiv preprints in the area of computer science and showed that there are several reasons why papers are deposited in preprint servers like arXiv. These include: (a) deposits become 'record of priority', (b) they allow 'feedbacks' to authors and (c) deposits create the possibility of submissions becoming 'attention grabbers'. In fact, a careful observation of the statistics of download of papers from arXiv substantiates these claims. According to the download statistics (https://arxiv.org/stats/monthly_downloads) of arXiv, a total of 1,648,280,932 download requests were processed by the server till June 2020. Figure 3 shows the number of downloads per month from arXiv during 1991 to 2020. The arXiv preprint server also includes a membership programme for institutions and libraries, and such members account for more than 75% of institutional downloads. The download statistics also shows the list of top 250 institutions (https://arxiv.org/about/reports/2019_usage) with highest downloads in