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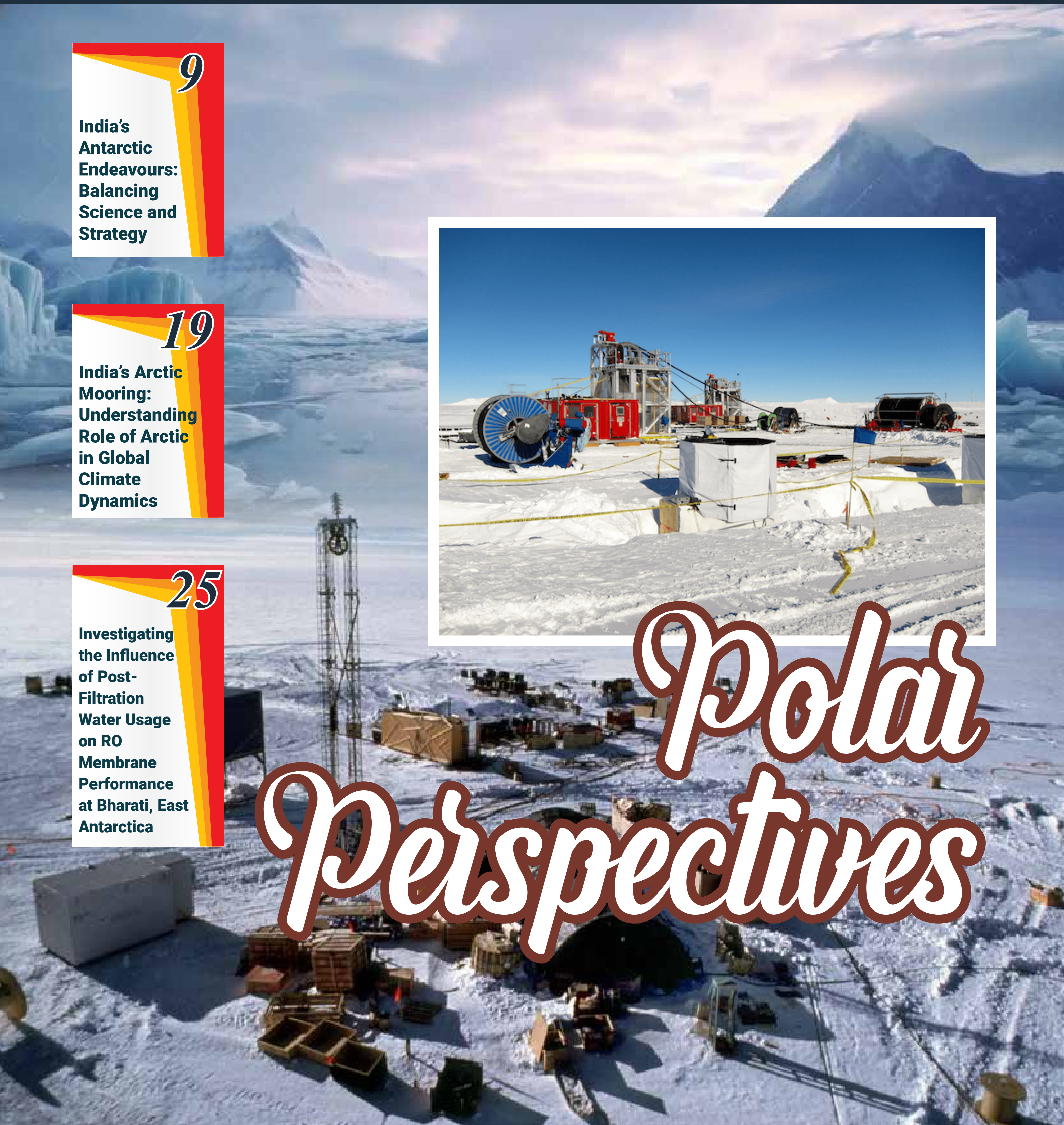

Polar Perspectives

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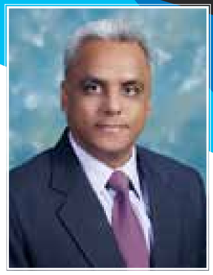
EDITORIAL



...Shining white, bright blue, utterly black illuminated by sunlight, the country looks like a fairy tale.
- Roald Amundsen (Polar Explorer) on sighting the South Polar Region

Arctic and Antarctic have been drawing space in many maritime discourses. The UArctic and other Universities are campaigning for interaction and attention. Be it the war or be it the Northern Sea Route, the reasons for this Polar interest cannot be set aside without deliberations, particularly from the current maritime perspective that India has now.

Rewind a few months back into 2024... A two-day academic forum on Polar Dialogues at National Institute of Advanced Studies, Bengaluru, had a range of polar talks by experts including those from Indian Administration (MEA, MoES etc.). The discussions centred around policies in particular; the Himalayas, the Global Commons and the impending claims (and counter claims) were all there. While it was all about the maritime space and policy issues, the technical topics needed a platform. The technological applications in the region are of consequential significance to the marine engineers also. While the geopolitical wrangles might change the Polar fairy tales into fiery jostle, technology would still have its part to play.

This was what prompted me to seek an array of articles as bunch them under the theme of Polar Perspectives. The Scientists from NIOT and NCPOR have provided their thoughts and efforts with enthusiasm. Trust you find this knowledge interesting.

In this issue

The first to go is on India's interests in the Antarctic region. Swati Nagar et al., explain India's physical connection and the influence on monsoon and climate. Then comes the chronicling of how India has been always a part of the Antarctic canvas. The Scientists then go on to list several efforts by India;: expeditions, establishment of research station, organising and participating in international forums and so on. The takeaway from the article: India's Research Stations Dakshin Gangotri, Maitri (future plans for Maitri II), Bharati, and their research efforts.

We get technical with the second article talking about buoys and ocean observation systems, particularly for the Arctic region. Arul Muthiah et al., explain the observatory buoys, their functions and a few features and describe the deployment of the moorings for scientific studies. The Scientists throw in some data analyses to explain the type of data and their significance. This is an educational read.

The takeaways: IndARC mooring Schematics, Arctic's 'Seasonal Temperature Inversion'.

The next in line, discussing Reverse Osmosis [RO] plants in Antarctic region, connects well with marine engineering. Rahul Mohan et al., look at RO membrane efficacies considering the post-filtration water outputs. The Authors describe the details for the feed and go on explain the studies on water demands, the environmental parameters and the focus on filtration and outcomes to optimise the systems. Researchers would find the study approach interesting. A description of the RO plant components, osmatic pressure ranges for production, the membrane materials (cellulose acetate?), inline mechanical filters (pre & post) would have added spice to the otherwise analytical article.

The takeaways: excess/waste water discharge being close to the intake and environmental factors affecting the water filtration.

The next in the Polar-pick is a discussion on underwater vehicle navigation, in the Polar regions, of course. Bala Naga Jyothi et al., describe the evolution of the UW vehicles and some of the unique challenges posed (thickness of ice hampering signals etc.). Then the discussion shifts to the PROVe (Polar Remotely Operated Vehicle). The Scientists explain the tests carried out for validation of the developed algorithms and the tests of the PROVe in the environmental chambers itself is explained. The story concludes with the successful deployment.

The takeaways: explanation of the earth's poles and UW compass issues; the transverse coordinate system.

We conclude the Polar dialogues with a discussion on the importance of Antarctica and the conservation of these parts of the planet. The article introduces Antarctica nicely and goes on to highlight climate change concerns describing the changes in the Antarctic region. The increase in vessel movements, tourism temptations and invasive species are concerns. Rasik Ravindra then takes us through various efforts by employing protocols, treaties, Antarctic Special Protection Area etc., and pitches for enforcement and action plans.

The takeaways: Increase in Antarctic tourism and ship/vessel movements; Indian engagements.

The MER Archives has an interesting Transaction on Residual Fuels. This could be of interest to practicing marine engineers.

Presenting the Thematic Issue on Polar Perspectives, here is the February issue for your reading pleasure.

Dr Rajoo Balaji
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India's Antarctic Endeavours: Balancing Science and Strategy

Swati Nagar, Avinash Kumar, Rahul Mohan

Abstract

India's Antarctic program highlights its dedication to scientific research and its geopolitical presence in this vital region-Antarctica. Since joining the Antarctic Treaty System, India has contributed significantly to governance, focusing on sustainable exploration, environmental protection, and international collaboration. Establishing research stations—Dakshin Gangotri, Maitri, and Bharati—and planning Maitri II demonstrates its commitment to multidisciplinary studies, including geology, climate variability, biodiversity, and polar-tropical teleconnections. India's research has advanced the understanding of Antarctic climate systems, their global impacts, and the region's role in the carbon cycle. However, the increasing complexity of environmental and geopolitical challenges demands strategic planning. Balancing scientific goals with conservation, fostering international collaboration, and strengthening governance roles are essential. This article reviews India's Antarctic efforts, emphasising the need for enhanced infrastructure, robust policies, and partnerships to sustain its geopolitical interest while protecting the fragile ecosystem and contributing to global scientific and environmental goals.

Keywords: Policy, Antarctica, Geopolitics, India, Polar Regions

1. INTRODUCTION

Antarctica- A No man's land with geopolitical claims

The Polar Regions are essential for global climate regulation and act as critical centres for climate research. These regions are witnessing stark impacts of climate change, with 2024 recording Antarctica's second-lowest sea ice extent in September (NASA) and the Arctic experiencing its second-warmest year since 1990 (NOAA report).

Unlike the Arctic, which has defined sovereignty claims, Antarctica remains a no-man's land, uninhabited and governed collectively. Its status as the youngest continent with immense resources has attracted geopolitical interest. Seven nations—Argentina, the U.K., Australia, Chile, France, New Zealand, and Norway—have made territorial claims based on sovereignty or historic exploration. To avoid conflict and foster collaboration, 12 countries signed the Antarctic Treaty in 1959, later joined by others, establishing a framework for shared governance (Sharma, 2024).

The Antarctic Treaty System (ATS), through its 14 articles, ensures Antarctica remains a zone for peace and science, freezing territorial claims (Article IV) and promoting international research and environmental preservation. Agreements like the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Committee for Environmental Protection (CEP) further strengthen environmental stewardship and sustainable management of the Southern Ocean. Antarctica stands as a model of global cooperation, where science drives diplomacy and collaboration.

India's Connection to Antarctica: A Geological and Geopolitical Perspective

India, a subtropical nation located approximately 11,000 kilometres from Antarctica, might initially appear unconnected to the icy continent. However, geological history unveils a profound link. About 180 million years ago, the breakup of Gondwanaland separated Eastern Antarctica from India's Eastern Ghat Mobile Belt. **India subsequently drifted northward, colliding with the Eurasian plate 50–52 million years ago, leading to the formation of the Himalayas** (Powell, 1988; Van Hinsbergen et al., 2012; Rao and Radhakrishnan, 2021).

This ancient connection continues to drive Indian scientific exploration of Antarctic processes and their influence on lower latitudes. The Indian Antarctic Program's initiative, *Geological Exploration of Amery Ice Shelf (GeoEAIS)*, aims to map the geological structures of the Amery Ice Shelf, study the interplay between mountain-building and stable continental elements, and enhance India-Antarctica geological correlations (Ray *et al* 2024). Scientists also focus on the dynamics of the East Antarctic Ice Sheet, examining its interactions with bedrock and crustal heterogeneity in the Amery region. This research highlights India's scientific commitment to understanding Antarctic processes and their global implications.

To avoid conflict and foster collaboration, 12 countries signed the Antarctic Treaty in 1959, later joined by others, establishing a framework for shared governance

2. India- Antarctic - Polar Link

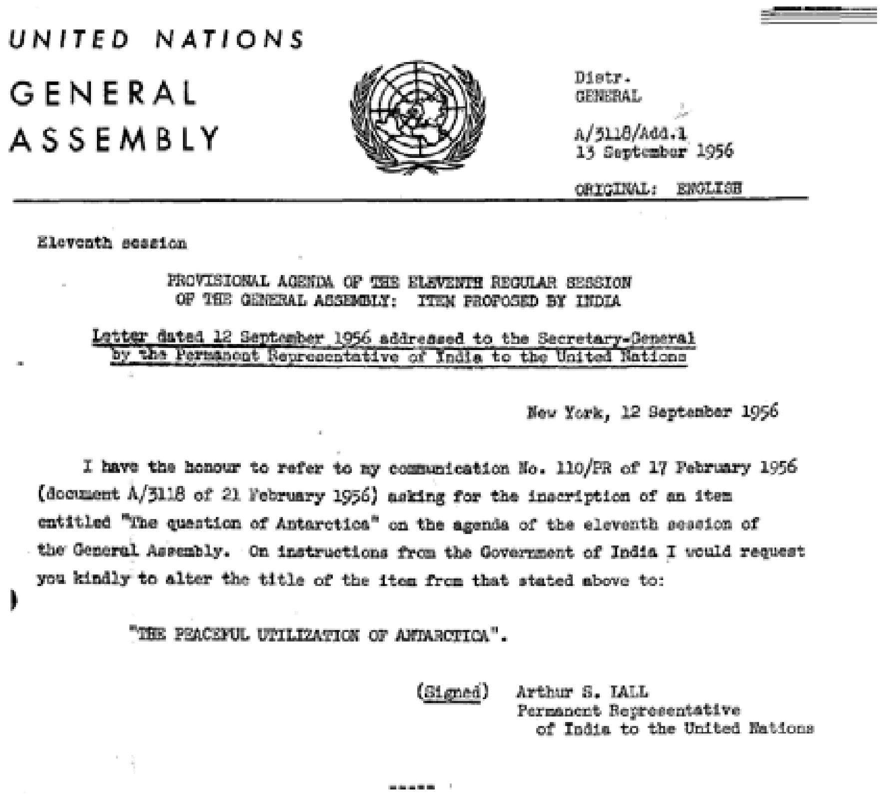
Antarctica's influence extends beyond its geological ties to India, significantly affecting the country's climate. Changes in the polar regions, transmitted through atmospheric and oceanic circulations, play a crucial role in shaping the Indian monsoon—a lifeline for the nation, where agriculture forms the backbone of the economy. Understanding these polar-tropical teleconnections is essential for enhancing the accuracy of monsoon predictions, with profound implications for India's socioeconomic well-being (Nair *et al.,* 2019; Bajish *et al.,* 2021; Chatterjee *et al., 2021*; Kumar *et al., 2021*; Kumar *et al., 2023* and Yadav *et al.,* 2024).

A Geopolitical Stake in Antarctica

India's involvement in Antarctica extends beyond scientific exploration to include significant geopolitical interests. As a consultative party with veto power under the Antarctic Treaty System (ATS), India actively contributes to shaping policies on the continent's governance. Through its participation in Antarctic Treaty Consultative Meetings (ATCMs), India consistently advocates for sustainable resource management, environmental conservation, and enhanced logistical coordination.

Legacy of Indian Antarctic Endeavours

India's engagement with Antarctica dates back to the 1950s when the then Honourable Prime Minister of India, Shri Jawaharlal Nehru, along with India's Permanent Representative to the United Nations (UN), Ambassador Arthur S. Lall, and the Chairman of the Indian delegation to the UN, Shri V. K. Krishna Menon, raised 'The Question of Antarctica' (renamed as 'The Peaceful Utilization of Antarctica'—Figure 1) during the United Nations General Assembly in 1956. They addressed the peaceful use of Antarctica and the impact of nuclear testing on global climates and monsoons. This period coincided with the International Geophysical Year (IGY) of 1957–1958, a landmark initiative that fostered global scientific collaboration, with over 67 countries participating in data collection in the Polar Regions. Although India did not participate in the IGY, its vision for safeguarding Antarctica's environment and ensuring peaceful access for scientific endeavours likely influenced the Antarctic Treaty (signed in 1959 and came into effect in 1961), particularly Articles I (which emphasises peaceful use) and V (which prohibits nuclear testing). India's stance also prefigured the Environmental Protocol of 1991, which came into force on January 14, 1998, after ratification by all Antarctic Treaty Consultative Parties (Nagar et al., 2023**).**



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Letter dated 12 September 1956 addressed to the Secretary-General by the Permanent Representative of India to the United Nations

New York, 12 September 1956

I have the honour to refer to my communication No. 110/PR of 17 February 1956 (document A/3118 of 21 February 1956) asking for the inscription of an item entitled "The question of Antarctica" on the agenda of the eleventh session of the General Assembly. On instructions from the Government of India I would request you kindly to alter the title of the item from that stated above to:

"THE PEACEFUL UTILIZATION OF ANTARCTICA".

(Signed) Arthur S. LALL
Permanent Representative
of India to the United Nations

Figure 1. A letter from Sh. Arthur S Lal, Permanent Representative of India to the United Nations dated 12 Sept. 1956 (Nagar et. al, 2023)

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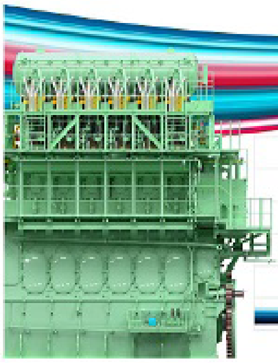

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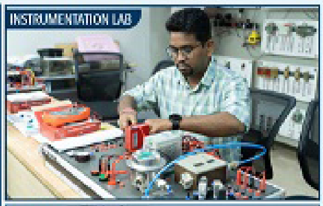

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3. Early participation of India in Antarctica

India's early Antarctic exploration began in the 1960s through individual participation. A 30-year-old Indian meteorologist, Lieutenant Ram Charan, joined the Australian Antarctic Research Expedition, while Dr. Giriraj Singh Sirohi, a biologist, participated in the U.S. Antarctic Research Program. Dr. Sirohi's 100-day stint enduring the harsh sub-zero conditions at McMurdo Station during 1960–61 earned him the rare honour of having "Sirohi Point" (83°57′S, 170°6′E) named after him, in recognition of his contributions to plant physiology.

To support its research endeavours, India established its first year-round Antarctic research station, Dakshin Gangotri, in 1983–84. This station was later succeeded by Maitri, a more advanced facility, which became operational in 1989

In the early 1970s, Parmjit Singh Sehra from the Physical Research Laboratory joined the 17th Soviet Antarctic Expedition under the Indo-Soviet agreement to study the upper atmosphere, becoming the first Indian to circumnavigate the Antarctic Ocean. These early efforts reflected India's growing interest in polar science and laid the groundwork for its future independent ventures.

4. India's Tryst in Antarctica

India's rendezvous with Antarctica is nothing short of a suspenseful story, akin to a secret mission. The Government of India's covert operation, named 'Dakshin Gangotri,' was launched under the guidance of then Honourable Prime Minister Mrs Indira Gandhi, and was largely kept under wraps from the public eye. **The first Indian Scientific Expedition to Antarctica was launched in 1981, with a 21-member team aboard the chartered Norwegian vessel *Polar Circle*, under the leadership of Dr. S. Z. Qasim.** Since its initial entry into Antarctic exploration, India has emerged as a key player in the international Antarctic scientific community.

To support its research endeavours, India established its first year-round Antarctic research station, Dakshin Gangotri, in 1983–84. This station was later succeeded by Maitri, a more advanced facility, which became operational in 1989. Around the same time, to consolidate and enhance the gains from various Antarctic expeditions, the Antarctic Study Centre started operating from Vasco, Goa, in 1988. On 5th April 2000, it was dedicated to the nation with its new name as the *National Centre for Antarctic and Ocean Research (NCAOR)* by Dr. Murli Manohar Joshi, the then Minister of Ocean Development. In 2018, the NCAOR rechristened as National Centre for Polar and Ocean Research (NCPOR) reflecting its tripolar activities.

India acceded to the Antarctic Treaty in 1983, becoming the first Asian nation (besides Japan, one of the original signatories of the Treaty) to attain consultative status within the ATS

Further expanding its research capabilities, India inaugurated its third station, Bharati, in 2012, reinforcing its commitment to Antarctic science and exploration. To date, India has successfully launched 44 Indian Scientific Expeditions to Antarctica, with involvement from more than 120 research institutions, universities and organisations across India.

A few special expeditions stand out, including (i) The *Weddell Sea Expedition* (1989–1990), led by Dr. V. K. Raina, onboard the chartered small Norwegian icebreaker *Polarbjørn*; and (ii) The *South Pole Expedition* (2010–2011), where an eight-member Indian team led by Dr. Rasik Ravindra, former Director, NCPOR successfully conducted research to mark the centenary of Roald Amundsen's historic South Pole expedition and celebrate 30 years of India's presence in Antarctica.

5. India's Presence in Antarctic Affairs - Beyond Science

India has established a significant presence in Antarctica through sustained efforts at its year-round permanent stations, Maitri and Bharati, located in East Antarctica. The National Centre for Polar and Ocean Research (NCPOR, erstwhile NCAOR), under the Ministry of Earth Sciences, leads India's Antarctic endeavours, providing logistical support for researchers across India and addressing critical scientific and environmental challenges through both national and international collaborations.

