India's Arctic involvement needs to set a new course with a multi-stakeholder approach, expanding its outreach to more institutions, think tanks, universities and the private sector; Spitsbergen, Svalbard, Norway.

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Recommendations

Policy Recommendations

Every chapter in this Report concludes with specific recommendations. They include advice for the policy makers of India's Arctic Policy and advice for India's role in mitigating climate change in Polar areas, including the Himalaya, advice for India as a stakeholder in the fate of the Antarctic Treaty, advice for working towards the engagement of youth and capacity building in Polar knowledge goals, advice for people centric climate change solutions, advice for working on maritime security, energy exploration as well as advice for working towards developing India's energy transition policy. This section is a distilled synopsis of all recommendations in order of their significance to India.

PR 1: India's Arctic involvement needs expansion at the domestic level. The six pillars of India's Arctic Policy must strengthen its multi-stakeholder approach and expand its outreach to more institutions, think tanks, universities and the private sector. India needs to heighten international engagement, creating a more proactive role for the Asian Observers of the Arctic Council and strengthening its foray through increased participation. International outreach through membership in the Arctic Economic Council needs to be sought. MoES and MEA need to calibrate India's efforts.

PR 2: Arctic living is congruent with the sustainability ideas of Mission LiFE, an India-led global mass movement encouraging individual and community action to protect and preserve the environment. Best practices from India, therefore, must be shared and assisting in satellite/digital medical services and engaging with far-flung communities may be a few such ideas. MoES, MoH&FW and AYUSH may work towards such integrations.

PR 3: India can build collaborations in strategic areas of oceanic routes in the Arctic waters and contribute officer-grade workforce for hydrography or satellite-based communications for ships on the Arctic routes. The Northern Sea Route is likely to become commercially important in the coming years, and India's involvement can help better ties with several nations in the region. The NSR is likely to become commercially viable in the coming years, and India's involvement needs to be enhanced to help develop multi-stakeholder collaborations with several nations in the region. MEA, MoPSW and MoPN need to review and take action.

PR 4: India needs to build a policy environment where sustainable energy transition models are a key adaptation measure for cryospheric regions. India needs policies to attract foreign investment in the geothermal or hydrogen fuel industry, best suited for the Himalayan region and its cold deserts. Therefore, a transitional-energy policy, aided by knowledge of geothermal and hydrogen utilization, should be popularized with capacity building through training and short courses in site-specific demonstration projects. MNRE, MoP and MoES need to take a lead.

PR 5: Antarctic governance requires democratization, revisiting the resilience of the Antarctic Treaty System. India and other like-minded nations must ensure that the existing Antarctic Treaty, built and strengthened over 60 years, continues to inspire the international legal regime and keeps Antarctica safe and pristine for future generations. As the Treaty was constructed on hope and trust, the Antarctic Treaty Consultative Meetings (ATCM), held annually, bear a significant role in channelling Member States' opinions and upholding the preamble of the Treaty, which says that Antarctica will never become a site of discord. India needs to work towards bolstering the environment of trust in its interactions while hosting the ATCM in 2024, which will be held in Kochi, Kerala. MoES and MEA need to work towards making ATS more inclusive and democratic.

PR 6: An innovative research ecosystem for India's youth needs to be ensured to provide strategic roadmaps in Polar studies at the primary and higher research levels. The culmination of the UGC Arctic courses and an introduction to the subject in NCERT textbooks are needed. Emerging courses in climate studies such as sustainability accounting, ecosystem accounting, zero-emission economy, sustainable finance, innovation and technology should be mainstreamed in India's academic institutions. Indian universities, institutes, and think tanks need to gain memberships in the UArctic, helping lead global linkages in research. Regular conferences, seminars and workshops are mandated to provide the requisite environment for dissemination, assimilation and query among the Indian intelligentsia. Mentoring research at the early stages, including new areas of research such as climate accounting and incentivizing it with recognition can drive significant improvements at the government sector, and at the institutional levels. MoES in tandem with MoE and UGC can build a cohesive platform for a Polar study ecosystem in India.

