SaGAA 7 | THE PEOPLE

The Future of Arctic Ice

An Indo-Pacific Connect

April 27-28, 2023 • India International Centre • Max Mueller Marg • New Delhi

Norwegian Embassy
New Delhi

Ties between Norway and India have deep historical roots, as early as the 1600s. In 1952, the "India fund" was established" with the aim to provide development assistance with a focus on fisheries. The same year, Norway opened its Embassy in New Delhi. In recent years, Norway has significantly strengthened its presence in India. The Consulate General in Mumbai re-opened its doors in 2015. In 2019, Norwegian Prime Minister Erna Solberg inaugurated the newly constructed and energy-efficient Embassy complex in New Delhi. India's developments will have a significant impact on how successful the world is in achieving the Sustainable Development Goals (SDGs) and global climate targets. Its geopolitical role, its large population, its long coastline and, not least its booming economy make India an increasingly influential regional and global player, and an important partner for Norway.

In December 2018, the Norwegian government launched a new 'India Strategy'. The strategy sets clear priorities for the Norwegian government until 2030 and gives renewed impetus to develop our bilateral cooperation. The India strategy outlines five thematic priorities:

- **Democracy and a rules-based**
- **world order**
- **The oceans**
- **Energy**
- **Climate and Environment**
- **Research, higher education and**
- **global health**

To achieve these objectives, Norway focuses on political contact and cooperation between the authorities, business cooperation, and research cooperation.

Norway's Foreign Mission in India also includes the Consulate General in Mumbai. The Ambassador in New Delhi is also responsible for the Honorary Consulates in Kolkata, Chennai and Bhutan.

To know more about Norway-India relations visit the following:

Norway in India
- https://www.norway.no/en/india/

News and Events
- https://www.norway.no/en/india/norway-india/news-and-events/

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The 7th Conference on Science & Geopolitics of

ARCTIC-ANTARCTIC

The Future of Arctic Ice

An Indo-Pacific Connect

PRE-CONFERENCE MATERIAL
April 2023

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The Prelude

The Conference on Science and Geopolitics of Polar Regions Arctic and Antarctic is being held with an objective to develop a synergy in the geopolitics and scientific studies of earth-atmosphere and ocean processes in the three regions of the Earth. This will help understand the processes that influence the variability in polar climate and influence our monsoons at millennial, decadal or even annual scales.

It is well known now that the thermohaline circulation that originates in the North Atlantic and southern Arctic is a major force driving not only the oceanic circulation but also regulating the global climate. A link between cold episodes in the North Atlantic and weakened Asian monsoon during the last glacial period has indicated the links between Asian monsoons. Scientists have also observed that deficient monsoon years were preceded by more than normal sea-ice extent and vice versa. Indian scientists have braved the vagaries of harsh Polar climate and added greatly to the international scientific knowledge of these areas. India's interest in Polar Regions is essentially driven by these links as also by our past geological connection and relative position in the Gondwana supercontinent and its fragmentation.

SaGAA has been institutionalised to synergise research of several institutions and universities that are active in cryosphere studies in the country. The active participation of a wide spectrum of scientists, administrators and students reflects growing concern of the nation towards response of climate change on glaciers and icecaps world over. SaGAA has been successful in bringing eminent scientists working in diverse subjects such as glacial, environmental, social and political fields together to add to the better understanding of issues involved and give relevant advice to policy makers.

(Dr Sulagna Chattopadhyay)
President,
SaGAA 7

(Prof N C Pant)
Co-Chairman, Organising
Committee, SaGAA 7

(Dr Rasik Ravindra)
Chairman, Organising
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May 29 – June 8, 2023
Helsinki ~ Finland