India acceded to the Antarctic Treaty in 1983, becoming the first Asian nation (besides Japan, one of the original signatories of the Treaty) to attain consultative status within the ATS. Its membership in the Scientific Committee on Antarctic Research (SCAR) in 1984 further emphasised its commitment to Antarctic science, with leadership roles such as vice-chairmanship during 2008–2012 and 2018–2022.

To tackle logistical challenges in the extreme Antarctic environment, India has been a member of the Council of Managers of National Antarctic Programs (COMNAP) since its inception in 1988. India has held leadership positions, including vice-chair positions (2008–2011, 2017–2020), and since August 2024, serves as vice-chair of COMNAP's executive committee.

India's commitment to the conservation and sustainable management of Antarctic marine ecosystems is reflected in its full membership in the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) since 1986, during which India chaired the Commission from 1998–2000. In 1997, India ratified the Protocol on Environmental Protection to the Antarctic Treaty, reinforcing its dedication to preserving the continent's pristine environment.

In 2023, the Centre for Marine Living Resources and Ecology (CMLRE), Kochi, India, hosted the CCAMLR Working Group on Statistics, Assessment, and Modelling (WG-SAM-2023) meeting from June 26 to 30, 2023. Indian scientists, many of them from NCPOR, currently hold or have held leadership positions at various platforms, showcasing India's growing influence and leadership in Antarctic governance, management, and science.

Regionally, India is a key member of the Asian Forum for Polar Sciences (AFoPS), alongside China, Japan, South Korea, Malaysia, and Thailand. India chaired AFoPS in 2010 and 2012, and in October 2024, India was elected

ATCM-46 and CEP-26, May 20-30, Kerala, India

International Conference on Antarctic Research, Antarctica, January 2020

Figure 2. Glimpse of some major events hosted by India, highlighting its leadership in Antarctic governance and capacity building

Chair of AFoPS for a period of two years, further highlighting its leadership in polar science initiatives.

Through these sustained efforts, India continues to make significant contributions to Antarctic governance, scientific research, and environmental conservation, strengthening its role as a global stakeholder in the future of the Polar Regions.

India is expanding its Antarctic presence by identifying a potential site for its new research station, Maitri II, near the existing Maitri station

6. India's Initiatives in Capacity Building and Governance

India, through its sustained efforts and active role in scientific research, is enhancing its visibility in the international Antarctic community by taking initiatives toward capacity building. In a significant milestone, NCPOR, Goa, India, hosted the International Conference on Antarctic Research (ICAR) at Bharati, India's third research station in Antarctica, on January 17, 2020 (Figure 2). This event, held during the 39th Indian Scientific Expedition to Antarctica (ISEA), was a collaborative effort led by Indian and Russian Antarctic scientists. The conference brought together 50 scientists from India (Bharati), Australia (Davis), China (Zhongshan), and Russia (Progress) to share insights and foster international collaboration. Remarkably, this in-person gathering occurred during the challenging early months of 2020 amidst the COVID-19 pandemic, marking a unique achievement in advancing Antarctic research under extraordinary circumstances.

NCPOR has hosted several other notable international Antarctic conferences, including the XII International Symposium on Antarctic Earth Science (ISAES) from July 13–17, 2015, in Goa, which saw the participation of over 436 scientists from 40 countries. This symposium featured eleven plenary lectures and more than thirty sessions, including around 202 oral presentations and 234 poster presentations. Similarly, the 10th SCAR Open Science Conference (SCAR 2022), virtually hosted by NCPOR from August 1–10, 2022, saw participation from approximately 2,800 scientists from over 40 countries. The conference included 48 parallel sessions, five workshops, five satellite meetings, and 945 presentations, providing a platform for global collaboration in Antarctic research. Additionally, NCPOR hosted the SCAR Delegates Meeting in hybrid mode in Goa from September 4–7, 2022, further cementing its leadership in Antarctic scientific governance (Figure 2).

The National Conference on Polar Sciences (NCPS), established in 2017, is a biennial event organised by NCPOR on behalf of the Ministry of Earth Sciences, Government of India. This conference provides a unique platform for the Indian Polar research community to share experiences, discuss challenges, and work collaboratively to develop solutions. Over 250 researchers from across the country have participated in each of the three editions held so far (2017, 2019, and 2023), with participation increasing every year. This growing interest reflects the commitment and expanding role of Indian scientists in polar research, underscoring India's dedication to capacity building and fostering global (and regional) partnerships in the Antarctic domain.

Antarctic Treaty Consultative Meeting

India plays a significant role in Antarctic governance as a consultative party to the Antarctic Treaty System (ATS), actively contributing to policy development on resource management, logistics, tourism, and environmental protection. Demonstrating its commitment, India hosted the XXX Antarctic Treaty Consultative Meeting (ATCM) in Delhi in 2007, where the establishment of its third research station, Bharati, was approved. More recently, India successfully hosted the 46th Antarctic Treaty Consultative Meeting (ATCM-46) and the 26th Committee on Environmental Protection (CEP-26) in Kochi, Kerala, from May 20 to 30, 2024 **(Figure 2).** This event brought together over 400 delegates from 56 countries and featured key discussions on Antarctic governance, environmental protection, and tourism. Among the significant outcomes of the meeting was the approval of the proposal to develop Maitri II, showcasing India's forward-looking approach to its Antarctic endeavours. Notably, India and Japan are the only Asian nations to have hosted the ATCM twice (https://www.ats.aq), underscoring India's leadership and growing influence in Antarctic matters.

7. India's role in Antarctic geopolitics

India plays a prominent role in the geopolitical landscape of Antarctica, leveraging its consultative status within the Antarctic Treaty System (ATS). Of the 59 signatories to the ATS, only 29 hold consultative status with veto power, including four Asian countries: India, China, Japan, and South Korea (ROK). Among 12 Asian countries that have acceded to the ATS, India stands out for its active contributions to scientific research and governance.

India is expanding its Antarctic presence by identifying a potential site for its new research station, Maitri II, near the existing Maitri station. Announced during the 46th ATCM, this station is expected to become operational by 2029, enhancing India's research capabilities in Eastern Antarctica. The existing Maitri station, operational since 1988-89, continues to support expeditions and international projects such as MADICE (Mass balance, dynamics, and climate of the Central Dronning Maud

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Land Coast, East Antarctica), SWIHA (Sea ice and westerly winds during the Holocene in coastal Antarctica), MARA (A moveable atmospheric radar for Antarctica), and SENS (Sub shelf Exploration of Nivl ice Shelf). Maitri's strategic location further strengthens its role in providing both scientific and logistical support to national and international research initiatives.

> *Through research stations, Dakshin Gangotri, Maitri, Bharati, and plans for Maitri II, India has established robust infrastructure supporting studies on Antarctic climate systems, geological processes, and polar-tropical teleconnections*

To reinforce its commitment to Antarctic governance, India enacted the Indian Antarctic Act, 2022, formalising regulations for activities on the continent and aligning with international frameworks. This legislative step underscores India's dedication to maintaining Antarctica as a zone for peace and scientific research. Globally, India's consistent contributions to Antarctic science and governance have been widely recognised, cementing its position as a significant stakeholder in polar affairs.

8. Challenges in the science backed geopolitics

Antarctica, often described as a realm where "science is the currency," faces mounting challenges as climate change and geopolitical interests intersect in this resource-rich yet fragile continent. While the Antarctic Treaty prohibits exploitation, scientific exploration has revealed the presence of valuable resources like petroleum and minerals. These discoveries, while ostensibly for research, often align with national interests, raising concerns about future geopolitical motivations.

China's expanding presence in Antarctica exemplifies these dynamics. Between 1985 and 2024, China established five stations, including Taishan, Zhongshan, and Kunlun in East Antarctica, Great Wall Station on King George Island, and the newly inaugurated Qinling Station on Inexpressible Island near the Ross Sea. The strategic location of Qinling Station, close to U.S. and Australian facilities has drawn attention, particularly given China's increasing investment in polar infrastructure, including two operational icebreakers and plans for further expansion.

Antarctic governance, which relies on international cooperation and consensus, is increasingly strained by geopolitical undercurrents. Decision-making in the Antarctic Treaty Consultative Meetings (ATCM) is sometimes delayed as nations prioritise their geopolitical interests. A notable instance is the failure to reach consensus on granting the Emperor Penguin "Specially Protected Species" status, a proposal by the United States that met resistance from countries concerned about potential restrictions on their activities. Similarly, efforts to establish Marine Protected Areas (MPAs) are met with opposition from nations fearing these measures might limit their regional influence or economic opportunities.

These tensions underscore the complex interplay between scientific research, conservation and national interests in Antarctica, where the continent's unique status as a global common is increasingly tested by the subtle but persistent influence of geopolitics.

9. Will the Antarctic Treaty expire in 2048?

The question of whether the Antarctic Treaty will expire in 2048 often arises in discussions about the future of activities in Antarctica, particularly in the context of geopolitics. This belief, however, is a common misconception and is factually incorrect. The Antarctic Treaty has no expiration date. What does change after 2048 is the possibility for any consultative party or group of parties to call for a review conference to assess the operations of the protocol. Such a review could potentially open discussions about the continent's economic resources, a prospect that raises concerns about the exploitation of Antarctica's vast but fragile environment. It is important to note, however, that any modification or enforcement of the protocol requires the approval of three-quarters of the consultative parties present at the time of the protocol's adoption. Additionally, such changes would need the backing of a majority of the current consultative parties. Given the current climate of conflicting geopolitical interests, achieving the necessary consensus for any modifications would be challenging unless nations can find common or mutually beneficial grounds for agreement (Sharma, 2024). This safeguard underscores the enduring strength of the Antarctic Treaty in promoting peace and scientific cooperation despite emerging pressures.

10.Conclusions

India's Antarctic program underscores its commitment to advancing global scientific understanding and maintaining the governance and environmental integrity of this vital region. Over the years, India has transformed from an observer to an influential stakeholder, balancing scientific exploration, environmental conservation, and geopolitical interests. Through research stations, Dakshin Gangotri, Maitri, Bharati, and plans for Maitri II, India has established robust infrastructure supporting studies on Antarctic climate systems, geological processes, and polar-tropical teleconnections. This research has contributed significantly to global knowledge, particularly regarding climate variability and its impacts on South Asia.

India holds consultative status under the Antarctic Treaty System and has leadership roles in SCAR, CCAMLR, and AFoPS, fostering international collaboration. Hosting Antarctic Treaty Consultative Meetings and enacting the Indian Antarctic Act 2022 highlight India's contributions to governance and environmental protection.

Challenges include the geopolitical landscape, climate change, and interests in Antarctic resources. Addressing these, and additionally keeping in mind the increasing activities of other countries such as China, it is important for India to enhance its presence through an increase in infrastructure, collaborations in scientific activities or logistic activities, and policy-making decisions.

Towards enhancing infrastructure, it's high time that India should expedite the long pending procuring or building of Ice-class vessels and think of more such vessels in the near future for bipolar operations. Recently, NCPOR-MoES initiated building deep ocean research vessels through M/s Garden Reach Shipbuilders & Engineers (GRSE) Limited, Kolkata. India's continued focus on scientific research, governance, and infrastructure will shape its engagement with Antarctica and contribute to global efforts in sustainable exploration.

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About the Authors

Dr. Swati Nagar is a Project Scientist II in Outreach and Cooperation at the National Centre for Polar and Ocean Research (NCPOR) in Goa, India. She contributes to NCPOR's mission of bridging science and society as a part of their Scientific Social Responsibility.

Email: swatinagar@ncpor.res.in

Dr. Avinash Kumar, Scientist E and Scientist-In-Charge, Outreach and Cooperation at NCPOR, Goa, leads polar and ocean outreach activities while conducting advanced research on sea ice and climate dynamics in the Polar Regions using remote sensing and field observations. His significant contributions include uncovering mechanisms of Arctic and Antarctic sea ice variability, forecasting ice shelf positions, and estimating ice change rates via satellite data. With over 40 international publications and recognition through numerous accolades, he has served as managing guest editor for Polar Science. Dr. Kumar's leadership in organizing scientific events has been pivotal in advancing India's polar research program.

Email: avinash@ncpor.res.in

Dr. Rahul Mohan is a distinguished geologist specialising in polar micropaleontology. He holds a Ph.D. from Banaras Hindu University and is currently Group Director at the National Centre for Polar and Ocean Research (NCPOR). His research focuses on foraminifera, coccolithophores and marine diatoms for climate reconstruction, spanning Antarctic lakes, Arctic processes and sea ice dynamics. With over 125 publications, he has mentored seven Ph.D. scholars. Dr. Mohan serves as India's Alternate Delegate to SCAR and National Coordinator for AFoPS. Honoured with numerous awards, including the National Geoscience Award 2023, he has significantly advanced polar research, enhancing the understanding of past climate variations and their global implications.

Email: rahulmohan@ncpor.res.in

India's Arctic Mooring: Understanding Role of Arctic in Global Climate Dynamics

M Arul Muthiah, B KesavaKumar, T Divya David, KJossia Joseph, K Thirumurugan, C.Muthukumar

Introduction

The recent advances made in observational technologies in the fields of sensors, platforms and real-time communication provide unprecedented capability to monitor the changes and understand the role of the oceans and the Polar Regions in climate change. Since the start of the ocean observations program in 1997, a number of data buoys were deployed by the Ocean Observation Systems (OOS) group of Ministry of Earth Sciences-National Institute of Ocean Technology (MoES-NIOT) at selected locations in the Northern Indian Ocean (Arabian Sea and the Bay of Bengal) primarily to monitor meteorological and oceanographic parameters in near real-time **(Figure.1).**

The OMNI (Ocean moored buoy network in the Northern Indian Ocean) buoy systems deployed by OOS since 1997 are the state-of-the-art deep-ocean moored buoy system equipped with sensors for measurement of atmospheric, surface and sub-surface parameters up to a depth of 500m **(Figure.2).** The meteorological sensors are mounted at the height of 3m. The Conductivity, Temperature and Depth (CTD) sensors are mounted at various depths, water current speed direction sensor for measurement near surface and profile of data upto 200m. The acoustic release enables to retrieve the mooring and data buoy for maintenance and redeployment purposes.

The Tsunami Buoys Network developed and maintained by OOS since 2005 serves as key input for the Indian

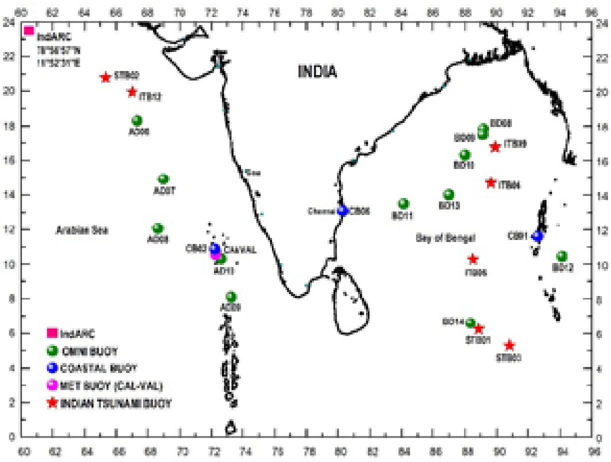

Figure.1. Moored data buoys deployed & operated by NIOT

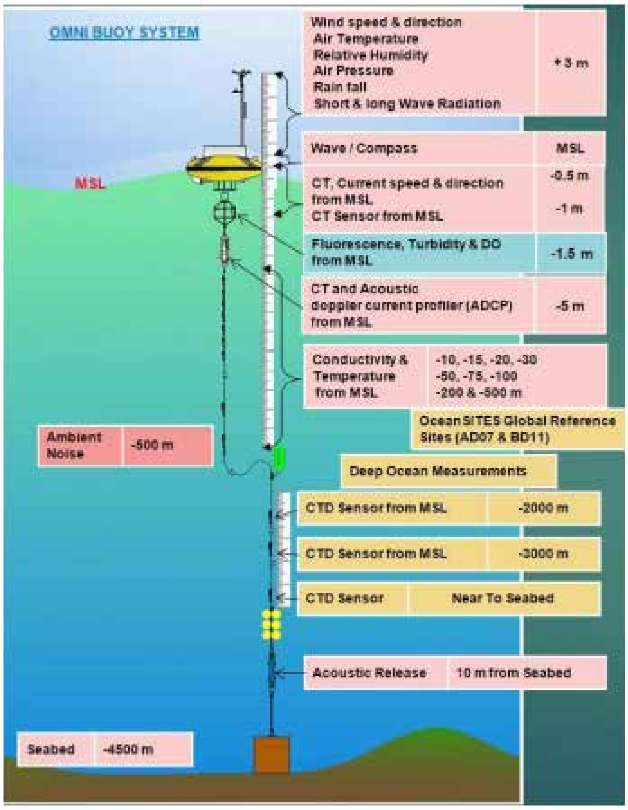

Figure.2. Configuration of the OMNI buoy

Tsunami Early Warning System (ITEWS). The principle of detecting a tsunami is based on monitoring and analysing changes in the water level using seabed-located pressure variation detectors that trigger an alarm by sending a warning message to an acoustic receiver mounted in the moored surface buoy. The surface buoy, in turn, relays the message through a satellite data link to respective control centre that can issue a warning to coastal communities **(Figure.3).**

Hitherto, **NIOT buoys have clocked >2.2 million hours at sea, and the data collected by them have been widely used both by operational and scientific communities** to understand and predict the observed variability of monsoons, cyclones and short-term climate change through an improved approach of air–sea interaction processes.

The Tsunami Buoys Network developed and maintained by OOS since 2005 serves as key input for the Indian Tsunami Early Warning System (ITEWS)

Importance of monitoring the Arctic & establishment of India-Arctic (IndARC) mooring

The Arctic has been warming ~ 4 times faster than the global average since 1979 due to various factors which creates scientific interest for many countries to observe this region.

The Arctic is a challenging region for ocean monitoring, with sparse observations beyond the surface due to limited satellite coverage and frequent cloud cover. Ship-based observations are also limited in the region due to difficulty in accessibility and such data are restricted to both time and space. In such an environment, moorings offer a promising means to measure ocean parameters at greater depths, and developing such systems for the harsh Arctic environment requires specialized expertise. **A critical knowledge gap in the region stems from the lack of long-term, multidisciplinary data that spans both summer and ice-covered winter seasons.** Further, variability in Arctic region has teleconnections to Indian summer monsoon rainfall.

To address the need for continuous monitoring, NCPOR has been collecting data in Kongsfjorden since 2011 during only summer season expeditions as part of a long-term monitoring project. India's establishment of its first multi-sensor moored observatory in the Kongsfjorden fjord marks a significant milestone in Polar research and showcases the capabilities of MoES. This mooring provides an innovative solution to the long-standing challenges faced by Indian researchers, especially the difficulty of measuring data in the harsh Arctic cold/ winter seasons. The observatory addresses critical gaps in understanding the fjord's interactions with surrounding

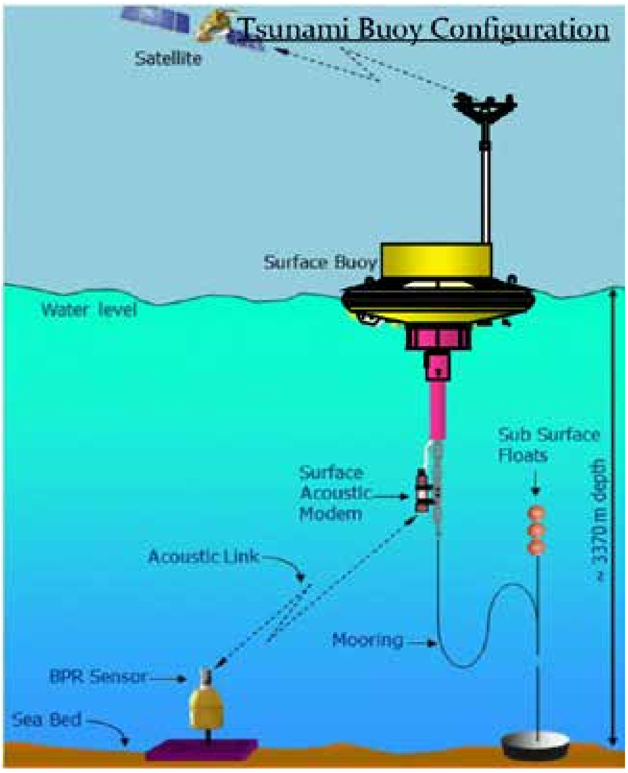

Figure.3. Principle of Tsunami buoy system

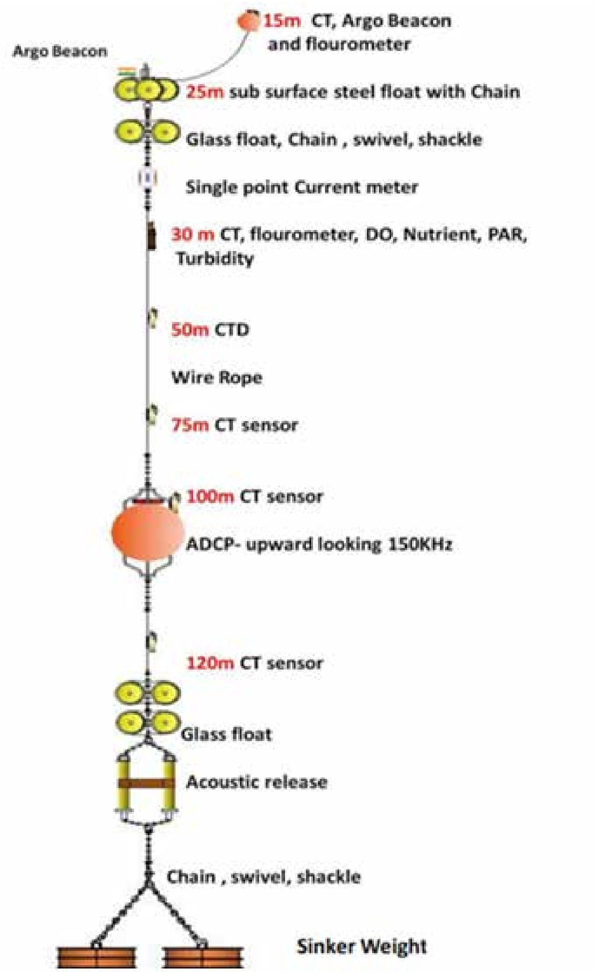

Figure.4. IndARC mooring schematics

shelf waters and the deep sea. These insights are vital for studying the fjord's response to climate variability across different temporal scales. This initiative strengthens India's role in studying polar ecosystems and their responses to changing climate conditions, fostering collaboration in international scientific research.