PR7: There are many countries, scientists and industries who lobby to promote sea bed mining. The UNCLOS needs to have an authority to declare any commercial mining as illegal or disprove it, in case a country intends to go for mining. There needs to be a moratorium on deep seabed mining.

Research Recommendations

Research recommendations are made throughout this Report at the end of each chapter. They include advice for India's scientific community working on Polar sciences, more specifically cryospheric research to synergize with the broader perspectives on oceans, disaster management and early warning systems, and energy transition. This part is a succinct synopsis of every recommendation in the report in order of their importance to India.

RR1: The Himalayan region is suffering the consequences of climate change and needs enhanced investments, institutional support, and state-of-the-art monitoring networks and satellite-based observations to better predictions. Increasing the number of observational platforms is required to avoid site-specific bias in the data. Early warning systems in the Himalayan regions are critical in disaster preparedness. To effectively provide early earthquake warnings and save lives, it is essential to have a sufficient number of seismological stations and a quick response time, which can be improved by networking and involving local agencies. In order to improve impact forecasting for potential disaster zones, there is a need for more comprehensive and standardized monitoring methods, which can be enhanced through new technologies such as UAVs and remote sensing. Besides, close scientific coordination among various science and research organizations such as MoES, MoS, MoM (GSI) and DST is needed for better preparedness against disasters.

RR2: Data on permafrost in the Himalaya is limited. There is a need to initiate a long-term programme for such areas and collecting depth profile data to map the extent of permafrost, especially in Lahaul and Spiti districts of Himachal Pradesh and Ladakh region. Research efforts may be guided through MoES, DST, MoS and MoM (GSI).

RR3: Development of newer instruments capable of measuring subtle variations in ocean observations for effective forecasting, date assessment, ocean and atmospheric modelling are needed. Innovative technologies for mapping of groundwater, subsurface aquifers, and their depths with spatial resolutions is also required. A self-propelled track based seabed mining system is imperative to address the challenges of

variable ocean dynamics. MoES, DSIR and MoS can develop actionable mechanisms to take it forward.

RR4: There is a need to focus on assessing the performance, accuracy, and penetration depth capacity of new altimeters for measuring glaciers, comparing them with existing technologies like LiDAR and microwave altimeters. There is also a potential of integrating explicit load balancing (ELB) synthetic aperture radar, such as NISAR, with the proposed altimeter technology. Feasibility and benefits of advanced altimeter in future technological usage needs to ascertained. Also, space based observations need to be supplemented by field checks and ground surveys. MoES, MoS and MoD (DRDO) may work in tandem towards new instrumentation needs.

RR5: Newer technologies must be developed to stop pollutants from reaching the oceans. Research on bio-plastic should be done to develop sustainable alternatives. C ost-effective technologies is needed for carbon capture and sequestration. Also, restriction on the construction along vulnerable coastal areas and preparing for planned relocation can help adapt to sea level changes. MoES, MoEF&CC and MoH need to fashion actionable mechanisms.

RR6: As the grounding line of Antarctica measures approximately 62,000 km, which is larger than the earth's circumference of 40,000 km, there is a need for heightened international collaboration for monitoring it. This entails creating and merging various regional initiatives to generate uninterrupted data. There is also a need to deploy drones to monitor the sea ice dynamics closely. MoS, MoES and MoM (GSI) may come together to develop new collaborations.

RR7: Research based on human ingenuity for cost-effective and efficient climate solutions are needed to address the climatic concerns that can lead to a sustainable transition in the model of economies worldwide. Relevant research infrastructure must be created in the domain of energy alternatives, sustainable utilization of oceanic and other hydrological resources, and identification of new resources. MNRE, MoP, MoF, MoWR and MoES need to take a lead.