XLV
ANTARCTIC TREATY CONSULTATIVE MEETING

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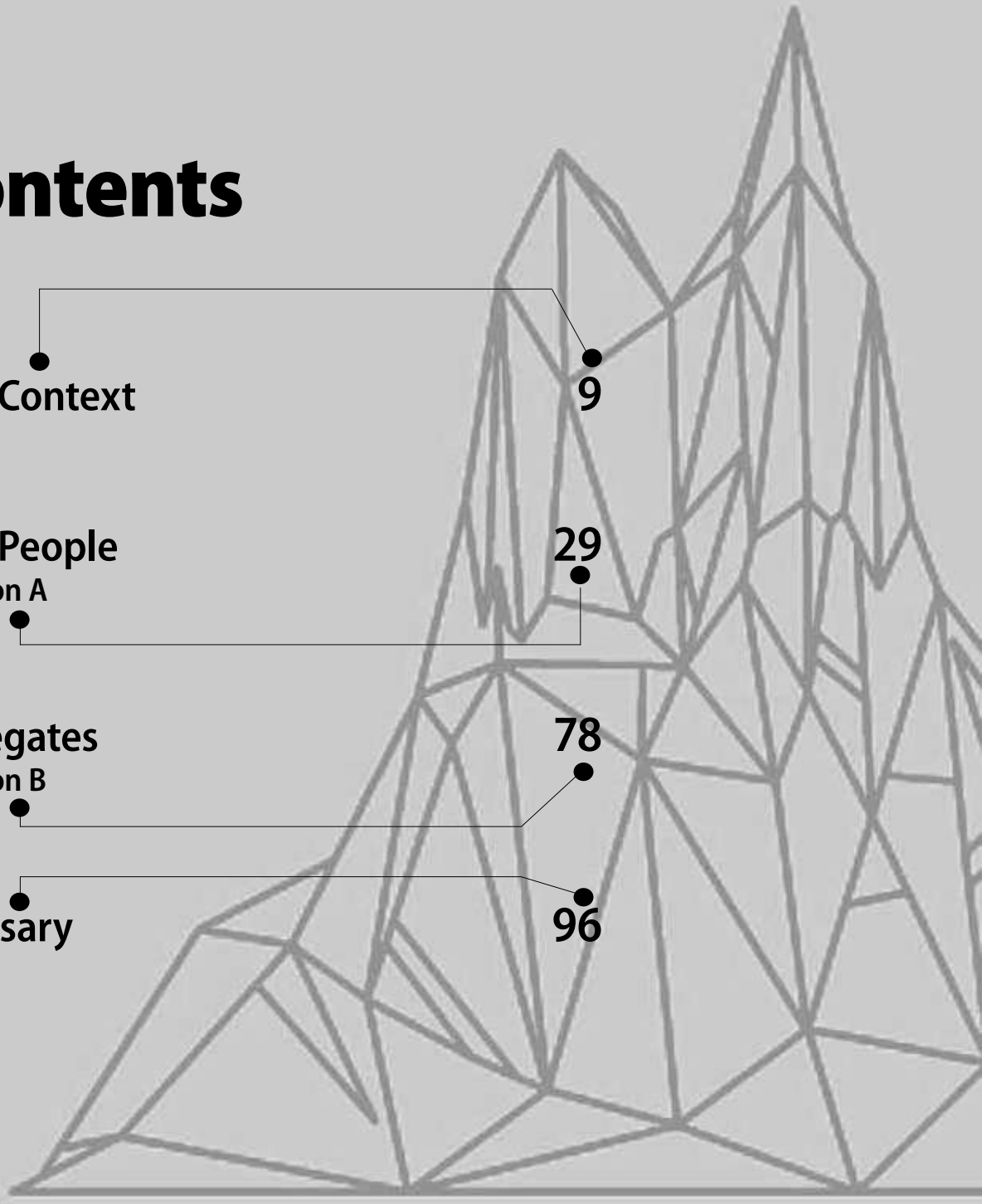

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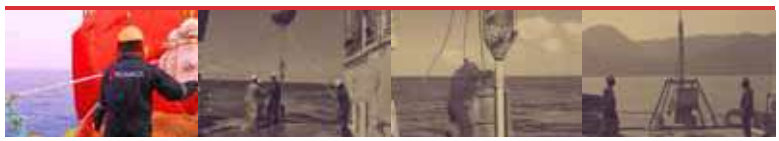

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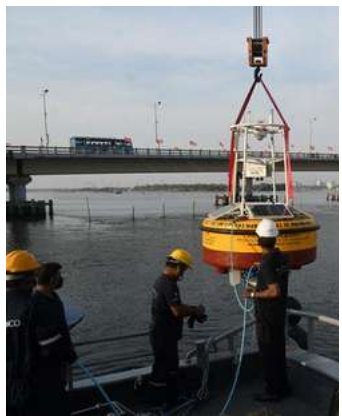