A major milestone in India's scientific endeavours in the Arctic region was achieved on the 23rd July, 2014 when a **team of scientists from the MoES-NIOT and MoES-National Centre for Polar and Ocean Research (NCPOR) successfully deployed moored observatory called IndARC, the country's first Indian Arctic multi-sensor moored observatory** in the Kongsfjorden an Arctic fjord, roughly half way between Norway and the North Pole. The observatory is presently anchored (78°57´N, 12°01´E), about 1000 km away from the North Pole at a depth of 192m and has an array of ten state-of-the-art oceanographic sensors strategically positioned at discrete depths in the water column. Various technological efforts were taken in order to ensure long term uninterrupted operation of mooring at sub-zero temperatures in the Arctic region. The IndARC provides vital data for Indian climate researchers and also contributing to the international efforts in understanding global climate dynamics due to Arctic variability.

Ship-based observations are also limited in the region due to difficulty in accessibility and such data are restricted to both time and space

Design and deployment of IndARC mooring

The IndARC moored observatory was designed to measure oceanographic parameters at different depths. The mooring diagram is shown in **Figure.4.** A significant challenge was the presence of ice cover, floating ice, and drifting icebergs with drafts exceeding 20m, which made conventional surface measurement methods unfeasible. To address this, a weak link was introduced at a depth of 25m, separating the surface segment of the mooring from the deeper portion. If the mooring experienced heavy loads from icebergs, the weak link would break, preserving the main mooring. Floats above the weak link would bring the detached section to the surface, and a beacon on the top float would transmit a signal, enabling remote tracking and retrieval. The IndARC enables year-round, continuous monitoring of water temperature, salinity, current, dissolved oxygen, photosynthetically active radiation (PAR), fluorescence, turbidity and nitrate.

Figure.5. Qualification of sensors in environmental chamber

Testing of sensors

In order to ensure reliable performance of the sensors and subcomponents in the harsh environment, testing of all of the sensors and other accessories at low temperature was carried out in the environmental chamber facility at NIOT. The environmental chamber can test components in the temperature range of -45°C to +180°C and a humidity range of 10% to 98% relative humidity. The components and sensors were monitored during low-temperature conditions **(Figure.5).**

The O-rings were subjected to very low temperature of -20°C and tested. The float with a mechanical fixture for

Figure.6. Deployment of IndARC from Polar ships

holding the satellite telemetry beacon was fabricated in-house and tested for stability and upright verticality of the beacon at the Acoustic Test Facility (ATF) Tank at NIOT. The instruments selected for IndARC have been programmed to work continuously for two years to record data. The power source requirements have been specially selected so that data collection is continuous without interruption. The sensor sampling depth is duly selected based on the vertical distribution of different water masses in the region.

The IndARC moored observatory was designed to measure oceanographic parameters at different depths

atmospheric conditions and higher temperature at deeper waters.

The Arctic lensing effect refers to the bending of light rays caused by variations in water density due to temperature and salinity gradients in the Arctic Ocean. The melting ice introduces freshwater into the Arctic Ocean, enhancing stratification and contributing to the lensing effect. This process can increase the Dissolved Oxygen (DO) in surface waters due to enhanced contact with the atmosphere and lower salinity, which in turn increases the oxygen solubility **(Figure.5).**

Deployment of mooring

The deployment of the mooring are facilitated by NCPOR based on the International collaborations with the Norwegian counterparts and before planning the deployment, extensive discussions with them will be held to ensure the completion of deployment within the stipulated time. **Figure.6** shows the photograph of deployment and research vessel.

Interesting phenomenon noticed from the data

The temperature data recorded from the sensors mounted at 22 m and 140 m depth is shown in **Figure.7.** In tropical waters, surface water and water at shallower depth will have relatively more temperature when compared with deeper waters. In contrary, the Arctic Ocean experiences a phenomenon called "***seasonal temperature inversion"***. In this the top layer of the sea water will have reduced temperature due to cold

Ocean Warming & Atlantification inferred from Kongsfjorden

The time-series water temperature and salinity **(Figure.9)** recorded by the SBE37 Conductivity-Temperature-Depth (CTD) microcat sensors in the mooring at the upper (31 m) and lower (140 m) common nominal observation depths over the deployment-retrieval periods from 2014 to 2020. Both temperature and salinity showed strong seasonality embedded with intra-seasonal variations. The year-to-year variations were also evident with larger variations found in salinity than in temperature. Highest temperatures at 31m were observed during Jul-Aug. Highest temperatures at 140m were found during Oct-Nov, the same time, when the upper layer started cooling down leading to temperature inversions.

This lower layer heating and high salinity during Oct-Nov even in the presence of surface layer cooling and freshening indicated the continued warm-saline Atlantic water (AW) intrusions in deeper Kongsfjorden supported by the inward flows indicated by the measured currents. The episodic winter intrusions of the AW were also seen in 2016, 2017, and 2018 which showed increasing warm water intrusions to the fjord during cold winters in recent times which is one of the major factors responsible for sea ice reduction and increase in subglacial melting, a process crucial to the ongoing changes in the entire Arctic Ocean realm. This external supply of ocean heat by the AW results in the overall increase in the Kongsfjorden water

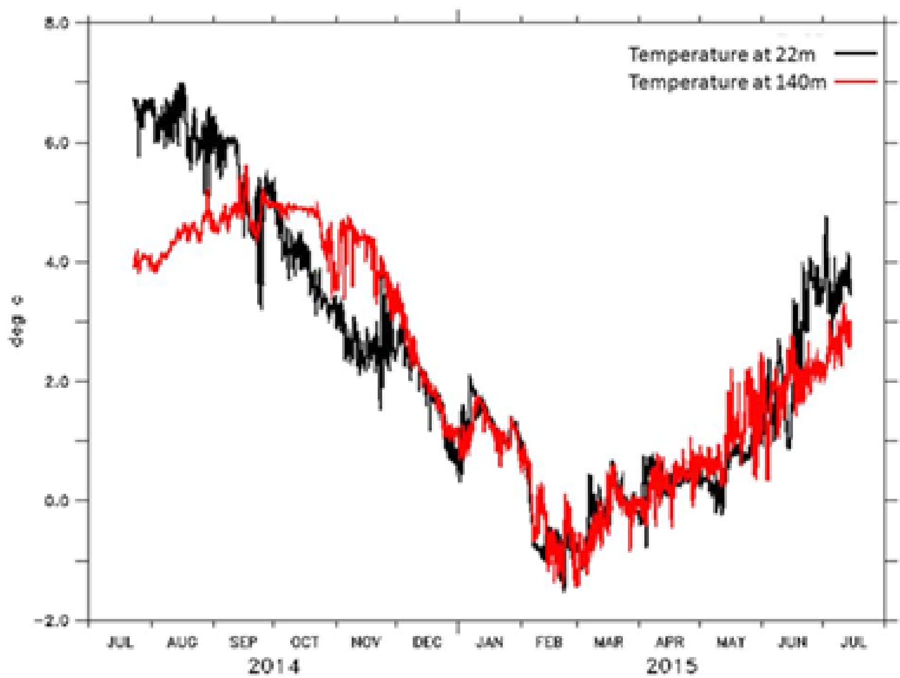

Figure.7. Temperature inversion

temperature over the years. On the other hand, salinity did not show any considerable increase due to the strong melting-induced surface freshening that influenced water column stratification, and further implicate the fjord biogeochemistry. Thus **the findings from the sensitive Kongsfjorden reflects changes in the Arctic climate and prove it to be an ideal location to continue the monitoring to address more scientifically relevant questions** and capture ongoing complex climate scale signals.

In this the top layer of the sea water will have reduced temperature due to cold atmospheric conditions and higher temperature at deeper waters

Conclusion

The successful deployment of IndARC, India's first multi-sensor moored observatory in the Kongsfjorden, marks a significant milestone in Arctic research and ocean observation. Despite the challenges posed by harsh environmental conditions, including ice cover and drifting icebergs, innovative engineering solutions ensured reliable data collection over extended periods. The observatory's ability to measure critical ocean parameters such as salinity, temperature, dissolved oxygen, and currents has provided invaluable insights into the Arctic's complex dynamics. The IndARC not only highlights India's growing technological and scientific capabilities in Polar research but also contributes significantly to the global understanding of Arctic systems and their linkage to broader climate phenomena. As an appreciation of the efforts, OOS scientists received the National Geo-science Award from Honourable President of India for the establishment of country's first mooring in Arctic region during the year 2016.

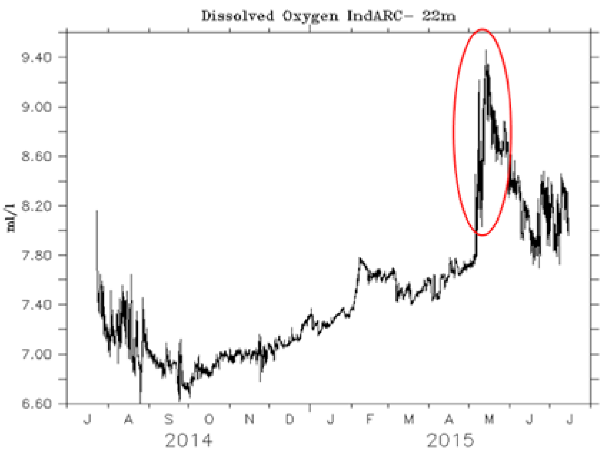

Figure.8. Observed increase in Dissolved Oxygen value in Arctic

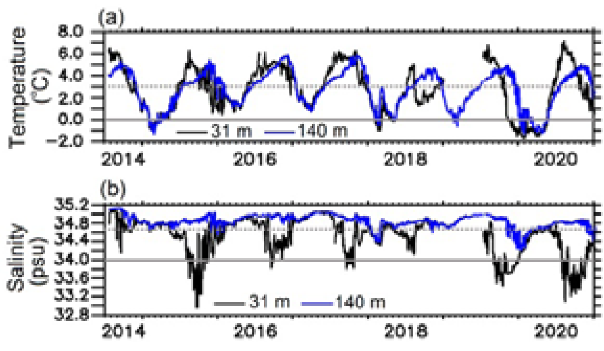

Figure 9: Hourly time-series of Kongsfjorden water (a) temperature and (b) salinity from the CTD sensors in the IndARC mooring at the upper and lower observation depths of 31 m (black line) and 140 m (blue line) over the deployment-retrievals from 2014 to 2020.

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About the Authors

M. Arul Muthiah, Scientist-F and Head of the Ocean Observation Systems Group at NIOT, Chennai, has 20+ years of experience in designing, developing and maintaining offshore autonomous data acquisition platforms. He led the indigenous development of a moored buoy data acquisition system transmitting 200+ real-time parameters. A key contributor to India's first underwater ocean observatory near the North Pole, he received the National Geosciences Award (2016) from Honourable President of India and the Meritorious Scientist Award (2008). Holding a B.E. (Electrical) and M.E. (VLSI), he has authored 28+ publications, holds five patents, and is an active IEEE and MTS India member.

Email: arul@niot.res.in, arulmuthiah.niot@gov.in

Thirumurugan K, Scientist E at NIOT, Chennai, specializes in ocean observation platforms, mooring systems, and underwater vehicles. He holds a B.E. in Mechanical Engineering from Bharathidasan University (2001) and an M.E. in Engineering Design from Anna University (2004) and is pursuing a Ph.D. He has deployed and retrieved mooring systems for cyclone and tsunami warning buoy systems, including the Indian Arctic mooring in 2019. He received the Scientific/Technological Excellence Award (2022) and the Er. M.P. Baya National Award (2024) for his contributions to mechanical engineering and ocean research. He has extensive experience aboard Indian and foreign research vessels.

Email: thirumurugan@niot.res.in

Muthukumar C has been serving as a Scientific Officer at the Ocean Observation Group of the National Institute of Ocean Technology, Chennai, since 2007. He holds a Diploma and Bachelor's degree in Mechanical Engineering. With extensive experience in mechanical assembly, integration, testing, deployment, and retrieval of moored

ocean observation platforms at both coastal and deep-sea locations, he has sailed on both Indian and foreign research vessels. Muthukumar has also participated in four Indian Arctic Expeditions, contributing to the maintenance of Indian subsurface moorings in the Kongsfjorden Arctic region. In recognition of his exceptional work, he was awarded the National Award for Innovation in Integrated Marine Surveillance Systems by the National Research and Development Corporation (NRDC) in 2015.

Email: cmuthu@niot.res.in

B. Kesavakumar, Scientist E at Ocean Observation Systems group at NIOT, specializes in offshore moored platforms, including tsunami and moored data buoy systems. With 12+ years of experience, he has led oceanographic buoy deployments as Chief Scientist on Indian and international research vessels in coastal, deep ocean and polar regions. He was involved in the design and deployment of India's first mooring in the Arctic. His work focuses on power optimization, satellite telemetry, and data acquisition for ocean observation. A recipient of the National Geoscience Award from Honourable President of India and IEI's Outstanding Young Engineer Award (2023), he has published 8+ journal articles, 14 conference papers, and filed 4 patents. He holds a B.E. in Electrical & Electronics and is pursuing his M.S. and Ph.D. at IIT Madras.

Email: kesavakumar@niot.res.in

Divya David T is a physical oceanographer, currently working as Scientist-E in the Arctic Ocean Atmosphere Sciences Group in the National Center for Polar and Ocean Research, Ministry of Earth Sciences, Goa. She is the lead investigator of the project 'Long term monitoring of Kongsfjorden-Krossfjorden for climate change studies' implemented in the Arctic region by India since 2014 under which the first Indian subsurface mooring 'IndARC' has been deployed for the ocean measurements even during the not so inaccessible polar winters. She is also associated with the logistical facilitation of the yearly Indian Arctic expeditions by NCPOR. With more than 15 years of research experience, she has 27 research publications in peer-reviewed international journals.

Email: divya@ncpor.res.in

Dr. K. Jossia Joseph, Scientist F at NIOT, specializes in physical oceanography. She holds a master's and doctorate in marine science from CUSAT, Kerala. She leads data analysis and applications under NIOT's Ocean Observation program, developing a patented algorithm for high-frequency real-time cyclone data transmission, recognized by WMO, NOAA, and IMD. She has participated in multiple research cruises, including Indo-US expeditions, and published 30+ peer-reviewed papers. Awarded the IVLP by the U.S. Department of State (2018), she also serves as Joint Secretary of the Ocean Society of India, supporting national oceanographic initiatives and academic collaborations.

Email: jossiaj@niot.res.in

Investigating the Influence of Post-Filtration Water Usage on RO Membrane Performance at Bharati, East Antarctica

Rahul Kumar, Vivek Kumar, N.S. Magesh, Ariz Ahmad, Jenson V. George, Anand K. Singh, Yogesh Ray, Shailendra Saini

Abstract

Research stations in polar regions, encounter unique infrastructural and technological difficulties because of the extreme environmental conditions. A key factor in maintaining operations is the effective management of freshwater supply, primarily through the use of Reverse Osmosis (RO) technology. RO systems, as the main method for converting seawater into drinkable water, depend on multi-stage filtration processes. The present study examines the performance of RO membrane filters at the Bharati Research Base over a 10-year period (2014-2023), analysing the replacement patterns of seawater intake filters, feed water intake filters, pre-filters, and absolute membrane filters. Although the seawater intake conditions remained stable, with temperatures consistently near -1.8°C and a salinity of 34 PSU, no distinct trends or seasonal patterns in filter replacements were identified. However, water demand peaks between December and February, leading to more frequent filter replacements. The higher consumption rate accelerates particle build-up, especially in finer filters like the 5 μm membranes. The paper emphasises that the increase in water consumption from an average of 900 KL to over 1100 KL necessitates more frequent maintenance to ensure system efficiency. Gaining insight into water usage patterns and environmental stability is essential for optimising the performance of filtration systems in polar environments. These insights offer valuable guidance for enhancing the sustainability of water management practices in extreme conditions, further advancing the broader field of polar infrastructure research.

Keywords: Polar infrastructure, Desalination plant, Extreme environmental conditions, Technological challenges, Antarctica

1. Introduction

Antarctica is one of the most extreme environments on planet earth, demanding sophisticated technology and infrastructure to support activities at research stations. Recognised as a peaceful area dedicated to scientific exploration under the Antarctic Treaty (1959), the continent's distinctive and delicate ecosystem necessitates thoughtful management and preservation. Research stations in Antarctica rely on dedicated systems for power generation, water supply, and waste management, where major difficulties were encounter due to the harsh weather, freezing temperatures, and remoteness. Due to the scarcity of freshwater sources, the majority of Antarctic stations depend on desalination systems or lake water for their water supply (Pekin, 2012; Zhang et al., 2016). Bharati, the third research base of India, situated in the Larsemann Hills of East Antarctica, heavily depends on reverse osmosis (RO) technology to desalinate seawater, supplying vital freshwater for drinking, scientific work, and day-to-day operations.

The vertical distribution of seawater temperature and salinity has been thoroughly investigated using Conductivity, Temperature, and Depth (CTD) stations in the Southern Ocean, including the area near the Bharati Research Base (Anilkumar et al., 2021; Deshmukh et al., 2024; George and Anilkumar, 2022; Noronha-D'Mello et al., 2023) The feedwater for Bharati's desalination system is sourced from seawater at a depth of 25 meters, where CTD measurements indicate stable temperatures of approximately -1.8°C and salinity levels of 34 PSU (Barnes et al., 2006; Clarke, 1988; Sewell and Jury, 2011). Water treatment systems at Bharati, like those at other Antarctic stations, have been upgraded for improved efficiency, but challenges persist (Bharti et al., 2016). Research comparing wastewater treatment at Bharati to other stations has highlighted the significance of advanced technology and consistent maintenance (Kumar et al., 2024).

Assessing the performance of filtration systems in polar technology infrastructure is key to ensuring the long-term sustainability of Antarctic research stations. Maintaining a delicate balance between environmental conditions, filtration system design, and water usage patterns is crucial to the success of ongoing scientific missions in Antarctica and other regions. A decade-long data gathered from the Bharati Research Base serve as a vital case study for sustaining essential infrastructure in extreme environments, aiding scientific missions in one of the most demanding regions on Earth.

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This study explores the relationship between water demand, filtration stages, and stable environmental conditions, providing important insights for optimising desalination and filtration systems in polar regions. The analyses underscore the operational challenges encountered by water filtration systems at Antarctic stations, stressing the importance of proactive maintenance and system optimisation to ensure long-term sustainability. To date, no research has been conducted on RO membrane usage and filter replacement specifically in the Antarctic context, making this study a ground-breaking endeavour in tackling these unique challenges.

2. Materials and Methods

2.1 Study site and system overview

The study focuses on the desalination system at Bharati Research Base, which uses reverse osmosis (RO) membranes to convert seawater into potable water.