G20 भारत 2023 INDIA

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पृथ्वी विज्ञान मंत्रालय
Ministry of Earth Sciences

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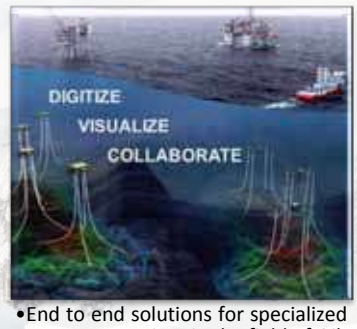

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The bridging together of scientists, policymakers, and academia has been the seminal effort of SaGAA-LIGHTS since 2009. The idea is to formulate the comprehensive dialogue that envelops diverse concerns and opportunities in the backdrop of constant change in the climatic and in the geopolitical context. India has cherished the values of the Common Heritage of Mankind and has contributed to upholding it in all matters pertaining to the global commons, whether it is on the high seas or in the distant frozen lands of the Antarctic. The following sections succinctly encases the concerns that the forum intends to address through its conferences, writing, papers, or representations.

A Changing Climate

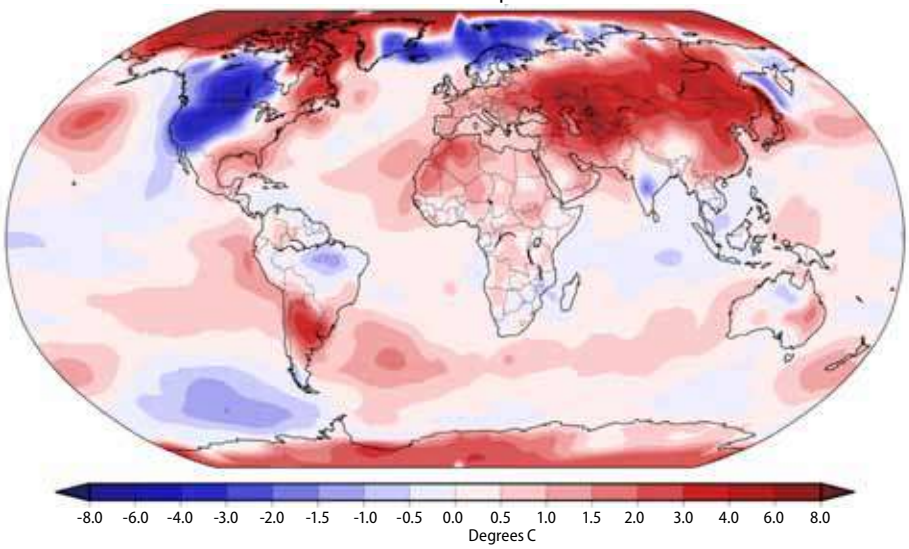
In recent years, the issue of climate change has become increasingly concerning. The Sixth Assessment Report of IPCC has confirmed that global warming is leading to increased frequency and intensity of extreme weather events, droughts, and tropical cyclones (IPCC, 2021). The world has surpassed an average global temperature of 1.2°C, which was the average global temperature limit set in the Paris Accord of 2015. The Report explicitly recognises that global warming is primarily caused by human activities and that policymakers have been slow to respond to the extensive warnings of the scientific community. Climate discussions are complicated by the lack of agreement between scientists and policymakers, as well as by the inclusion of other interests/variables, business opportunities, and economic constraints all of which are entangled in a stranglehold of low political will making it challenging to take adaptive action. Therefore, it is crucial to raise awareness and engage in multiple platforms to encourage faster climate action. Interestingly, not all regions of the world are warming at the same rate as the polar regions are experiencing accelerated warming compared to the oceans and equatorial regions, making it difficult to obtain a clear picture. The Arctic, which is the focus of the SaGAA Conference, has warmed nearly four times faster than the global average in the last four decades (Retanen et al., 2022).