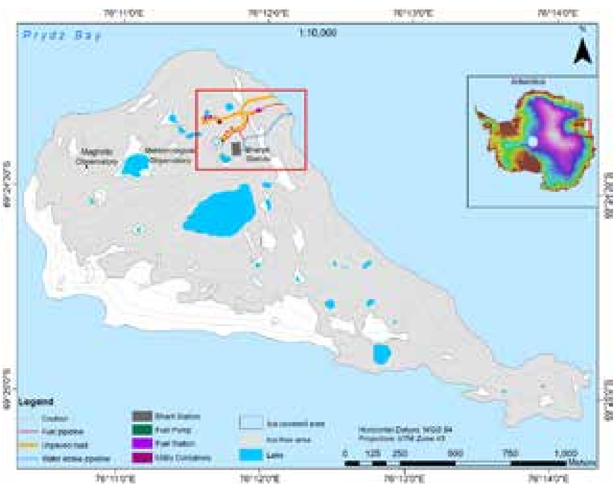

Figure 1: Detailed location of Bharati research bases in Antarctica showing water intake lines

The station relies on consistent water intake and filtration to supply freshwater for its operations. The base is located in the Larsemann Hills, East Antarctica, Bharati, the third permanent station of India located in Larsemann Hills, has all the modern research facilities and is equipped with a modern wastewater management system (Bharti et al., 2016; Kumar et al., 2024). Detailed location of the Bharati research base and water intake lines are shown in **Figure 1**.

2.2 Data and Analysis

The data spans a ten-year period (2014 to 2023), detailing filter changes and maintenance events for four key filtration components: Sea Water Intake (50 μm) Filters, Feed Water Intake (50 μm) Filters, Pre-filter Membrane (5 μm) and Absolute Membrane (5 μm) filters. These filters are part of a multi-stage process designed to purify seawater before desalination via the Reverse Osmosis (RO) system. Data were collected from December 2013 to April 2023, including membrane replacement dates, water quality parameters, and operational performance metrics of the RO system.

The analysis focuses on identifying patterns in membrane replacement frequency and performance, correlated with water quality and total water consumption. A time-series analysis is conducted to explore how membrane replacements align with environmental variables and water usage patterns.

The data was sourced from maintenance logs and operational records at the Bharati Research Base, detailing the frequency and circumstances of filter changes over the past decade. Each filter type's replacement schedule was documented alongside system performance and water usage during significant operational events. The intake water's temperature and salinity were consistently

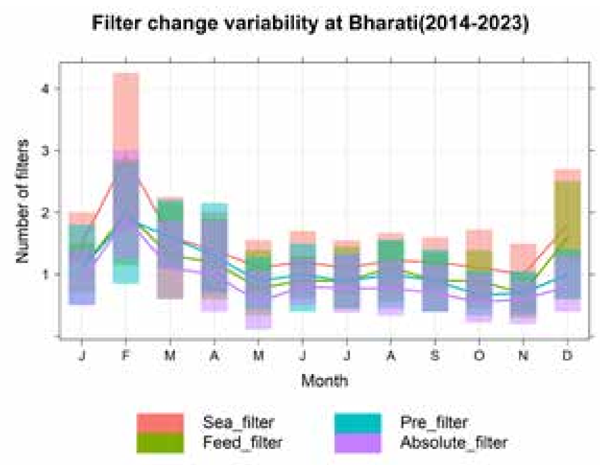

Figure 2: Yearly variations in filter usage at Bharati during 2014-2023

recorded using Conductivity, Temperature, Depth (CTD) instruments, showing stable readings with a mean of -1.8°C and 34 PSU, with minimal variation (-1.89 to -1.74°C and 34.03 to 34.41 PSU).

Filter replacement frequency was measured based on accumulated water throughput, providing insights into the relationship between water demand and filter performance. Data on operational anomalies, such as spikes in water demand or system downtime, were also logged to identify potential causes of variability in filter changes. Time-series analysis was conducted using R software to interpret the findings.

The analysis focuses on identifying patterns in membrane replacement frequency and performance, correlated with water quality and total water consumption

3 Results and Discussion

The discharge point of the wastewater is relatively close to the intake, and the need to control environmental discharges has gradually increased the salinity of the feed water to the RO plant, as it also serves as the receiving water for the RO concentrate (*Pekin, 2012*). However, despite this proximity, the discharge has not significantly deteriorated the feed water quality (*Kumar et al., 2024*).

3.1 Filter Replacement Trends

An initial review of the data indicates periods of increased membrane replacements during specific months, potentially linked to higher water usage at the station, although no clear linkable effect from seasonal glacial meltwater influx has been observed. We examined the frequency of filter replacements across the four types to identify any potential patterns over time. It was found that water demand surges when new expedition team members arrive in December and during the docking of ships at the Bharati station in January and February **(see Figure 2).** Despite the stable environmental conditions at the seawater intake point, individual filter trends suggested periodic spikes in filter changes. This implies that environmental factors—such as temperature and salinity—are not the primary drivers of filter wear.

The total number of filters used over the ten-year period, in descending order, were: Sea Water Intake

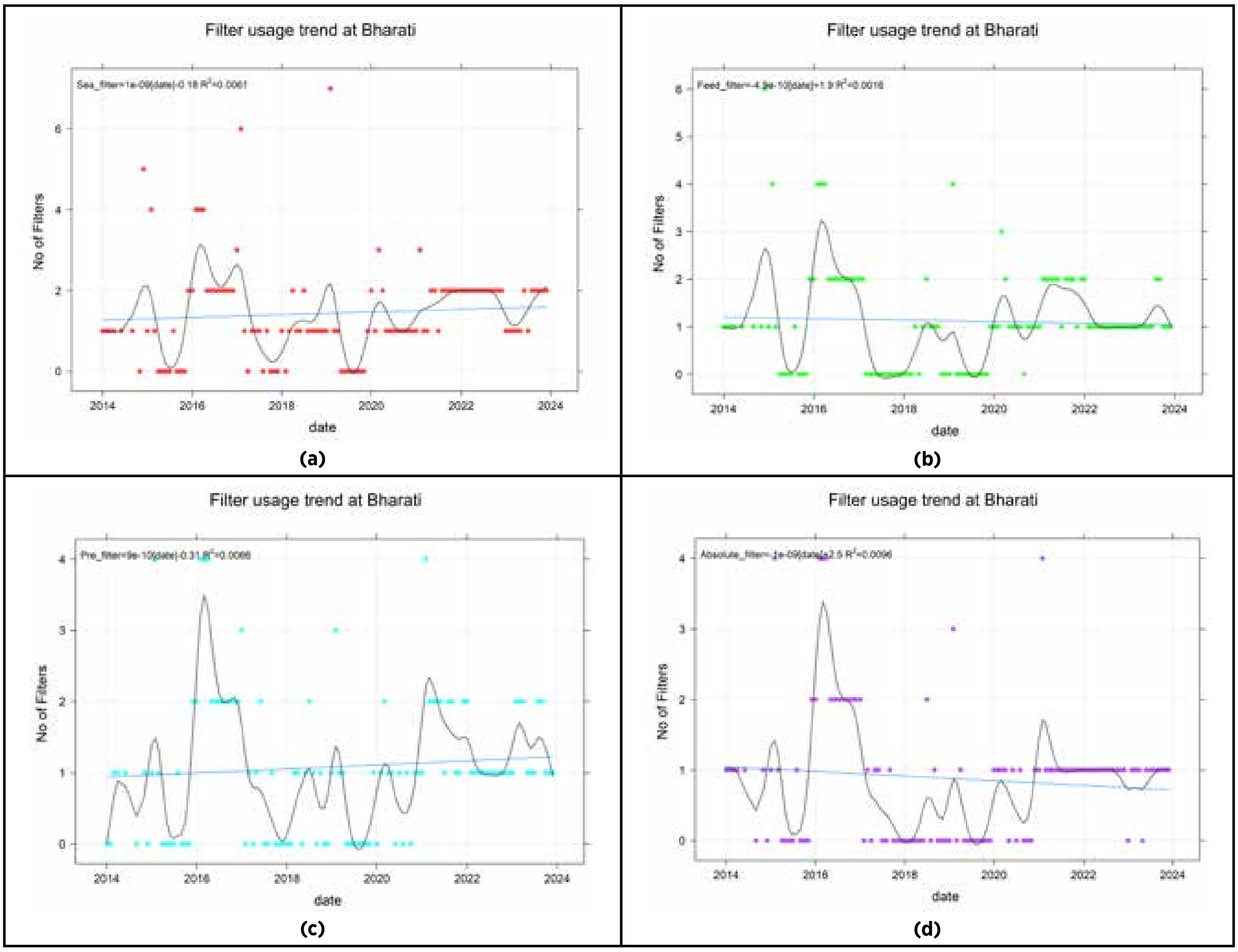

Figure 3: Filter change trend (a) Sea water intake filter (50 µm), (b) Feed water Intake filter (50 µm), (c) Pre-filter membrane (5 µm), (d) Absolute filter (5 µm)

Filter (167), Feed Water Intake Filter (130), Pre-filter Membrane (126), and Absolute Filter (102), corresponding to the filtration stages. While individual filters showed non-significant trends for both 50 µm and 5 µm filters, there was an increasing trend in the first stage of both 50 µm and 5 µm filters, and a decreasing trend in the second stage of both **(see Figures 3(a) to 3(d)).** A significant spike in filter replacements during 2016 points to improper filter usage during that year.

Statistical models revealed a significant relationship between water demand and filter longevity, showing that higher water throughput corresponds to a shorter operational lifespan for these fine filters

3.2 Impact of Water Usage

To assess the impact of water usage on filter lifespan, we correlated the filter replacement data with water demand records at the station. Our analysis indicates that changes in water usage—particularly increases in demand—led to more frequent filter replacements. This was especially evident for the Pre-filter for membrane (5 µm) and Absolute membrane (5 µm) filters, where higher flow rates through the system accelerated fouling and clogging. Statistical models revealed a significant relationship between water demand and filter longevity, showing that higher water throughput corresponds to a shorter operational lifespan for these fine filters.

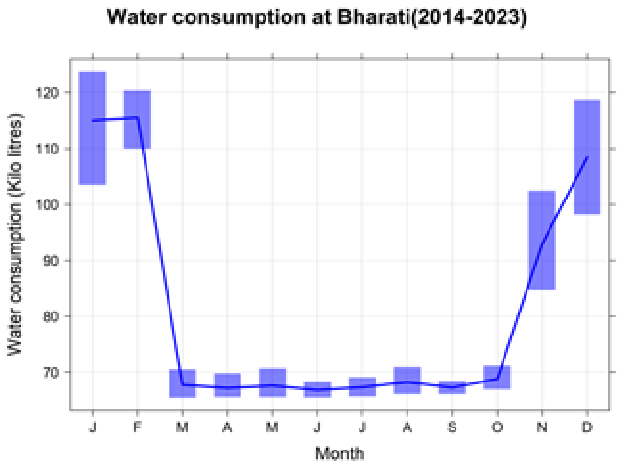

Figure 4: Water consumption pattern at Bharati from 2014-2023

The mean water consumption during the summer months (December to February) was 112 KL, reflecting the presence of more expedition members, while the mean consumption during the winter months (the remaining nine months) was 70.4 KL over the past 10 years. The analysis showed that fluctuations in water usage, particularly during summer **(see Figure. 4),** had a measurable impact on filter performance. High usage periods correlated with more frequent filter changes, especially for the finer filters used in pre-membrane and RO membrane filtration stages. This suggests that managing water demand and ensuring consistent usage patterns could extend filter lifespans.

Trends in water consumption **(see Figure. 5(a) and (b))** also revealed increasing demand, particularly in 2022 and 2023, with water usage soaring more than 20% compared to the previous years over the ten-year period. The system generally operates in a stable, controlled environment, with 2020 being the only exception, showing a dip to 925.3 KL due to the COVID-19 pandemic when the number of expedition members was reduced due to medical and logistical challenges (Table 1). Winter usage follows a similar pattern. This consistency allows for more predictable maintenance schedules and reduces the risk of unexpected filter failures, which is critical in such a remote and isolated location. Optimising filtered water consumption will help minimise unplanned maintenance and ensure long-term system reliability.

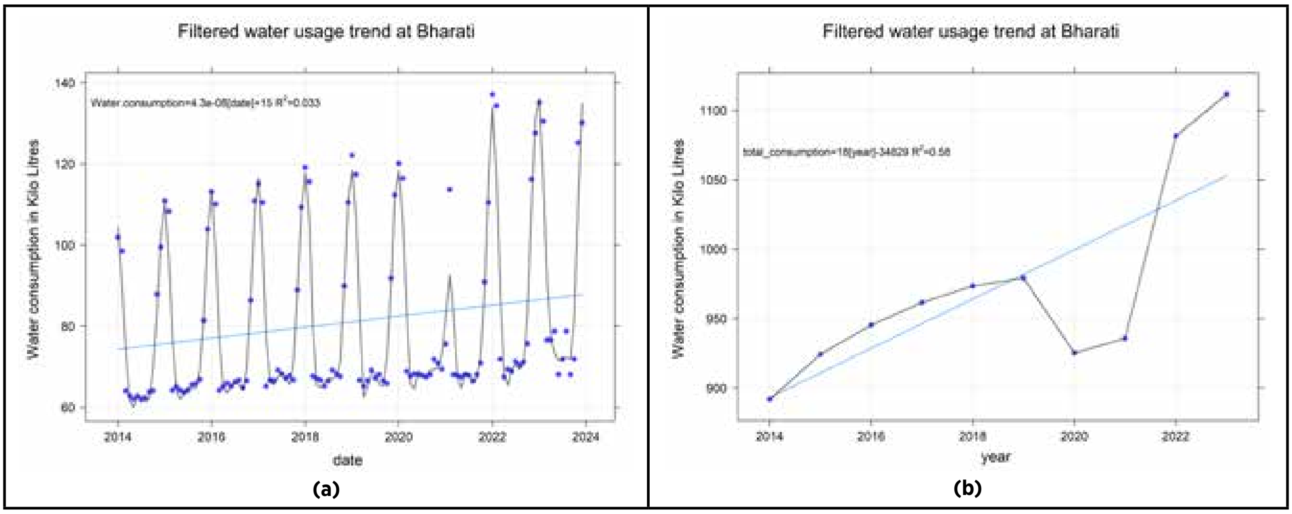

Figure 5: Water consumption trend(a) Monthly, (B) Yearly at Bharati from 2014-2023

3.3. Impact of Environmental Conditions on RO Membranes

In 1965, Littlepage demonstrated that in the shallow waters of southern McMurdo Sound, Ross Sea, the seasonal variability of sea temperature at a depth of 25 meters ranged from −1.99 to −1.41°C, with a standard deviation of only 0.11°C. This made it one of the most thermally stable near-surface environments on Earth. However, lower salinity levels and higher concentrations of suspended particles, including organic matter and silt, increase membrane fouling, leading to shorter operational lifespans and more frequent replacements. These replacements pose logistical and financial challenges in the remote polar environment.

RO membranes, primarily designed for saline water, struggle when exposed to organic matter and suspended particles, leading to fouling

RO membranes, primarily designed for saline water, struggle when exposed to organic matter and suspended particles, leading to fouling. Fouling from organic matter, silt, and other suspended particles reduces filtration efficiency and shortens membrane lifespan. Despite this, the temperature and salinity of the intake water, drawn from 25 meters below the surface, remained stable over the study period, indicating that natural environmental factors do not place significant stress on the filtration system. The absence of seasonal variation in these parameters supports the conclusion that filter wear is driven primarily by water demand, not environmental conditions.

Seawater drawn from this depth must undergo several filtration stages before it is suitable for use. At 25 meters, the seawater maintains a consistent temperature of approximately -1.8°C and a salinity of 34 PSU (Practical Salinity Units), with less than 2% variation throughout the year. Salinity averaged 34.31 PSU, with only a 1.1% variation, while the intake water temperature averaged -1.86 °C with an 8.3% variation—suggesting little impact from these factors on filter degradation. Stable seawater intake conditions do not necessarily translate to stable filtration system performance, as the outside air temperature varies from 0°C to -20°C (*Kumar et al., 2023*). **The feed water is heated by the station's ambient heated air, adding to the complexity of managing filter clogging and membrane fouling, which remains a pressing operational challenge.**

3.4. Technological and Infrastructural Challenges

Maintaining water intake infrastructure in Antarctica presents significant challenges due to extreme weather conditions, isolation, and logistical difficulties. The increase in membrane replacements adds to operational costs and requires meticulous planning for material supply. Harsh environmental factors make routine maintenance and system optimisation difficult. Frequent membrane replacements lead to both increased operational costs and system downtime in Antarctic research stations. Adjustments to pre-treatment systems, optimisation of membrane types, or increased cleaning frequencies may help mitigate these effects. This section discusses potential design improvements and operational modifications.

Additionally, employing more resilient membrane materials or developing adaptive cleaning and maintenance protocols could extend membrane lifespans. Further research is needed to explore innovative desalination technologies and infrastructure designs suited to the unique challenges of polar regions. The multi-stage filtration system has proven to be highly effective, with each filtration stage playing a key role in managing the filtration load. The coarse filters (50 μm) handle the bulk of larger particulates, allowing the finer 5 μm filters to function optimally for longer

Year	Sea-water Intake Filter (50 μm)	Feed water Intake Filter (50 μm)	Pre-filter membrane (5 μm)	Absolute membrane (5 μm)	Total water consumption (KL)
2014	11	13	4	6	891.9
2015	9	9	9	9	924.3
2016	30	30	30	30	945.4
2017	14	4	8	6	961.6
2018	13	7	7	3	973.5
2019	11	5	7	4	979.1
2020	16	14	9	7	925.3
2021	21	21	22	15	935.7
2022	24	13	13	12	1081.6
2023	4	4	7	3	1111.6

Table 1: Details of filter usage and total water consumption at Bharati during 2014-2023

periods, reducing stress on the overall system and enhancing operational efficiency. Future work should explore advanced pre-treatment systems and innovative membrane technologies to further improve performance in extreme environments.

4. Conclusion

This study examined the impact of water usage patterns on the performance and longevity of the filtration system at the Bharati Research Base in East Antarctica. The harsh and remote environment of Antarctica presents unique challenges for maintaining critical infrastructure, particularly water intake systems. The data from the Bharati Research Base underscores the importance of efficient water filtration processes in sustaining operations under extreme conditions. Despite stable seawater intake conditions—such as temperature (-1.8°C) and salinity (34 PSU)—the increased frequency of membrane replacements is primarily driven by operational factors like water demand surges during expedition team arrivals and ship docking. These surges place strain on the filtration system, leading to more frequent replacements, particularly in the finer filtration stages.

While the stable environmental parameters mitigate natural stress on the system, the operational challenges, such as fouling caused by suspended particles and fluctuating water demand, remain a significant issue. The study highlights the need for optimising water filtration processes through improved pre-treatment systems, the use of more resilient membrane materials, and adaptive maintenance protocols to reduce operational costs and extend membrane lifespans.

Furthermore, innovations in desalination technologies tailored for polar conditions are crucial for ensuring long-term sustainability. The multi-stage filtration system, with its ability to manage filtration loads effectively, plays a critical role in minimising fouling and protecting the RO membranes. However, continued research is necessary to enhance system performance, ensuring the continued success of scientific missions in one of the most challenging environments on Earth.

Acknowledgement

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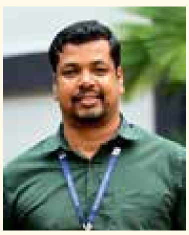
[**Authors' Contribution:** RK- Original draft, writing, visualization, formal analysis; MS-Editing and Review; AA- Resource, Review; AKS- Resource, editing, review, supervision; YR- Resource, editing, review, supervision; SS-Resource, editing, review, supervision; VK- Software and analysis; JVG-Editing and review]

About the Authors

Rahul Kumar earned his B.Tech from Delhi University in 2012 and M.Tech from Punjab Technical University in 2014. He began his career as a Graduate Engineer Trainee at Suzuki Ltd. and later worked as a Senior Engineer in Plant and Utility Maintenance at Thermax Ltd., Pune. In 2017-18, he served as a Project Engineer at Antarctica's Bharati Station with Techbean Systems. He then joined GE Diesel Locomotive Ltd., as an Assistant Manager in 2018. Since 2019, Rahul has been a Project Scientist at NCPOR-Goa, overseeing Life Support Systems and Mechanical components at Bharati and Maitri Stations. He is currently studying aerosol characteristics near these stations under Dr. Anand and Dr. Shailendra Saini.

Email: rahulkumar@ncpor.res.in

Vivek Kumar is a Meteorologist with the India Meteorological Department. He is an environmental meteorology and Atmospheric science enthusiast with expertise in Meteorology, Instrumentation, Air Pollution, Data Science and Polar Science. Passionate about research and innovation, exploring advancements in data tools, techniques and global collaborations, particularly emphasising India's contributions.



Dr. Magesh N.S. earned his Ph.D. in Environmental Science from MS University, Tirunelveli, in 2015. He began as a visiting scientist at Coastal Specialists Limited, Mauritius, researching coastal erosion and reef bathymetry. He later worked as a D.S. Kothari Postdoctoral Fellow at Anna University (2015–2018) and as a Project Scientist – II at NCPOR, Goa (2018–2022). He participated in the 38th and 41st Indian Scientific Expeditions to Antarctica, assessing environmental impacts near India's polar stations. Since 2022, he has been a Scientist at KSCSTE-CWRDM, Kozhikode, focusing on environmental science and water resource management, contributing significantly to climate impact studies and sustainable water resources.

Ariz Ahmad has earned Bachelor in electrical engineering from Nagpur University in 2013. He worked in SEE-Tech Solutions Pvt Ltd, Nagpur as a Project In-Charge for implementing energy cost saving projects, and Tech bean Systems Pvt Ltd as a Project In-charge. In 2014-16 he got the first opportunity to go to Antarctica,Bharati station as a project engineer from Techbean Systems Pvt Ltd as a part of 34th Indian Scientific expedition to Antarctica. After that he repeatedly participating in Indian Scientific expedition to Antarctica. From 2022 onwards he is working as a Project Scientist in NCPOR-Goa and handling the Maintenance activities of Life Support System of two Indian Scientific Research Stations, Bharati and Maitri in Antarctica.

Dr. Jenson George is a scientist NCPOR, Goa has a keen research interest in oceanography, in particular the nutrients and linked biomass variability. He regularly participates in the Southern Ocean and Antarctic Expeditions for data collection. He also works on the air-ice-sea interaction in Antarctic coastal waters. Dr. George leads the unique sea-ice-tethered mooring platform, PRAISE for profiling the Antarctic water column in the Prydz Bay.

Dr. Anand K. Singh is In-Charge of the Space Weather and Atmospheric Sciences division at NCPOR, Goa. His research includes dynamics of the upper atmosphere in the polar region and its teleconnection in the opposite hemisphere and low latitudes. Dr. Singh leads the integrated atmospheric observation facility for Antarctica (IAOFA) and represents Indian scientific and logistics interests at various national and international forums, including BRICS.

Email: aksncaor@gmail.com

Dr. Yogesh Ray, Scientist-E, is In-Charge of the Antarctic Logistics and Science Coordination at NCPOR, Goa. As a geologist by profession, the research of Dr. Ray focuses on the Late Quaternary. He conducts regular fieldwork and sampling in the high Himalayas and remote Antarctica. Dr. Ray is Co-Editor of the Advances in Remote Sensing Technology and The Three Poles series of Wiley. He also served as the Guest Editor of the Polar Science journal of Elsevier. Dr. Ray is an Antarctic veteran and Young Researcher awardee of the Ministry of Mines.

Dr. Shailendra Saini is the Group Director of Antarctic Operations at the National Centre for Polar and Ocean Research. With over two decades in the Indian Antarctic Programme, his research focuses on polar ionospheric changes due to solar activity. He has contributed to wildlife monitoring, space-based sea-ice studies, and instrument development for auroral and permafrost research. Dr. Saini has participated in Arctic and Antarctic expeditions, serving as Voyage Leader. Holding a Ph.D. in Electronics Communication, he has been a guest editor for Polar Science (Elsevier). As Vice-Chair of COMNAP, he represents India in national and international polar research forums, advancing multidisciplinary studies in extreme environments.

Email: shailendrasaini@gmail.com

Underwater Vehicle Navigation in Polar Regions: Case study from NIOT's PROVe Development

V Bala Naga Jyothi , R Ramesh,
A Vadivelan, N Vedachalam,
S Ramesh

Abstract

Navigation of underwater vehicles in Polar Regions poses unique challenges due to extreme environmental conditions such as ice cover, low temperatures, limited satellite visibility and high-latitude geo-magnetic field anomaly. Under-ice referenced vehicle velocity measurements helps in achieving precise navigation and positioning performances required for Polar research. A navigation suite with upward-looking Doppler Velocity Log, high-latitude calibrated magnetic compass and transverse coordinate system-based position estimation algorithm was developed and found to have a position estimation performance of 1.5% of the total distance travelled, which was improved to 0.5% (CEP50) by incorporating a Kalman filter. The developed polar navigation system is installed in NIOT-developed Polar Remotely-Operable Vehicle (PROVe) and was deployed in a scientific expedition in Antarctica.

Introduction

Underwater vehicles play a critical role offshore sector including oil and gas, mining, environmental monitoring, seabed mapping, biological research, and engineering interventions. However, Polar Regions introduce unique challenges for navigation and positioning due to their extreme environmental conditions. The thick ice cover blocks GPS signals, rendering traditional satellite-based navigation systems ineffective and magnetic anomalies near the poles disrupt compass-based navigation. Further performances of batteries and navigation sensors like Doppler Velocity Logs (DVLs) and acoustic systems are influenced by extremely low temperatures. These limitations necessitate alternative navigation solutions to obtain precise navigation and positional accuracies to perform precise manoeuvring, long-duration autonomous operations with minimal deviation in mapping missions, ensuring safe and efficient use of vehicles in Polar Regions.

Review of Polar Underwater Vehicles

Polar exploration technologies have progressed significantly over the decades. Starting with rudimentary tools in the early 20th century, technologies have evolved into sophisticated autonomous and hybrid systems that address specific challenges, while laying the foundation for future advancements. The 1990s marked the introduction of autonomous underwater vehicles (AUVs) in polar research with Theseus, developed for deploying communication cables beneath thick ice sheets. **Theseus used a fibre-optic tether for real-time navigation and data transmission, enabling extended under-ice missions.** However, tether management was a challenge as it introduced operational challenges, such as entanglement risks and limited adaptability in dynamic ice conditions, highlighting the need for untethered systems that are capable of autonomous navigation in GPS-denied regions.

Past two decades saw significant advancements with the Autosub AUV series, particularly Autosub3, in which a DVL aided- Inertial Navigation Systems (A-INS) enhanced the navigation accuracy, specifically critical for GPS-denied environments. Additionally, multi-beam sonar enabled detailed bathymetric mapping beneath ice shelves like the Pine Island Glacier, providing valuable insights into sub-ice terrain. Unlike tethered systems, Autosub3's autonomous operation allowed large-scale surveys in inaccessible areas. However, there were limitations in supporting multi-disciplinary payloads and achieving real-time adaptability, restricting its scope for simultaneous physical, chemical, and biological measurements. Parallel advancements were reported from the Atlantic Layer Tracking Experiment (ALTEX) AUV, that utilised Kearfott-make INS, DVL, and GPS receivers for under-ice positioning. A key innovation/take-away was the upward-looking DVL, which tracked ice velocity to compensate for drift errors. Despite its success, ALTEX encountered challenges such as geomagnetic disturbances, which disrupted compass-based systems near the poles, and difficulty transitioning between ice-covered and open-water environments during navigation. These learning emphasised the need for application of Kalman Filters and advanced sensor calibration for achieving reliable navigation in ice-covered and dynamic environments.

While conventional ROVs are effective for precise manipulation tasks, they are constrained by limited range due to tethered operations and complex ice entanglement risks

By mid-2010s, advancements in sensor modularity and endurance were exemplified by the PAUL AUV. Designed for biogeochemical research, PAUL was equipped with sensors like radiometers and chlorophyll fluorometers to measure ice-algal biomass and ecosystem dynamics. Its real-time data acquisition capabilities provided critical insights into polar ecosystems. However, power limitations during extended deployments demanded the need for energy-efficient systems, modular payloads, and improved redundancy for reliable long-term operations. In 2023, Japan's MONACA AUV (Mobility Oriented Nadir Antarctic Adventurer), developed by the University of Tokyo and deployed by the National Institute of Polar Research (NIPR), represented a significant leap in under-ice exploration.

MONACA introduced hover-capable navigation, enabling precise bathymetric mapping, temperature profiling, and salinity measurements in complex environments like grounding zones and dynamic ice sheets. MONACA successfully completed 20 dives near the Lang Hovde Glacier, utilising INS, DVL and aiding systems. However, challenges such as navigation gaps in fragmented or icy surfaces; and energy efficiency for prolonged missions remain active areas for research.

While conventional ROVs are effective for precise manipulation tasks, they are constrained by limited range due to tethered operations and complex ice entanglement risks. The development of polar ROVs **(Figure.2)** have advanced significantly, incorporating specialised sensors to address extreme under-ice challenges. The P2-ROV features a mechanical arm with a suction pump, enabling biological sampling of larvae and fish eggs. It also uses thrusters for manoeuvring in six degrees-of-freedom and cameras for under-ice imaging, operating at depths of 250m deployed through 350 mm auger-drilled ice holes. Similarly, the SCINI ROV is equipped with high-resolution video cameras, scaling lasers, and an acoustic positioning system, allowing precise navigation and imaging of benthic habitats. Its compact design enabled deployment through 20cm holes and successful mapping under the Ross Ice Shelf, though it faced manoeuvrability constraints.

The Australian Micro ROV used three cameras, eight thrusters, and light-weight sensors for environmental monitoring, offering rapid under-ice marine surveys near Antarctic stations despite its limited payload capacity. The Nereid Under Ice (NUI) vehicle combines INS/DVL systems, breadcrumb navigation, and acoustic triangulation for accurate positioning under fragmented ice.

Polar Navigation and Positioning Challenges

a. Global Positioning System challenges and technological maturity

Non-Polar regions

Underwater navigation in equatorial regions benefits from consistent satellite visibility and minimal environmental interference. GPS is accessible near the

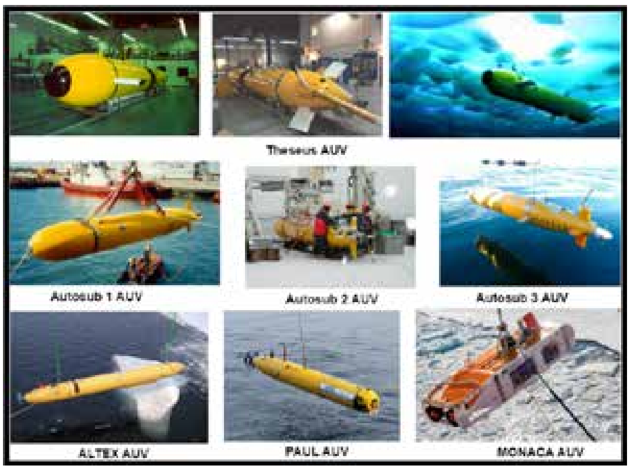


Figure.1 Different AUVs operated in Polar Regions

Figure.2 ROVs operated in Polar Regions

surface, and environmental conditions are relatively stable, which simplifies underwater navigation for industrial applications such as offshore drilling and cable laying to enhance operational accuracy and speed, minimising downtime. Navigation in tropical regions involves more variables than equatorial zones. The temperature and salinity gradients, as well as variable currents, impact acoustic navigation. Technologies like DVL-aided A-INS allow for precise ROV control and positioning, critical for deep-sea drilling and pipeline inspection.

The auroral activity and solar radiation levels in the Polar Regions can interfere with signal transmission, affecting the reliability and quality of communications

Polar Regions

Satellite networks are vital at the poles. Providing reliable navigation and communication in extreme conditions and involvement of orbital dynamics where the Geo-stationary satellites have limited coverage and depending polar orbiting satellites to ensure coverage. The auroral activity and solar radiation levels in the Polar Regions can interfere with signal transmission, affecting the reliability and quality of communications. This is over come with the Low Earth Orbit based Iridium satellite comprising of 66 satellite constellations covering the entire polar regions for continuous positioning and video & audio communication **(Figure.3).** Iridium's ability to provide reliable communication services in the Polar Regions significantly supports expeditions, research, and operations in these remote areas, interoperability, ensuring safety, facilitating scientific endeavours, and supporting global connectivity.

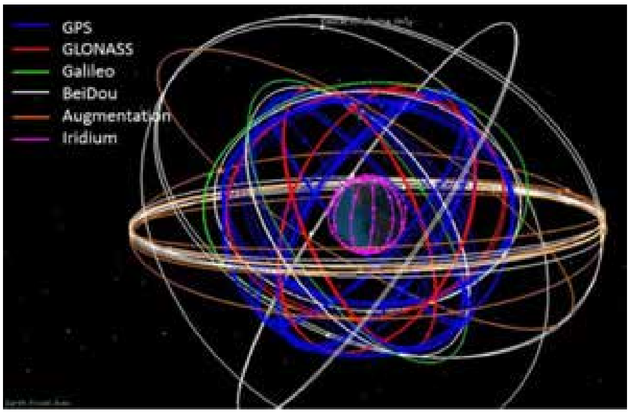


Figure.3.Mutiple satellite constellations for positioning services

b. Earth's Magnetic field Anomaly &Challenges

Magnetic variation changes very rapidly towards poles that affect position computation due to high dip angles. It is also known that the GMF at equator is 35μT and±60μT in the Polar Regions. The difference between Magnetic North and Geographic North is known as declination, angle which depends on the Latitude and Longitude **(Figure.4).**

The accuracy of the magnetic compass is highly influenced at the Polar Regions, resulting in erroneous performance. Hence the high latitude calibration must be carried out locally (in-situ) to cancel the hard iron and soft iron interferences, so as to improve the compass heading accuracy. For understanding, **Figure.5** shows the magnetic field distribution before and after calibration. This procedure has been introduced for using MEMS-based magnetic compass modules (TCM2.6 from M/s PNI

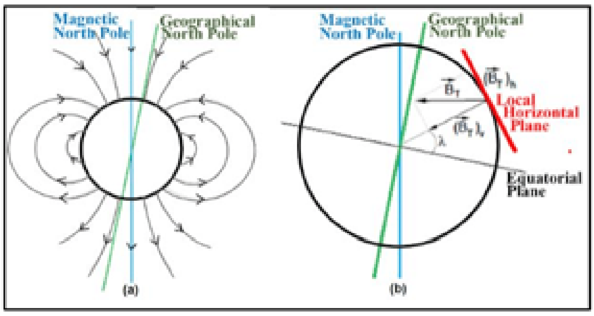


Figure.4. Magnetic and Geographic North with declination

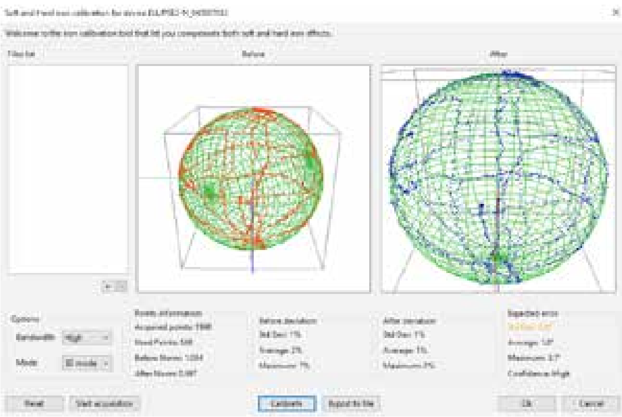


Figure.5.Magnetic calibration showing GMF distribution before and after calibration

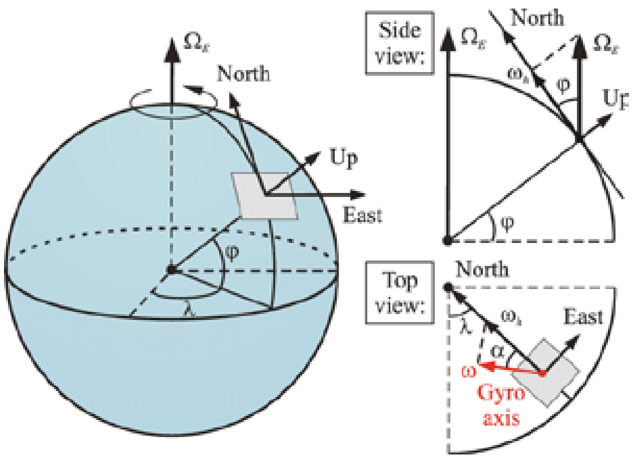


Figure.6. North-seeking gyro mechanism to sense earth rotation

sensor Corp., USA). The use of magnetic compass in underwater near-polar regions needs high latitude calibration for compensating the in-situ hard and soft iron components and obtain accurate heading measurements for position computations.

The Earth rotates at approximately 15 °/ hour with the horizontal component is equal to those times the cosine of latitude (Φ)

c. North-seeking algorithm for FOG/ RLG based INS systems

True North finding/ determine heading is essential for target orientation and localisation applications. True North finding is carried out by gyro-compassing technique **(Figure.6).** A gyrocompass detects true North by directly measuring Earth's angular rate as it spins on its axis once a day. The Earth's angular rate (ΩE) can be decomposed into horizontal (ωN) and vertical (ωD) components, with the horizontal component pointing due north. The direction of that horizontal component with respect to the sensor axes provides the heading (ψ). The Earth rotates at approximately 15 °/ hour with the horizontal component is equal to those times the cosine of latitude (Φ). As an example, at 45 ° latitude, an error as small as 0.1°/hour in the angular rate measurement results in 0.5° heading error, is likely. Achieving accurate heading via gyro compassing requires a low-noise sensor with superior bias stability.

It is to be understood that a 2-axis gyroscope can find True north, and a 3-axis gyroscope can detect the Earth's axis of rotation. Many types of gyroscopes, based on different principles include:

- Classic Mechanical - Spinning wheel mounted on a gimbal
- Optical – Fibre optic gyros (FOG) and Ring Laser Gyro (RLG), based on the Sagnac effect
- Vibrating – Coriolis effect – Hemispheric Resonating Gyros (HRG), Micromechanical Gyros (MEMS)
- Gyroscopes measure True north and are not affected by external magnetic fields or surrounding metals but they are affected by bias drift

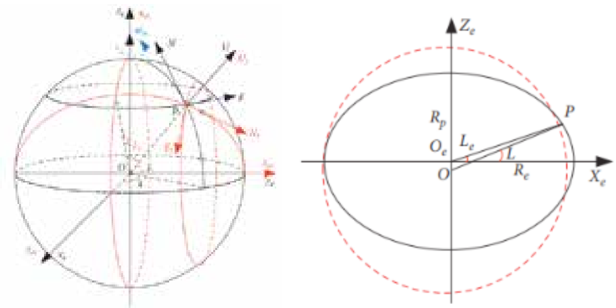


Figure.7 Transverse co-ordinate system with virtual sphere

Figure.8. View of the PROVe 500

d. Transverse Co-ordinate based Positioning & Navigation technique

The transverse coordinate system (TCS) is an alternative Earth coordinate frame (ECF) developed to address the unique challenges of navigation in Polar Regions, where traditional geographic coordinate systems become ineffective in high latitude zones. In conventional systems, latitude (Lat) and longitude (Lon) are defined relative to the equatorial plane and prime

Table 1. Specifications of PROVe

Diving Depth	500m
Weight	175 kg
Dimension	0.96 m x 0.61 m x 0.63 m
Movement	Three axis, plus rotation on its own axis
Speed	~ 3 Knots
Payload	10 kg
Buoyancy	Syntactic foam (Modular)
Power	300V DC, 5 kW
Thrusters	Four thrusters powered by Brushless Direct Current motors
Umbilical Cable	500m, 27.5 mm diameter, Positively Buoyant
Manipulator	1 No , 5 Functions (Electric)
Data telemetry	Single Mode Fibre optic communication
Hardware	National Instruments make Compact RIO Controller with FPGA
Software	LabVIEW
Cameras	Colour, Monochrome and Mini Camera-1 each
Luminaries	2 LED and 2 halogen lights
Scientific sensors	Scanning sonar, Conductivity, Temperature and Dissolved Oxygen
Navigation	MEMS based Inertial Navigation System, iDVL (Doppler Velocity Log), 3 axis tilt compensated Compass module Depth Sensor

meridian. However, at Polar Regions, the convergence of meridians causes significant distortion, making the standard definitions of direction ambiguous.

To mitigate this, the TCS redefines Lat and Lon by rotating the ECF such that the poles are placed on the equatorial plane **(Figure.7).** In simpler terms, the transverse system aligns the navigation reference frame along a “transverse equator,” where the Earth’s poles become new “equatorial points,” enabling more stable calculations. One of the prominent advantages is its stability in Polar Regions, where conventional coordinates lose accuracy due to meridian convergences. By redefining Lat and Lon, the TCS ensures more stable and reliable positioning when the following steps are adopted.