The Arctic, Antarctic, and Himalayan cryosphere are particularly vulnerable to the impact of climate change and their rapidly changing conditions are a cause for concern. In the Arctic, temperatures have risen twice as fast as the global average in the past 50 years (NASA, 2021). This has led to the melting of sea ice resulting in decline of the Arctic sea ice extent by an average of 12.8 per cent every decade since satellite records began in 1979 (NSIDC, 2021). Similarly, warming trends have been observed in the Antarctic, particularly in the West Antarctic Peninsula, where temperatures have increased by 2.5°C over the past 50 years (Turner et al., 2016). This warming has resulted in significant ice mass loss, primarily from the melting of ice shelves, which has the potential to contribute to sea level rise (Rignot et al., 2019). In the Himalayan cryosphere, warming has resulted in the retreat of glaciers that are a critical source of water for millions of people living downstream. Studies suggest that Himalayan glaciers have lost over 15 per cent of their volume since the 1970s, with the rate of loss accelerating in recent years (Mukherjee et al., 2020) severely affecting the regions where water scarcity is already an issue. Overall, the warming trend observed in the Arctic, Antarctic, and Himalayan cryosphere underscores the urgent need to reduce greenhouse gas emissions and mitigates the effects of climate change. Failure to address the issue could poorly impact the planet's ecosystems and the life dependent on them.

Recent Cooling Trends

Despite the cooling effects of La Niña, the year 2022 was the sixth warmest year on record (WMO, 2022). According to WMO, this cooling effect is temporary and will not reverse the long-term warming trend caused by high levels of greenhouse gases in the atmosphere. The WMO predicts a 60 per cent chance of La Niña persisting until March 2023, after which conditions are expected to be ENSO neutral. However, even with the cooling impact of La Niña, 2022 was still marked by extreme weather events that are linked to climate change (United Nations 2023). These include catastrophic flooding in Pakistan, deadly heatwaves in China, Europe, and North and South America as well as ongoing drought and hardship for millions in the Horn of Africa. Additionally in late December, severe storms caused widespread damage across North America, including high winds, heavy snow, flooding, and low temperatures.

Land and Ocean Temperature Departure from Average March 2023
(with respect to a 1991-2020 base period)
Data Source: NOAAGlobalTemp v5.1.0-20230406



Land and Ocean Temperature Departure from Average March 2023
Source: NOAAGlobalTemp

Record levels of greenhouse gases in the atmosphere continue to cause a long-term warming trend that will ultimately lead to more severe weather events. While La Niña may have provided temporary relief from extreme heat, it did not address the root cause of climate change. In conclusion, the La Niña phenomenon prevented 2022 from being the warmest year on record, but the cooling impact was temporary and did not reverse the long-term warming trend caused by high levels of greenhouse gases. Furthermore, extreme weather events linked to climate change such as flooding, heat waves, and drought continue to occur despite the cooling effect of La Niña; therefor, it is crucial to address the root cause of climate change by reducing greenhouse gas emissions to prevent further damage to the planet.

The Arctic

The Arctic was once a largely unknown region having harsh and unforgiving environment making it difficult for human habitation. Despite its vast land area of 16.5 million sq km, it has a population of only 4 million (as of 2020), resulting in a population density of less than one person per sq km. However, increased research efforts from multiple countries have bridged the knowledge gap surrounding the Arctic, shedding light on its climatology, oceanography, ecology, glaciology, anthropology, and exploration geology and as a result, the Arctic is slowly undergoing transformation.

Arctic Warming

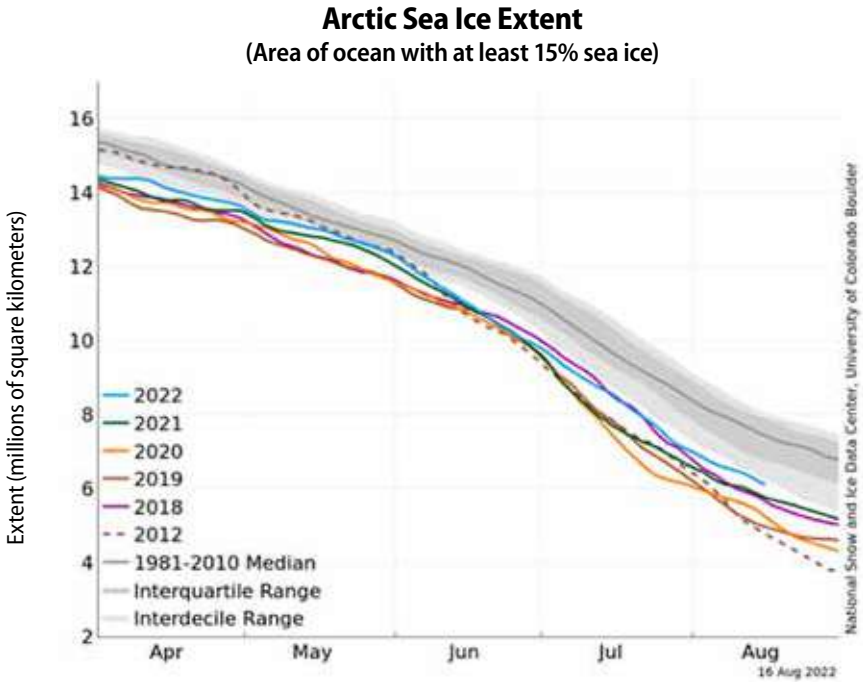
The warming of the Arctic, at a rate double than the global average is causing alterations in sea ice, snow coverage, and the amount of frozen ground in the region. This is an evidence of global warming and its effects will have far-reaching implications at the local, regional, and global levels. The Arctic is melting more rapidly than other polar regions due to its proximity to the industrialised and heavily populated Northern Hemisphere.