The transformation from the traditional to TCS that redefines Earth-fixed coordinates to align with the transverse frame for polar navigation stability.

$$X_e, Y_e, Z_e = Y_e{}', Z_e{}', X_e{}'$$

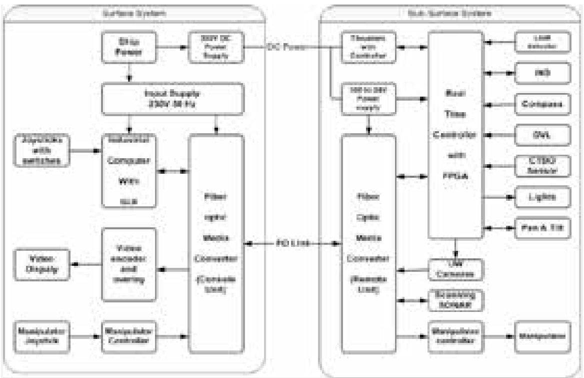


Figure.9. PROVe control system block diagram

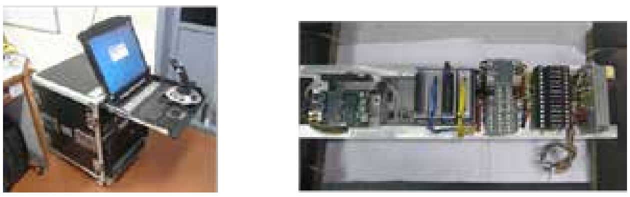


Figure.10. Surface and subsurface control architecture

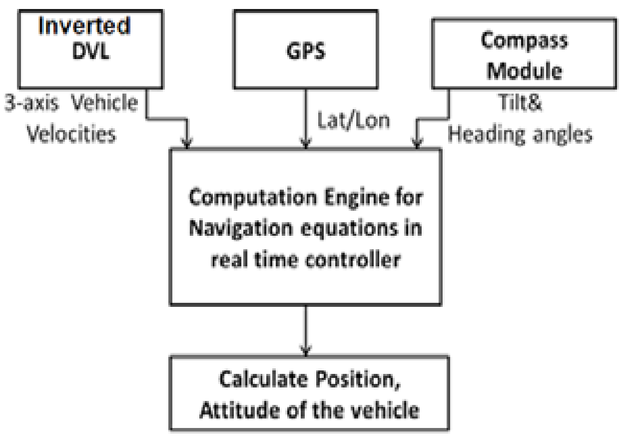


Figure.11. PROVe navigation system architecture

The Direction Cosine Matrix (DCM) for transformation rotates the traditional frame to the transverse coordinate frame for accurate directional mapping.

$$C_{\{e'\}}^{e} = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

The transverse Lat and Long that defines TCM stabilizing angular calculations near the poles.

$$L' = \arcsin\left(\frac{\{\cos L * \sin \lambda\}}{\left\{\sqrt{\{1 - (\cos^2 L * \sin^2 \lambda)\}}\right\}}\right)$$

$$\lambda' = \arctan\left(\frac{\{\cos \lambda\}}{\{\tan L\}}\right)$$

Converting back to traditional coordinates that allows transformation of transverse coordinates back to traditional earth-fixed coordinates is.

$$L = \arcsin\left(\frac{\{\cos L' * \cos \lambda'\}}{\{sqrt\{1 - \cos^2 L' * \cos^2 \lambda'\}\}}\right)$$

$$\lambda = \arctan\left(\frac{\{\tan L'\}}{\{\sin \lambda'\}}\right)$$

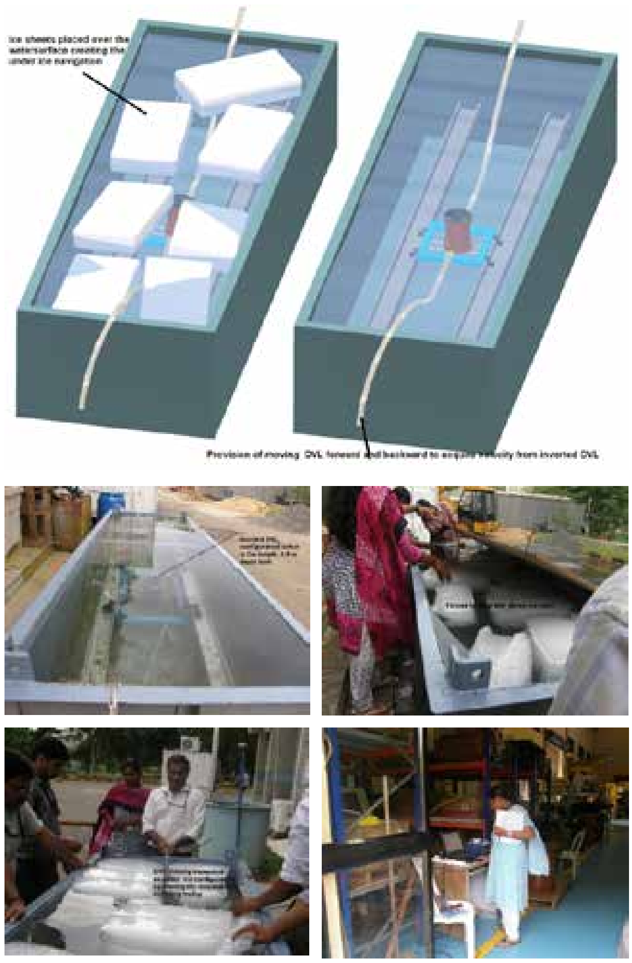


Figure. 12. 3D illustration of the test (Top) Inverted-DVL setup for validating under-ice navigation (Bottom)

The transformation for attitude angle matrix that accounts for angular differences between transverse and traditional frames is

$$C^{g}_{\{g'\}} = \begin{bmatrix} cos\beta & -sin\beta & 0 \\ sin\beta & cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The velocity update in the transverse System that updates velocity in the transverse frame using accelerometer readings and angular velocities is

$$\{\dot{v}\}_{\{g'\}} = C^{b}_{\{g'\}} f^{b} - 2C_{\{g'\}}{}^{\{e'\}}_{\{ie'\}}\omega \times v_{\{g'\}} + G_{\{g'\}}$$

The angular rate in the transverse frame that tracks angular rates in transverse coordinates, which is essential for inertial navigation is

$$\omega^{\{e'g'\}}_{\{g'\}} = \begin{bmatrix} -\{\dot{L}'\} \\ \{\dot{\lambda}'\}cos\, L' \\ \{\dot{\lambda}'\}sin\, L' \end{bmatrix}$$

The position update for transverse Lat and Long that updates the position coordinates in the transverse system for precise navigation is described as

$$\{\dot{L}'\} = -(1/\{\tau\})v'_e + (1/\{R_y\})v'_n$$

$$\{\dot{\lambda}'\} = (1/\{R_x * cos\, L'\})v'_e - (1/\{\tau * cos\, L'\})v'_n$$

The navigation system developed for NIOT's PROV took into consideration these challenges for developing the indigenous systems suitable for operating in Polar Regions.

PROVe developed by NIOT

Based on the return of experiences from the development of 6000m depth-rated electric work class ROV ROSUB 6000, NIOT designed, developed, and qualified a 500m depth-rated Polar Remotely Operated Vehicle (PROVe 500) for carrying out scientific research in the Polar Regions. The vehicle is designed in such a way that it could be operated from any vessel of convenience. The view of the vehicle with inverted DVL is shown in **Figure.8** and detailed specification of the vehicle can be seen in **Table 1.**

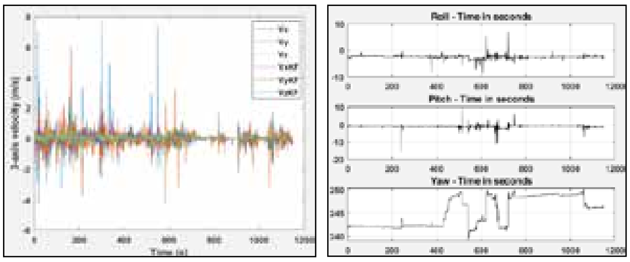


Figure.13 3-axis DVL velocity data with and without KF and attitude information

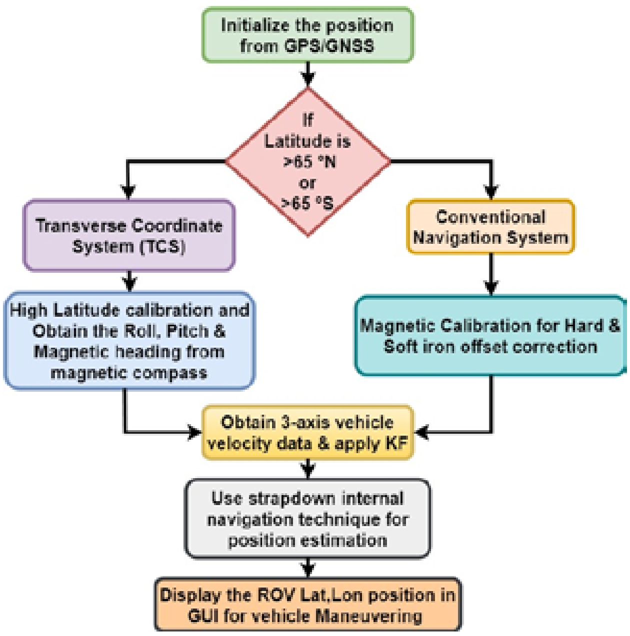


Figure.14 Position estimation algorithm for polar and non-polar locations

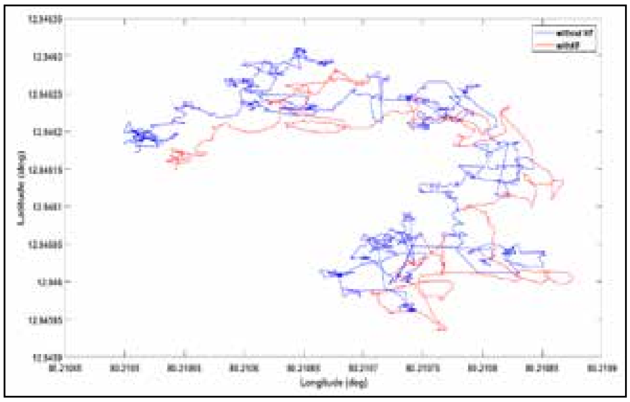


Figure.15 Position estimation using conventional navigation algorithm

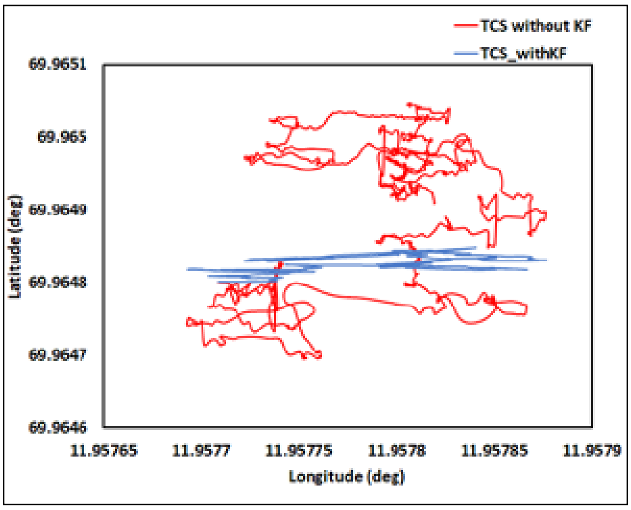


Figure.16 Position estimate using indigenous TCS Polar navigation algorithm.

Guidance, Navigation and Control System

The block diagram of PROVe control system is shown in **Figure.9.** The visual guidance for piloting the underwater vehicle is provided by the two underwater cameras and four underwater lights mounted on-board PROVe. The vehicle control system consists of National Instruments make Field Programmable Gate Array (FPGA) with compact reconfigurable Input/ Output (CRIO) real-time controller and I/O modules and optical media converter. The vehicle control algorithm for PROVe is developed using LabVIEW software. The vehicle controller receives commands from the surface control system and it executes commands to control the subsurface components and sensors which includes thrusters, cameras, luminaries, acoustic DVL and scanning sonar. The navigation algorithm is developed for underwater vehicle position estimation in dead-reckoning mode with aid of DVL and attitude sensors.

The communication system between the PROV and the surface system is achieved by a single-mode fibre-optic link in the umbilical with fibre-optic media converter. The optical media converter in the surface and subsurface units are used to convert electrical to optical and vice-versa at wavelengths of 1550 and 1310 nm, respectively. The remote unit of media converter is interfaced with PROVe controller, underwater cameras and scanning sonar for data and video transmission.

The communication system between the PROV and the surface system is achieved by a single-mode fibre-optic link in the umbilical with fibre-optic media converter

The surface control system shown in **Figure.10,** comprises of an industrial computer, console fibre media converter, navigational joystick, video encoder and video overlay system. The industrial computer with 3.4 GHz processor speed, 8 GB RAM, executes the developed LabVIEW application with Graphical User Interface (GUI) for envisaged vehicle operation. The navigation joysticks with soft switches are used to operate thrusters, camera, and lights. The video overlay system is interfaced with industrial computer to provide real time navigational data to have effective piloting of the vehicle.

The navigation support for the vehicle is provided by on-board navigation sensor suite comprising of in-house

Table 2. Performance of the algorithms in inverted-DVL configuration in total distance travelled of 50 m * 40m

Position accuracy	Conventional Algorithm		Polar Navigation with TCM	
	Posn. in Lat (m)	Posn. in Long (m)	Posn. in Lat	Posn. in Long
CEP 50 Without KF	5.4	4.6	10.5	15.2
CEP 50 With KF	3.5	2.8	2.5	1.8

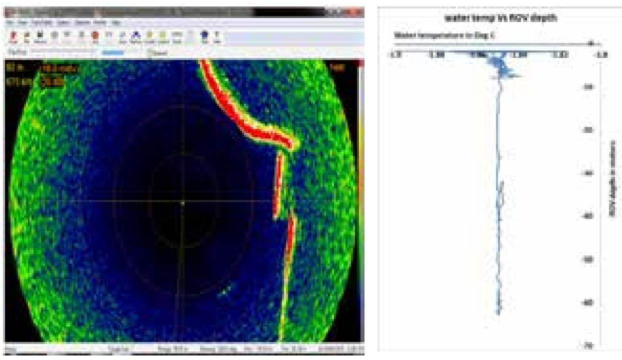


Figure 19 SONAR image of ice shelf & Temperature profile with depth

Figure.17 a. Functionality check in ATF b. Low temperature test

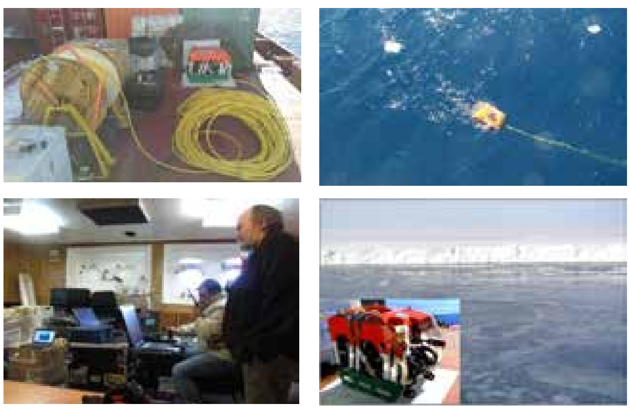


Figure.20 PROVe manoeuvred from vessel in Indian barrier ice shelf

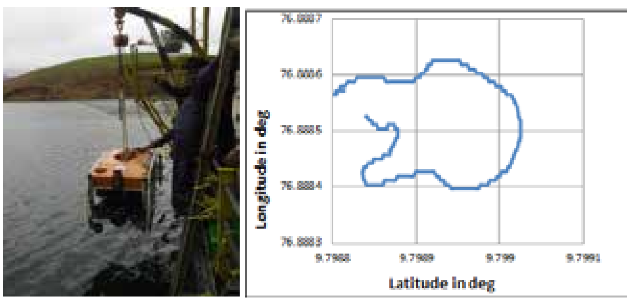


Figure. 18a. Idukki trials b. Navigation plot

developed navigation algorithm aided by attitude and velocities inputs from three-axis tilt compensated compass module and DVL with Kalman filter. The architecture of the navigation system is shown in **Figure.11.** The algorithm receives initial position from the GPS, which is provided prior to launching of the vehicle, and once the vehicle is launched, the algorithm updates the position based on the three vehicle axis body frame (BF) velocity from the inverted DVL and attitude data from the three-axis tilt compensated compass module. PROVe velocities are estimated during DVL outages using a Kalman filter with measurement covariance of DVL and field tuned process covariance. The BF velocities are transformed into EF velocity with Euler angles. The developed terrestrial-based strap-down navigation algorithm estimates the vehicle position in real-time.

"The PROV was transported to Indian Antarctic station MAITRI and was deployed in the Priyadarshini Lake and lake bed photographs were acquired"

Qualification of the PROVe

In-house testing of Inverted-DVL configuration and performance validation

For achieving precise PROVe navigation when operating below the ice-covered Antarctic regions, the DVL has to operate with reference to the ice and hence has to be located above the vehicle. To understand the performance of DVL in the upward ice-looking mode (inverted configuration), a test rig comprising of a 1.5m long, 0.5m-deep test tank (with 20cm floating ice) with DVL mounted in a sliding trolley suitable for acquiring the 3-axis velocity in inverted configuration is realised as shown in the **Figure.12a.** The same setup was realised and when the trolley is moved, the velocity is measured by DVL resembling vehicle moving under-ice **(Figure.12b).** The test rig and the 3-axis velocity in BF, magnetic compass-based attitude data (roll, pitch and magnetic heading) were also acquired after calibration and processed as inputs for the NIOT-developed TCS-based position estimation algorithm.

When the DVL is in operation with reference to the ice, due to multiple reflections and limited thickness of the ice, the DVL data quality is not consistent, and hence a Kalman filter is used to filter out erroneous data. The 3-axis velocities, altitude and attitude information logged is shown in **Figure.13.**

The logic flow diagram of the polar and non-polar based navigation algorithm is explained in **Figure.14.** The real-time data is used for position estimation using NIOT indigenous TCS navigation algorithm and the results are shown in **Figure. 15 and 16,** respectively. From the performance results summarised in Table.2, the challenges due to inconsistent reflections acquired by the DVL is to overcome using a Kalman filter, which improves the position estimation accuracy from 1.5% to 0.5% of the distance travelled with a CEP50.

Tank tests and qualification in the Lake

The developed PROVe is tested for the basic functionality in NIOT's in-house Acoustic Test Facility (ATF) **(Figure.17a)** and qualified for low temperature performance (up to -5 °C) in NIOT's in-house environmental chamber **(Figure.17b).**

Prior to deployment in the open-ocean, design qualification of the PROVe was done by deploying in Idukki Lake, Kerala (DRDO-NPOL facility) where PROVe was operated up to depths of 106m (9.7913° N &76.8749° E) and manoeuvred in all four degree of freedom at a speed of 2 knots covering a total distance of about 300 m **(Figure.18a).** From the navigation plot of the PROVe shown in **Figure.18b,** the position error was 1% of the total distance travelled and 0.5% with Kalman filter for DVL data.

Deployment in Antarctica

Subsequent to the qualification, a team of 6 scientists along with the PROVe participated in the 34th Indian Science Expedition to Antarctica (ISEA) during 2015. The PROV was transported to Indian Antarctic station MAITRI and was deployed in the Priyadarshini Lake and lake bed photographs were acquired. After the lake trials, the PROVe with subsystems were mobilised to ship MV Ivan Papanin from MAITRI station by helicopter. PROVe was assembled, integrated on-board ship, and deployed at New Indian Barrier ice shelf (Location 69.9648° S and 11.9577° E) **(Figure.19)** and piloted up to water depths of 62 m **(Figure.20)** and the envisaged functions were realised. The images of the ice shelf captured from the vehicle sonar and the plot of the sea water temperature and ROV depth recorded during the operations are shown **(Figure.20).**

Conclusion

In this paper, the challenges for navigation and positioning in Polar Regions, and the present technological maturity in achieving enhanced position accuracy are detailed. The case study based on the navigation sensor suite developed by NIOT incorporating transverse coordinate system, inverted DVL configuration and high-latitude magnetic compass calibration was installed in NIOT-developed PROVe and used for scientific exploration in Antarctica ice shelves. The described methodologies shall be useful to the polar scientific community and academia to develop precision under-ice navigation and positioning solutions.

Acknowledgments

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About the Authors

Dr. V. Bala Naga Jyothi is Scientist-E in National Institute of Ocean Technology, India. She is a lead electronics engineer for the development of navigation and positioning systems for India's indigenously-developed deep-water manned scientific submarine Matsya6000 and unmanned remotely operated vehicles. Prior to NIOT, she was working as a Scientist/ Senior Engineer in Indian Space Research Organization (ISRO) involved in the control and automation of Cryogenic Propellant Systems of Geo-Stationary Launch Vehicles (GSLV) and Attitude On-Orbit Control Systems of geo-stationary satellites. Her areas of interest include underwater navigation, positioning, and communication, AUV homing & docking systems and situation-aware digital twins. She has published more than 40 papers in indexed journals, international and national conferences. She is a member of Ocean Society of India (OSI), Marine Technology Society (MTS) and IEEE.