Air temperatures in the Arctic during the first half of 2010 were 4^{O}C higher than in the period from 1968 to 1996. Over the past three decades, satellite data have shown a 30 per cent decrease in Arctic sea ice coverage in September 2010, as well as a decline in snow coverage over Arctic land, and the retreat of glaciers in Greenland and northern Canada. The frozen ground in the Arctic has also started to thaw out. Perhaps most alarming is the loss of Arctic summer sea ice, which is melting at a rate of 12.6 percent per decade, according to NASA GCC.

On the other hand, as the Arctic becomes more accessible due to melting sea ice, it opens up opportunities for resource extraction, shipping, and tourism. At the same time, it also raises concerns about the impact on the region's fragile ecosystem, particularly, indigenous communities and the potential for conflict over territory and resources. The melting permafrost and changing weather patterns are affecting traditional hunting and gathering practices damaging infrastructure, such as homes and roads, and threatening food security and cultural heritage. Also, the loss of sea ice and changes in ocean currents are affecting the migration patterns of marine mammals and fish making it difficult for indigenous hunters to access traditional fishing grounds.

Causes of Arctic Warming

The collapse of the Polar Vortex that typically shields the Arctic from warm equatorial air masses, during extreme heat waves or cold snaps, may be responsible for enhanced warming of the region (Petrie, R. E., & Branstator, G. W. 2020). The intensity of the Polar Vortex is determined by the temperature contrast between the Arctic and the Tropics, but this difference is decreasing because of the Arctic's rapid warming. While the Arctic experiences temperature fluctuations due to the strength of the Polar Vortex and the Polar Jet Streams, the occurrence of such temperature spikes has become more frequent and prolonged.



The graph shows Arctic sea ice extent along with daily ice extent data for four previous years and the record low year (as of August 16, 2022).
Source: National Snow and Ice Data Center

Global Impact of Arctic Climate Change

The melting of the Polar ice caps in the Arctic poses a risk of triggering 19 climate tipping points. A climate tipping point is when a natural climate system, such as the ice caps, undergoes a dramatic change. The Earth is an interconnected system and any change in one part of it is bound to send feedback to the other parts including further south. The melting of the Arctic ice caps has ripple effects that can be felt around the globe such as the albedo effect, sea level rise, extreme weather conditions, thawing permafrost, and a threat to biodiversity and the economy.

The albedo effect refers to the reflective ability of any surface, which determines the Earth's terrestrial or outgoing radiation. Thick ice and clouds have a high albedo of around 70-80 per cent which means that they reflect back most of the sun rays as compared to the barren surfaces and open seas that have a low albedo, meaning they absorb the majority of incoming heat. Glaciers and snow, therefore, help in maintaining the Earth's delicate solar insolation balance.

Sea level rise occurs when continental or land-based glaciers melt, raising the level of the sea. The process is evident from the frequent flooding in coastal areas of the USA. Island nations like Indonesia, the Caribbean, Polynesia, and even the Indian Ocean islands are at high risk of losing land to seawater.