Email: nagajyothi@niot.res.in

Ramesh Raju is a Scientist- E at the National Institute of Ocean Technology, Chennai, India. He is a Lead Electronics Engineer for India's first indigenously-developed deep-water scientific manned submersible (MATSYA6000). He had designed, developed, and tested control hardware and software for shallow water and deep-water Remotely Operated Vehicles (ROV) up to a depth of 6000m. He is an ROV pilot for NIOT-developed ROVs and operated up to 5289m. He has participated 34th Indian Scientific Expedition to Antarctica for Shallow water cum polar ROV operation and Piloted the ROV at Lake and New Indian barrier in East Antarctica. His experience includes data telemetry and control systems for unmanned and manned underwater vehicles, Instrumentation and automation for the Compact disc industry, and calibration and testing of test and measuring instruments. He is a recipient of the National Geoscience award 2010 and National societal innovation award 2018 for the development and scientific exploration of deep water and Shallow water robotic vehicles. He has published more than 40 papers including in indexed journals, International and National conferences.

Vadivelan. A is working as Senior Scientific Assistant in the Submersible & Gas Hydrate group of Deep-Sea Technologies division under National Institute of Ocean Technology (MoES), India. He has more than 20 years of experience in interfacing the Electrical and Electronics- imaging, navigation, optical, propulsion, power, and mechanical sub systems. With the experience he has obtained the skills in optimisation of assembly of electronics, instruments, and communication circuits, in the available minimal space of the subsea enclosures complying the IEC standards. Also, his contribution includes indigenous fibre optic connectorisation from the ship to submersible communication systems. He has received the Best Employee Award from MoES. He has two patents and 20 publications in national and international journals.

Dr. N. Vedachalam is currently Scientist G in Deep Sea Technologies division of National Institute of Ocean Technology, India. He is the Project Director for India's first indigenously-developed deep-water human-occupied scientific submersible Matsya6000. His 30 years of experience include industrial power, process, offshore and subsea domains at Aditya Birla group, General Electric & Alstom Power Conversion in France. His research interests include energy, subsea robotics and reliability. He has more than 100 publications in indexed journals, holds an international and two national patents in subsea robotics and subsea processing. He is a recipient of the national meritorious invention award in 2019 for the development and usage of underwater robotic vehicles. He is a member of Marine Systems Panel of Indian Naval Research Board, Member of Bureau of Indian Standards and was the Secretary of IEEE OES - India Chapter. He is a regular contributor to MER

Dr. S. Ramesh is currently Scientist G and Heading the Submersible & Gas Hydrate group of Deep Sea Technologies division under National Institute of Ocean Technology (MoES), India. As a exploration marine geologist with experience of about 32 years involved in realisation and execution of deep sea mineral exploration technology using ship-based and underwater vehicles. His research contributions include deep-ocean mineral (Gas hydrate, poly-metallic manganese nodule and hydrothermal sulphides) exploration, paleoclimate signals from the sediments, participation in national and international expeditions including Polar Regions at Siberia and Antarctica. He has more than 70 publications in national and international journals, holds two national awards (National Geoscience Award by Ministry of Mines and National Innovation Award by NRDC-CSIR and two national patents in subsea robotics. He is a Member of Legal and Technical Commission (LTC) representing India for the International Seabed Authority under United Nations for five year term up to 2027, and Life member of Ocean Society of India.

Towards Preserving the Intrinsic Values of Antarctica

Rasik Ravindra

Abstract

The earth and its environment work under a close knit coupled system, where every component is dependent and linked to the other. There exists a close and delicate balance between atmosphere, lithosphere, hydrosphere, biosphere and cryosphere of the earth. This is better realised in the Polar Regions, more so in Antarctica, which acts as a precise tool for recording any imbalance in the global ecosystem. The continent was inaccessible to humans till around early nineteen century which helped it in preserving its environment and dependent and associated ecosystems as also in protecting the great wilderness and its intrinsic values.

Post, 1957-58 IGY, the continent has seen a furry of activities that primarily pertain to scientific domain but also extend to adventure, tourism, fishing and allied fields that have raised concern for increasing human foot prints, introduction of non-native species, pollution and other anthropogenic interference. The global warming and climate change are already adversely impacting the biodiversity and fragile ice shelves that are removing the natural buttress that holds the ice sheet in its place.

The paper points out international and national measures that are already in place, as also those that are being planned to save the Continent and preserve and protect it as a Common Heritage of Mankind (CHM).

Figure. 1 Satellite Image of Antarctica (NASA)

INTRODUCTION

Antarctica, is rightly designated as the last wilderness of planet earth. It is a continent of superlatives with vast expense of snow and ice spread over around 14 million sq. km that makes it as the fifth largest continent. During the winters, the part of Southern ocean surrounding it, freezes and clings to the continent swelling its extent to twice its original size.

Recognised as the most inaccessible with hostile weather, it is the coldest, windiest, driest and the highest continent of our earth. Temperatures as cold as -89^{0}C (recorded at Vostok Station) and maximum winds of 327 km/hr (recorded in 1972 at French station) are reported from here. The average height of the continent is about 2000 m above the mean sea level.

The frozen continent is a silent witness to many secrets and stories of past climatic conditions, warming and glacial events and is a repository of evidences of multiple phases of drifting continents over more than

2,500 million years that the earth has seen. It is, therefore, important that Antarctica be preserved and protected along with its intrinsic values, that the continent holds.

> **Antarctica or the 'terra Australis Incognita', though conceived by the ancient Greeks as the unknown Southern landmass to balance the northern 'Arctic', remained a mystery till it was sighted by Capt. Bellingshausen, a Russian explorer in 1820**

Rediscovering the Continent and its environmental potential

Antarctica or the '*terra Australis Incognita',* though conceived by the ancient Greeks as the unknown Southern landmass to balance the northern 'Arctic', remained a mystery till it was sighted by Capt. Bellingshausen, a Russian explorer in 1820. An earlier sea voyage of Captain Cook in the southern hemisphere during 1772-1775, could not establish the presence of any landmass beyond the Antarctic circle, as he could not penetrate the great ice barrier, forcing him to presume that "if at all any land lay farther south, it was practically inaccessible and of no economic value." However, he crossed Antarctic Circle at least three times discovering several sub-Antarctic islands thereby setting stage for subsequent expeditioners to hunt whales and seals.

The 19th and 20th centuries, under the 'heroic age,' saw many explorers venturing to search the elusive continent culminating in the two landmark expeditions to South Pole led by Robert F. Scott and Roald Amundsen in 1910-12 and establishing peaks of endurance in a landmass covered by huge thickness of ice, locking nearly 70% of the world's fresh water resources.

The significance of this icy continent was soon realised and major initiatives to conduct scientific study of entire earth, including Antarctica, with involvement of 67 nations was planned by International Council of Scientific Union (ICSU) in 1957-58 under the auspices of the International Geophysical Year (IGY). This development came in view of the successes of two previous International Polar Years (IPY) during 1882-83 and 1932-33. Availability of better technology and transportation facilities and more or less known geography of the continent, helped in planning and executing the scientific objectives of the IGY. Twelve nations namely- Australia, Argentina, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, UK, USA, and USSR established about 50 over-wintering stations to conduct wide ranging studies in the fields of atmosphere, astronomy, biology, geology, geophysics, glaciology etc.

Figure. 2 Grounding of MV Ushuaia with 82 Passengers and 40 crew on Dec. 4, 2008

The wealth of data that was collected over 18 months of IGY, encouraged member-nations to work out a strategy that could continue the international cooperation gained in IGY and avoid conflicts due to overlapping territorial claims. The efforts culminated in signing of the Antarctic Treaty in 1959, which finally came into force in 1961. Over the years, the Treaty developed into a comprehensive Antarctic Treaty System (ATS) with adoption of several measured to strengthen the goals of Treaty.

RISK ASSESSMENT

It soon became obvious to Treaty members that pristine nature of Antarctica needs to be preserved from large scale tourism, invasive non-native species, increasing human imprints, rise of non-governmental activities, unregulated fishing and accidents. The seriousness of impact of climate change on Antarctica was also recognised by early sixteen's when data about increasing CO_2, Ozone hole and influence of anthropogenic activity on Antarctica were established as the major causes requiring urgent global attention.

Impact of climate change of Antarctica:

EU's Copernicus Climate Change Service (C3S) has confirmed that climate change is pushing the planet's temperatures to levels never before experienced by modern humans. The year 2024 has been the first year that has seen temperatures exceeding 1.5^0 C above the pre-industrial times. The last 10 years were the 10 warmest years since the records began. A warming of 2.5^{0}C observed in Antarctic Peninsula over last few decades has been the highest surface warming on the earth. In response to this trend, nearly 90% of the glaciers of the region are in the state of retreat.

The temperature rise has resulted in successive disintegration of ice shelves. Data from National Snow and Ice Data Centre (NSIDC) shows that breaking away of parts of Larsen 'B' ice shelf in 2002 was followed in 2008 by the loss of Wilkins ice shelf. The warm oceans are resulting in eroding of the West Antarctic Ice sheet (Rignot et al., 2008) as seen for the Pine Island Glacier in west Antarctic. Similar or graver is the situation for Doomsday Glacier (also known as Thwaites Glacier, Graham et al 2022) which already accounts for 4% of the earth's sea level rise and loses of 50 billion tons of ice annually.

The significance of this icy continent was soon realised and major initiatives to conduct scientific study of entire earth, including Antarctica, with involvement of 67 nations was planned by International Council of Scientific Union (ICSU) in 1957-58 under the auspices of the International Geophysical Year (IGY)

Studies by Juhi et al (2022) have shown that the decade-long overall increase in the Antarctic sea ice extent (SIE) until 2015, showed a decrease in recent years since satellite records were available". Their studies show a record low of SIE of 2.16×106 km^2 in February 2022, which was 43% lower than the mean extent of the previous February months since the satellite era.

The east Antarctica, which till now was considered free of ice mass loss, is also reported to have suffered loss of sea ice. Studies conducted by Suryawanshi et al (2023) in association with British Antarctic Survey were able to report that since 2016 Antarctica witnessed sudden decrease in Sea ice extent. Antarctica saw extremely low sea ice conditions during each summer from 2016 to 2023, with unprecedented slow ice expansion or retreat in 2023. **The slow ice expansion in Antarctic occurred ahead of the annual maximum on 7 September 2023 with an ice extent of 16.98 million km^2, which was 1.46 million km^2 below the long-term average.** The ice-edge in the Weddell Sea was moved southwards quickly up to 256 km southward in a matter of few days, with an ice area loss of ~2.3 × 105 km^2, equivalent to the size of United Kingdom. "The low ice conditions is likely to have a significant impact on the amplification of global warming (through ice-albedo feedback process), life in the Southern Ocean, the regional ecosystem, ocean circulation, ice shelf stability and sea level rise" –concludes the study.

Impact on Antarctic flora and fauna

Though the cold loving bacteria (psychrophilic) have a vast habitat in Antarctica, the Antarctic flora and fauna thrive on a limited area that is free of snow and ice. The low temperatures, high UV-B radiation, strong winds and other environmental peculiarities especially the climate change put lot of stress on plant growth. Several research investigations are in progress to understand the trends of climate change and their impacts on plant biodiversity, distribution and their adaptations. **Most of the Antarctic fauna, including penguins are threatened, due to dwindling sea ice and changes in the climatic conditions.** Singh, et al (2018) have pointed out that "Antarctic climate change, specially increase in temperatures will results in more water availability and it will lead to (i) increased rates of local and long distance colonization, and (ii) local-scale population expansion, leading to (iii) increased terrestrial diversity, biomass and trophic complexity, (iv) more complex ecosystem structure, and (v) a switch from the current dominance of physical environmental variables to biotic factors".

The Antarctic microbial diversity too is facing the challenge of climate change

Impact of Tourism

The Tourism industry is the largest non-governmental activity in Antarctica that has both positive and negative

Figure 3. Visitor trends, fastest-growing source markets, distribution of visitor sites and growth in tourism activities (data source: IAATO, IUCN issues briefs: @IUCN www.iucn.org/issues-briefs

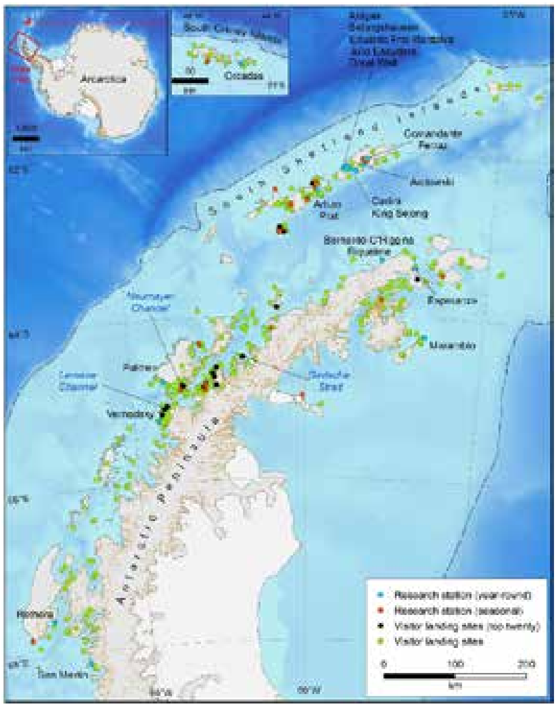

Figure 4. Map of the Antarctica Peninsula region showing the location of major research stations and infrastructure and tourist visitor sites. The dashed line indicates the edge of the continental shelf at 1,000 m depth (Source: Global Change Biology, Online ISSN: 1365-2486 © John Wiley & Sons Ltd)

angles to it, though more negative than the positive. While educational value of tourism to the continent cannot be denied as it raises awareness about pristine environment of Antarctica among the visitors, who then appreciate the values and need for protecting the fragile ecosystem and consequently become strong advocates for promoting the preservation of Antarctic wilderness, the fact remains that large footfall of tourists to limited and focused sites of interest may cause irreversible environmental damage. The negative impacts of tourism compound other threats to Antarctica's biodiversity, which risk the survival of many species and the continent's ability to help regulate the global climate.

EU's Copernicus Climate Change Service (C3S) has confirmed that climate change is pushing the planet's temperatures to levels never before experienced by modern humans

The accidents involving ships in Antarctic waters are also increasing, causing fears of oil spills and loss of life **(Figure 2).**

Tourism, as a profit making industry, started in early 1970 and by 1990s it grew significantly. The report of the IAATO (International Association of Antarctic Tour Operators) shows that number of tourists grew from a few hundred at the beginning of the tourist industry in the 1950s to 38,478 visitors in 2015-2016. The growth of tourism between 1992 and 2020, increased ten-fold, rising to 75,000 in the 2019-20. During 2022-23 season 104,897 tourists visited Antarctica while this figure stood at 122,000 in 2023-24 season.

There were about 65 ships of different sizes and categories engaged in taking people to Antarctic Peninsula and western Antarctica during 2016-17, which varied from small yachts carrying about 12 people to bigger cruise ships capable of ferrying more than 500 passengers. **The wide ranging activities of visitors include: ship-based cruises, sightseeing, visits to historical and wildlife sites, hiking, kayaking, mountaineering and scuba-diving etc. (Figure 3 and Figure 4).**

The Antarctic Peninsula region remains the most visited region in Antarctica due to ease of approach. Recently, tourists have also started using dedicated flights to camp at interior places for short durations (e.g. White Desert).

The Antarctic tourism has a high carbon footprint. These activities stand to cause damage to the sites visited and disturb the wildlife. **Research has shown that tourist activities are causing penguin species to change their reproductive and social behaviours.** During the 46th Treaty meeting held at Kochi, India in 2024, some State parties raised the issue of dwindling population of emperor penguins and stressed the need to declare as an endangered species. Concerns about the impact of tourism activities have been raised in nearly all the meetings of Antarctic Treaty held annually and several recommendations, Measures and Decisions have been arrived at for implementation.

Though India has not promoted tourism as of now, but it has been argued (Ravindra, 2018) that in view of providing a fair chance to Indian Tourism industry vis a vis the international practice as also considering the increasing demand from enthusiastic Indians who have to travel to Argentina or Chile to board a tourist ship and pay a hefty amount, India may consider to encourage responsible and regulated tourism.

Non- native species

The issue of accidental introduction of non-native species to Antarctic environment threatens its ecosystem and biodiversity and has been under discussions among the environmentalists, biologists and several dedicated research groups as this has the danger of resulting in adversely impacting the Antarctic environment and associated ecosystem. Human activities such as, ships touching Antarctic coast, flights landing on make-shift runways, establishment of research stations, building of habitats and replenishment of machinery, goods, food and other products give rise to unintended induction of species that are not indigenous to the local environment.

That non-native species present an increasing risk to pristine Antarctic ecosystems, has been raised by Hughes et al (2016) who state that these can reduce biodiversity, alter the habitats of native species and may result in mass extinction of some delicate species. The Antarctic Peninsular region has emerged as a main area that is under threat.

A study conducted at the request of Treaty nations and headed by Hughes KA et al (2020) identified 103 species, currently absent in the APR, as relevant for review. 13 species were identified as presenting a high risk of invading the Marine invertebrates with flowering plants and terrestrial invertebrates also represented".

INSTRUMENTS TO PROTECT ANTARCTIC ENVIRONMENT

The Antarctic Treaty of 1959 remains, till date the most concise and successful international agreement that has stood the test of time in keeping the icy continent free of any discord and preserving its inherent unique intrinsic values. The preamble of the Antarctic Treaty recognises that "it is in the interest of all mankind that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord. In furtherance to this and to achieve the objectives of the Treaty, it recommends under Article

IX measures for: the use of Antarctica for peaceful purposes only; facilitation of scientific research and international cooperation and preservation and conservation of living resources in Antarctica among others.

The need to have an internationally binding agreement to safeguard the pristine Antarctic environment and dependent and associated eco system, emanated from initiative of a few consultative Parties of the Antarctic Treaty System (ATS) at a time when negotiations on regulating mineral activities in Antarctica (Convention on the Regulation of Antarctic Mineral Resource Activities- CRAMRA), were at an advanced stage.

The accidents involving ships in Antarctic waters are also increasing, causing fears of oil spills and loss of life

In spite of the initial resistance from some claimant Parties, 'The Protocol on Environmental Protection to the Antarctic Treaty or the Madrid Protocol, was signed in 1991 and entered into force in 1998. This historical step gave teeth to the ATS by putting various articles in place that ensured protection of scientific, historical and intrinsic values of the Antarctic environment. There is sufficient emphases on the wilderness and aesthetic values that make Antarctica so unique and challenging. The Protocol has proved vital to achieve the global goals for preserving nature, climate and sustainable development.

The support and commitment to the Antarctic Treaty and the Madrid Protocol, has been reaffirmed in 2009 (XXXII ATCM) and 2016 (XXXIX ATCM), during their 50th and 25th anniversary, respectively

Madrid Protocol as a tool to protect Antarctic environment

The Protocol on Environmental Protection to the Antarctic Treaty, popularly called Madrid Protocol, designates Antarctica as a "natural reserve, devoted to peace and science" (Art. 2). Article 3 of this Environment Protocol sets forth basic principles applicable to human activities in Antarctica and Article 7 prohibits all activities relating to Antarctic mineral resources, except for scientific research. The Protocol establishes in its Schedule the procedure for the constitution and function of a Permanent Court of Arbitration.

Article 2 mandates that the Parties commit themselves to the comprehensive protection of the Antarctic environment and dependent and associated ecosystems. There is no end date prescribed for the Protocol. It only provides for a review. If a review conference is called, it can be modified or amended by a majority of all Parties, including three-quarters of the Consultative Parties at the time of the Protocol's adoption. Any modifications or amendments will only enter into force with the agreement of all 26 Consultative Parties that adopted the Protocol in 1991. Additionally, the prohibition on Antarctic mineral resource activities in Article 7 cannot be removed or amended unless a binding legal regime on Antarctic mineral resource activities is in force. The introduction of such a regime would require consensus.

The Protocol also provides broad rules for tourism, though day-to-day management is mostly regulated by the International Association of Antarctica Tour Operators (IAATO) that places its reports before the State Parties during annual meetings of the Antarctic Treaty members.

Many researchers and conservation organisations are concerned that self-regulation is no longer sufficient to protect Antarctica's wildlife and ecosystems from the impacts of tourism. Measures are therefore needed to better protect the environment of Antarctica from tourism. There are gaps in existing governance frameworks. Accordingly, ATCM has decided to draw framework on regulation of activities related to tourism. The modalities of this were discussed during 45th and 46th meetings of the ATCM at Helsinki and Kochi in 2023 and 2024 respectively. The framework and rules are expected to be finalised and adopted by 50th anniversary of Madrid Protocol.

On the question of Non- native species, experts recommend that the species identified in Antarctic Peninsula during the horizon scanning be kept under surveillance and this be extended to other areas of Antarctica. The experts have also cautioned that "without the appropriate biosecurity measures, the invasions of non-native species are likely to increase, resulting in negative consequences for the biodiversity of the whole continent" (Hughes, et al 2020).

Treaty and the provisions of protection

The guiding principle of Antarctic Legal regime is founded on following guiding principle:

"....maintain, protect and preserve the aesthetic and wilderness values of Antarctic environment and its dependent and associated ecosystem, keep it free from any military discord and recognise it as a continent devoted to Peace and science"

The Environmental laws are therefore fundamental to the Antarctic Treaty and its sustainability, more so in the present day situation.

The Article 16 of the Protocol on Environmental Protection to Antarctica Treaty contemplates that State Parties

> "ensure comprehensive protection of the Antarctic environment and its dependent and associated ecosystems......."

It also asks the Parties to undertake to elaborate rules and procedures relating to "liability for damage arising from activities taking place in the Antarctic Treaty Area……"

For the sake of avoiding accidents and ensuring that liability for such incidents is recognised, an Annex to the Protocol referred as "Liability Annex " has been framed and State Parties have been encouraged to adopt the same . The said Annex includes:

a. Preventive Measures to reduce the risk of environ. Emergencies (Art 3)

b. Contingency Plans (Art 4)

c. Prompt and effective Response Action (Art 5)

d. Liability in absence of prompt action/damage limit of liability (Art 6 & Art 9)

> **"There were about 65 ships of different sizes and categories engaged in taking people to Antarctic Peninsula and western Antarctica during 2016-17, which varied from small yachts carrying about 12 people to bigger cruise ships capable of ferrying more than 500 passengers"**

The ATCM is supposed to frame laws and regulations to act against the "operators" within the Limits of Liability (Art 9). Modalities to determine cost of environmental damages, the process of arbitration to pronounce liability, management of the Fund (Art 12) remain as the critical issues, which need further discussions.

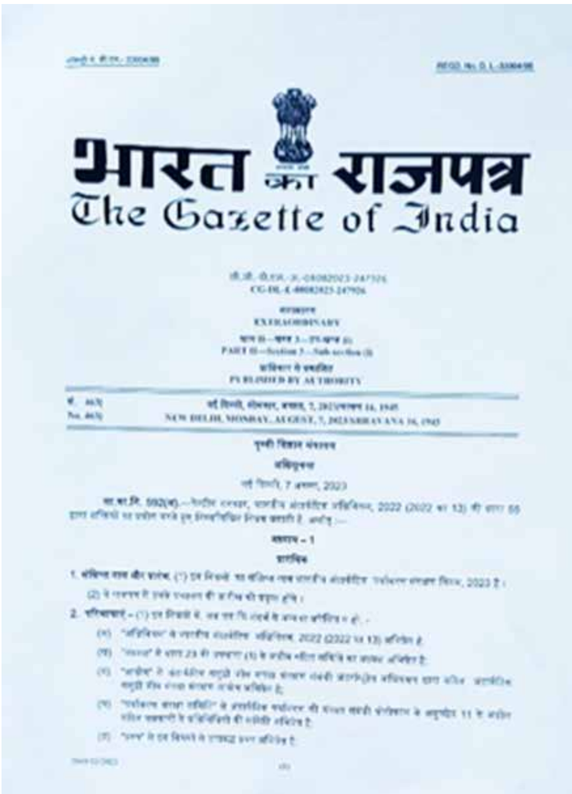
भारत का राजपत्र
The Gazette of India

Figure 5. Gazette Notification of the Rules to Indian Antarctic Act 2022.

Some State Parties, including India, have made substantial progress towards framing national legislations as an initial step towards approving the Liability Annex.

Committee for Environmental Protection

Perhaps the most significant act of the Madrid Protocol has been to establish a Committee for Environmental Protection (CEP) through Article 11. All the States, party to the Antarctic Treaty, are entitled to be members of the CEP. Over the years the CEP has attained an important place in the ATS and has taken central stage in playing a crucial role in ensuring effectiveness of measures taken pursuant to the Protocol. The CEP has outlined detailed Rules and Procedures, under which its meetings and deliberations are held concurrently with the meetings of the Antarctic Treaty Consultative parties (ATCM) to which it forwards all recommendations for final approval. Since science plays a crucial role in most of the environmental issues, CEP takes advice of SCAR (scientific Committee on Antarctic Research), CCALMR (Committee for the Conservation of Antarctic Living marine Resources and other relevant scientific, environmental and technical organisations.

Protecting the Wilderness and Aesthetic Values

Antarctica is rich in its wilderness and aesthetic values together with the scientific elements that have been identified over the decades of research and exploration. The earlier expeditions launched in the continent have left huts and marks that speak of the courage and endurance of human spirit to unearth the "unknowns". These huts and monuments build in the memory of explores who laid their life, represents a history of Antarctic exploration and therefore need to be preserved as Historical Monuments.

In order to preserve these and other intrinsic values of Antarctica, ATCM has made provisions under ANNEX V to the Madrid Protocol for "Area Protection and management". The said Annex has 12 Articles that deal in detail about objectives and criteria for designating relevant areas as Antarctic Spatially Protected Area (ASPA), Antarctic Specially Managed Area (ASMA), Historical and Monumental Sites (HSM) etc.

An area may be designated an ASPA to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of these values, or ongoing or planned scientific research. The area to be designated as such say, for the Conservation of Antarctic fauna and flora, breeding sites of native birds or mammals, type locality or only known habitat of a species, area of particular scientific interest, sites of outstanding geological, glaciological or geomorphological features, sites of outstanding aesthetic and or wilderness value etc. must be defined by geographical coordinates and maps and have a management plan (Article 3, of ANNEX V).

On the other hand, an area where activities are being conducted or may be conducted in the future, may be designated as an ASMA, to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between Parties or minimise environmental impacts (Article 4, of ANNEX V) .The ATCM has adopted guidelines to assist Parties in selecting sites for designation and in preparing management plans.

> *"The earlier expeditions launched in the continent have left huts and marks that speak of the courage and endurance of human spirit to unearth the "unknowns""*

A permit is required for entry into any ASPA site. Several State parties such as Australia, Argentina, Chile, China, France, Italy, India, Korea, New Zealand, Norway, Poland, Russia, Spain, United Kingdom and United States have designated the ASPAs. There are currently 78 ASPA sites, numbered serially from 101 to 178. Under this list, India has designated two sites one is the Dakshin Gangotri Glacier at Schirmacher Hills in Central Dronning Maud land while other is the Stornes Peninsula in Larsemann Hills. The latter is in association with Australia, China and Russia.

The ATCM under the protected areas, has also designated 7 sites as Antarctica Specially managed Area (ASMA) and 95 sites as Historical Sites and Monuments (HSM) according to guidelines adopted in 2009. There are also 2 Marine Protected sites (MPA) located in Ross Sera Region and South Orkney Island (Southern Shelf). Among the ASMAs, India in partnership with Australia, China, Romania and Russia manages an ASMA in Larsemann Hills.

Among some of the famous HSM are HSM 15, HSM 16 and HSM 18 that relate to Shackleton's Nimrod Hut and Scott's Terra Nova and Discovery Huts in Ross Sea Region, respectively.

India also maintains two Historical Sites and Monuments in Antarctica. These are designated at HSM 44 and HSM 78 and relate to the site of Dakshin Gangotri Station and a Memorial Plaque at Humboldt Mountain, respectively. The Plaque was erected in memory of the four Indian expedition members (V K Shrivastava, B L Sharma, A K Bedi and N C Joshi) who lost their lives at this camp in 1990.

The Indian obligation

India being a signatory to the Antarctic Treaty as also to the Madrid Protocol, has an obligation under Art 15 and Art 16 of the Protocol to

(i) provide for prompt and effective response action to environmental emergencies,

(ii) establish contingency plans for incidents with potential adverse effect on Antarctic environment and dependent and associated ecosystem, and

(iii) formulate elaborate Rules and Procedures relating to liability for damages arising from activities taking place in Antarctica

(iv) formulate laws on jurisdiction issues of Indian nationals in Antarctica

There are several laws existing in India that pertain to environmental Protection , such as: the Environmental (Protection) Act 1986 including ozone depleting substance (Regulation and Control) Rules, 2000, Wild Life Protection Act (1972) with Amendment in 2002, Water and Air (Prevention and control of pollution) Acts of 1974 & 81, The Biological Diversity Act, 2002 in tune with the UN Convention on Biological Diversity, Hazardous Wastes (Management & Handling) Amendment Rules 2003, etc. However, as jurisdiction of these laws did not extend to Antarctica, an Act, named as ""the Indian Antarctic Act" was enacted in 2022 to take care of its obligation towards protecting and preserving the Antarctic Environment. The Rules to this Act were framed

Subsequently and notified as "The Indian Antarctic Environmental Protection Rules, 2023" (Fig 5).

The CGA-EP

The Indian Antarctic Act 2022 provides for constitution of a high level Committee headed by the Secretary to the Government of India, Ministry of Earth Sciences with members from several Central Ministries and three independent experts to oversee the functioning and operation of the Act. The Committee is named as 'Committee on Antarctic Governance and Environmental Protection (CAG-EP)' and is mandated to provide a stable, transparent and accountable process for the sponsorship and supervision of Antarctica, ensure the protection and preservation of environment and to ensure compliance by Indian citizens engaged in the Antarctic activities to relevant rules and internationally agreed standards .

The CAG-EP has been authorised to receive applications and issue permits for Indian citizens to visit Antarctica, designate the areas to be considered as Antarctic Specially Protected Areas or Antarctic Specially Managed Areas or marine and coastal protected areas and designate Areas to be considered as Historic Sites and Monuments or sites of Cultural Heritage.

It has also been mandated to seek environmental impact assessments from the seekers of permits for visiting Antarctica, if the impact of their activity on Antarctic environment is believed to be more than minor. It enforces strict regulations for waste management plans and emergency plans for the purposes that must be in place for all the visitors.

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About the Author

Dr. Rasik Ravindra, is the current Chair of INSA National Committee of SCAR (Scientific Committee on Antarctic Research), Member of the National Committee on Antarctic Governance and Environmental Protection (CAG-EP) and member of the Governing Body of National Centre for Polar and Ocean Research (NCPOR), Goa. He held the position of Director, NCPOR between 2006 and 2012, after putting 35 years of active service with Geological Survey of India. A veteran geologist his area of activity has been the Polar areas – Arctic, Antarctic and higher Himalaya where he has contributed since last forty years and led several expeditions to all the three regions, including the one to South Pole. He has led the Indian delegations to the Antarctic Consultative meetings held between 2006 and 2012.

He has been awarded the National Mineral Award, National Award in Polar and Cryosphere, SCAR Medal for International Coordination, IGU Gold Medal, Antarctic Award, Life Time Achievement Award by Paleontological Society of India, Professor West Oratory Award by Dr Hari Singh Gour University, among others.

Email: rasikravindra@gmail.com

Going Astern into MER Archives…

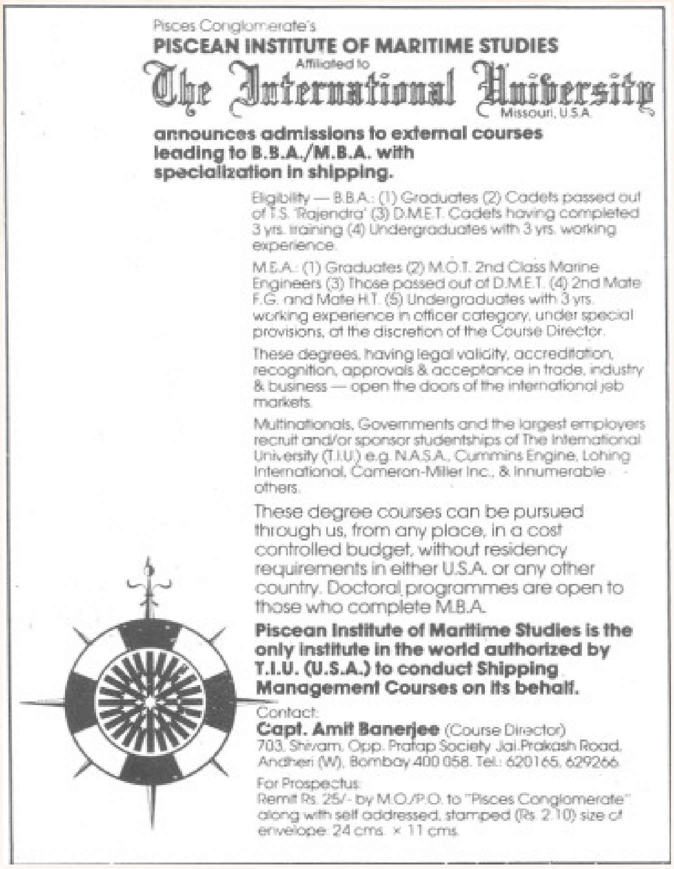
The Editorial comments on MARPOL and the idea of reception facilities. There are some statistics talked about (assume for 1985). It would be interesting to compare these in present times: Total oil discharged in the seas: 5 M tons. Mediterranean Sea related data: Oil discharged 1.7 M Tons; 19 Crude loading terminals/ exports 360 M Tons. Biggest Port: Rotterdam; Cargoes handled: 250 M Tons out of which 125 M Tons of Crude & Chemicals. Cost of erecting a reception facility: US$3-100 M. Japan planning for floating reception facility. The Editorial's emphasis: More reception facilities are needed.

So, are there any data on the status today, after 4 decades?

The next appeal is on an advertisement [extract inserted; Pisces Institute of Maritime Studies]. Any one has news on how many got these Degrees and the status of the Institute?

The technical articles line-up start with Gears and move on to shafting, and one on training at Hong Kong Poly. Three interesting articles on following topics spotted: crankcase explosions, hydraulic machinery noises and 'engineering economics as a tool in ship decisions' . The issue carries one Transaction: A Review of the Quality of Residual Fuels Supplied to Motorships Worldwide (Read on Feb 1983).

POSTBAG has interesting discussions on turbo generators and engine units' numbering convention.



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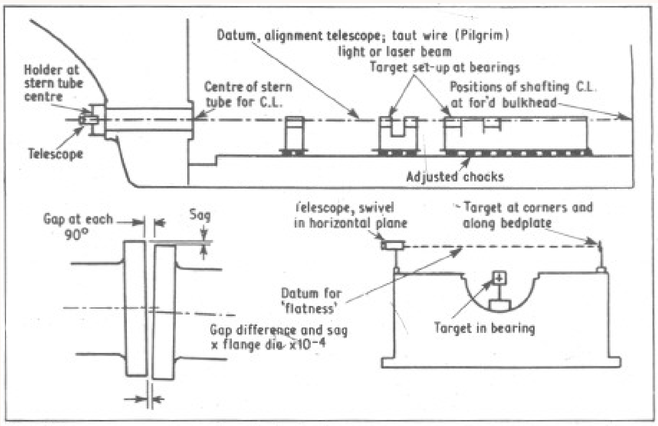

Fig. 2: How measurements are taken for shaft alignment.

POSTBAG

Advanced WHR turbogenerator systems

Sir,
Mr Croxon's article (MER Nov 84) was interesting reading but the word 'advanced' seems to have lost its meaning. For instance, the Sumitomo advanced system referred to as a 'combined turbo-generator and shaft generator system'. It is nothing of the kind.

It is a separate turbo-generator and separate shaft generator system. Indeed, the turbine itself is only a single-pressure unit, although it is agreed the exhaust gas boiler (economiser) is dual pressure. There is nothing new or advanced in this. Ships have been at sea for some years now with a turbo-generator and shaft generator system running in parallel.

We do have, though, a real combined shaft generator/turbo-generator system, which is currently in production. While there has been talk of such possibilities in the past we have actually engineered it in collaboration with Siemens. It utilises a Senior-Green 'Diesecon' exhaust gas boiler (economiser). Admittedly, the actual production unit is only a single-pressure system, but the client was given the option of a dual (plus) pressure boiler and even a dual-pressure turbine. The economics in this particular instance did not justify the additional expense, but maybe the next time it will.

A combined shaft generator/turbo-generator system means just that. The main supply generator receives input power essentially from the available waste heat via the turbine and any power make-up is supplied from the (variable frequency) shaft generator to the main generator via a dc motor drive. This means that, whatever the trading pattern of the vessel at any one time, all available waste heat is transformed into electrical energy.

The system's control has been carefully engineered to the extent that, in the case of manoeuvring or at sea when there is a sudden call for refrigeration load, as in a containership, the power management system automatically introduces a diesel generator or generators as the need arises.

But one does not necessarily have to consider electrical augmentation of the waste heat turbo-generator. We have too, in the case of retrofits, introduced a hydraulic augmenter to the turbo-generator.

Kawasaki's 'super economic' system (despite the claims made about dispensing with diesel generator/turbo generator paralleled operation) is simply a 'slave' turbine connected to the main engine—an alternative 'supercharger'. It relates to medium-speed engine operation and it is interesting to record that we did initial exercises for SEMT on such a system, and indeed the IHI type, many years ago.

I notice, too, the claims on output being made for certain boiler installations but I also notice the outlet gas temperature that is now being talked about, namely 130 °C. Of course, there is more extractable heat available as outlet temperatures are reduced. If an owner is prepared to accept the idea of renewable boiler sections there is no reason why such concepts should not be put into practice.

So it all comes down to cost, both initial and operational and this seems to be missing from the article. An owner can have anything as long as he pays for it, but he does have to consider the return on capital.

John Gilbert

Peter Brotherhood Ltd,
Peterborough.

Mr T Croxon replies:
The term 'Advanced' refers, of course, to a turbo-generator system capable of supplying a ship's total electrical load utilising waste heat from a modern diesel engine. 'Conventional' systems are those unable to achieve this.

As regards the combined system of Sumitomo's, I do make it clear that it is a combined turbo-generator and shaft generator system and the mode of combination is explained in the article.

Mr Gilbert's comment that Kawasaki's system is simply a 'slave turbine' being 'an alternative supercharger' is incorrect. The engine shown is fitted with turbo-chargers. I am not clear as to the expression 'slave turbine' in the sense used by Mr Gilbert. In a sense, all turbines operating on steam generated by exhaust gas are 'slaves'.

Concerning reduced outlet temperatures, and Mr Gilbert's 'renewable boiler sections', I do state in the article that, with the Mitsui system, tube life is lengthened by the use of corrosion resistant steels in the low-temperature section of the economiser.

Sir,
I wish to draw attention to Fig 8 in Mr Croxon's article on 'Advanced WHR turbogenerator systems', concerning the flow diagram of Hitachi's system. In my opinion the arrow showing the steam flow direction from the HP separator should be reversed to indicate supply of steam to the superheater.

M A Iqbal

Chief Engineer
MT 'Five Brooks' Kuwait

● *Mr Iqbal is quite correct—Ed*

Wrong number

Sir,
Situation: No 7 big-end bearing is due for survey. The bearing is opened up. The Lloyd's surveyor arrives with the Chief Engineer and 2nd. Other engineers are on stand-by to start boxing back the bearing as all engineers are sure that the bearing halves, pin, webs and bolts are in good condition.

On the contrary, the surveyor says 'Wrong Number'. You should have opened up No 7 and not No 2. This meant 4×6 manhours thrown away.

The manufacturers of the engine numbered the cylinders from aft to f'wd, ie, No 1 unit nearest the flywheel, but Lloyd's Register number them from f'wd to aft. What stupidity and a waste of manhours on such a 'minor thing' as numbering.

Will engine makers and classification societies please agree on a standard. I suggest units are numbered f'wd to aft for longitudinally mounted engines and port to starboard for transverse mounted ones.

A K Asamoah

MV 'Iran Borhan'

The editor welcomes readers correspondence on all articles and topics discussed in MER.
News and articles are also most welcome. Please address correspondence to the Editor, 76 Mark Lane, London EC3R 7JN.

Swan Hunter privatisation

Sir,
I would draw your attention to errors of substance in your December 1984 issue concerning the bid for Swan Hunter.

Neither the Deputy Chairman of British Shipbuilders nor any Board Member are parties to bids for their wholly-owned subsidiaries which are scheduled to be privatised.

As the then Deputy Chairman of Swan Hunter, I announced my intention of joining two other Swan Hunter Directors in mounting a bid for Swan Hunter. Simultaneously with that announcement, on 5 November 1984, I relinquished all my positions in British Shipbuilders, thus avoiding any possible conflict of interests.

British Shipbuilders is not providing funding to aid a take over of Swan Hunter. Up to 50% of the documented costs of mounting a bona-fide management/employee buy-out of any of the BS subsidiaries scheduled for privatisation will be met by BS. In the event of a successful bid these costs will be repayable to BS.

I suggest that there is nothing 'odd' in the above situation. A nationalised industry is fulfilling the wishes of the Government of the day, and the individuals involved have scrupulously adopted the highest levels of business ethics.

You may care to set the records straight!

K R Chapman

Stocksfield,
Northumberland

● *We do not feel that our version constitued an 'error', but are grateful to Dr Chapman for explaining the situation.—Ed MER.*

We invite observations, discussion threads from readers, taking cues from these sepia-soaked MER pages. – Hon.Ed.

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