India and the Arctic Climate Connections

The Indian monsoon is intricately connected to the Arctic glaciers. Arctic oscillation, which is a climatic pattern characterised by winds circulating counter-clockwise around the Arctic at around 55°N latitude, is also one of the drivers of the monsoon and melting of Arctic ice. Increased ice melting will affect the land-sea temperature differences, resulting in monsoon extremes. India is therefore likely to face frequent hydrological disasters, which will result in homelessness and the migration of millions who live along the coasts.

India and the Arctic Council

The Arctic Council is an intergovernmental forum that promotes cooperation and coordination among the Arctic states, indigenous communities, and other inhabitants on common issues related to sustainable development and environmental protection. At present, eight countries exercise sovereignty over the lands within the Arctic Circle and constitute the member states of the council: Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States. Non-Arctic nations and organisations can become Observers and contribute to the Council's work. The Council has several working groups that focus on reducing emissions, monitoring the Arctic environment, and conserving biodiversity.

India was an original signatory of the Svalbard Treaty and has the right to use the Arctic islands of Svalbard for commercial activities and scientific research. India became an Observer at the Arctic Council in 2013, which allows us to observe but not directly influence the developments in the Arctic Sea region. The region is changing due to global warming and opening up to shipping and hydrocarbon prospecting, leading to broadened areas of interest for the Council. The Kiruna Declaration in 2013 empowered the Council to regulate shipping lanes, hydrocarbon prospecting, and marine resources exploitation.

India has the potential to collaborate with the Arctic Council on matters pertaining to climate change and advance its scientific research in this Region. The impact of melting Arctic ice on the Indian monsoon is well-known, and India can utilise this platform to engage in cutting-edge global research on such issues. Despite the differing bio-climatic settings between India and the Arctic, both regions have a fragile glacial ecosystem in common. India's participation in the Council would facilitate cordial relations with member nations, as demonstrated by existing collaborations with Russia and Norway in the fields of polar sciences, biotechnology, and Earth sciences. As an Observer of the Council, India's field of Arctic research is enhanced, and think tanks can work closely with their Arctic counterparts to understand the evolution of the Arctic sea.

In terms of geopolitics, India could garner support from Arctic Council members for its demand for UN reforms and UNSC membership. Russia has been a long-standing supporter of India's entry into UNSC and in 2011, Norway voiced its support for UN reforms.

Moving forward, India can offer its expertise and engage in partnerships with the Arctic Council and Arctic Nations in various fields such as scientific research and development, oil exploration, and tourism to showcase the natural pristine environment. Additionally, India can

lend its support to the cause of Arctic Nations in international forums. To further strengthen its presence in the North Polar Region, India can also explore the possibility of joining the AEC.

Economic Endeavours of India in the Arctic

With the country's first Arctic research expedition in 2007, India's economic endeavours in the Arctic region are relatively new. Since then, India has been increasingly interested in the economic opportunities the region presents, including the potential for resource extraction, scientific research, and tourism.

One area of focus for India is the exploration of hydrocarbons in the Arctic region. India's energy needs are growing rapidly and the country has been looking to diversify its energy sources. The Arctic region is estimated to hold vast reserves of oil and gas making it an attractive destination for countries like India. In 2013, India became an Observer of the Arctic Council which allowed it to participate in discussions related to the region's energy resources. India's pursuit of energy security through its 'Make in India' campaign has led it to seek out new opportunities with a particular focus on cooperation with Russia and other Arctic Nations. For example, India's ONCG Videsh Ltd has a 20 per cent stake in the Sakhalin-1 project in the Russian sub-Arctic North Pacific. India's collaboration with Russia includes joint oil and gas projects, access to Northern Sea Route for trade, and the development of oil fields. This alliance allows India to diversify its sources of oil and gas, reducing its dependence on politically unstable areas like the Gulf and mitigating the effects of US sanctions on major oil suppliers such as Iran. However, this shift towards fossil fuels poses challenges to India's commitments to the Paris Agreements and the Kigali Amendment necessitating India to balance economic growth with environmental protection.

India has also been investing in scientific research in the Arctic. In 2014, India's NCPOR established a research base in Svalbard, Norway that is used for conducting research on climate change, oceanography, and glaciology. India has also been collaborating with other countries, including Russia and Norway on scientific research projects in the Arctic.

Tourism is another aspect where India sees potential in the Arctic. In recent years, there has been a growing interest in Arctic tourism attracting travellers seeking to experience the unique landscapes and wildlife of the Region.

The Himalaya

It is well-documented that the changes in the Arctic have impact on the Himalayan region (Jan et al., 2021; Arctic Circle, 2022; Sharma et al., 2019, The Third Pole, 2017). This impact is particularly concerning given the significant retreat of glaciers in the region estimated to be around 40 per cent over a period of 400-700 years (Lee et al., 2021). The glacial retreat poses a serious threat to the lives and livelihoods of more than 2 billion people living in the subcontinent, as well as the 0.65 billion individuals residing in the Gangetic plains who will be directly affected. Additionally, the increased melt runoff from the glaciers may lead to flash floods, landslides, and GLOFs.

(Ahmed et al., 2021), (Nie et al., 2021). It is crucial to understand that the upper atmospheric currents in the Arctic, known as Rossby waves, can have a profound impact on weather patterns and cloudburst events in the the Himalaya (Sharma et al., 2019), (Jan et al., 2021). Therefore, comprehending the changes in the Arctic is essential for the future of the subcontinent as these changes may have implications for the sustainability of Indian water resources, which are already under stress from over-extraction and pollution.

Indian Himalayan Region: Its Significance and Threats

The IHR is home to glaciers that serve as the primary source of three major river systems - Indus, Ganges, and Brahmaputra. These rivers provide water to millions of people, earning the Himalaya the nickname 'Water Towers of Asia'. The glaciers play a significant role in maintaining water availability even after the monsoon season by contributing to the base flow of glacial streams and groundwater supply to the river system. However, the region is vulnerable to frequent disasters, such as landslides and GLOFs, which pose a significant threat to the stability of water resources and the lives of those living in the foothills.

According to a study conducted to estimate the mass balance and retreat of glaciers in the IHR, the glaciers are shrinking and losing mass, except for some in the Karakoram that are growing or advancing, a phenomenon known as the 'Karakoram Anomaly' (Singh Shruti et al., 2018). Recent research has attributed this anomaly to the intensity of Western disturbances, which has puzzled glaciologists and provided climate deniers with a rare argument. Nevertheless, the stress on water resources in the region is likely to increase significantly in the coming decades (Ministry of Science and Technology, 2022). A recent study spanning India, China, Nepal, and Bhutan reveals that glaciers melted at a pace of 0.25 m annually from 1975 to 2000 and the rate of melting has doubled since 2000 to approximately 0.5 m per year. As a result, the retreat and melting of Himalayan glaciers pose a significant threat to the country's water security. However, there is no complete data on the volume loss of glaciers in the IHR.

Another factor affecting Himalayan glaciers Black carbon formed by the incomplete combustion of fuels that consists of pure carbon with some oxygen and hydrogen. It absorbs more sunlight and emits radiation, contributing to the increased melting of glaciers in the Himalaya. Studies have detected a moderate presence of carbonaceous aerosols including black carbon on glaciers. The government has taken steps to reduce pollution in the Himalayan region, such as leapfrogging to BS-VI norms, introducing cleaner fuels, promoting electric vehicles, and setting up waste processing plants. The National Clean Air Programme aims to reduce PM10 and PM2.5 levels by 20-30 per cent by 2024, and city-specific clean air action plans have been implemented in non-attainment cities (Standing Committee on Water Resources, 2023). The states have also taken measures, including banning the burning of plastic and garbage and regulating the number of vehicles plying to Rohtang pass.

Need for Early Warning Systems in IHR

There is an increase in mountain hazards such as GLOF, LLOF, snow avalanches, cloud bursts, and landslides in recent years. It is believed that these hazards are interconnected potentially causing multiple disasters. However, current warning systems are not adequate as they are designed for single disasters; therefore, a robust early warning system is essential. Identification and assessment of hazardous glacial lakes, landslide susceptible areas along with their associated risks have become a crucial task due to global warming challenges. Once a susceptible site is identified, planners, developers, and scientists must implement appropriate measures to minimise potential risks. These measures include monitoring changes, establishing early warning systems, and implementing mitigation measures to reduce risk. Disaster preparedness involves the application of remote sensing tools, telecommunication, and broadcasting to develop effective GLOF monitoring and early warning systems. Countries like Bhutan, Nepal, and India have already initiated programmes in this field, such as the National Action Plan for Adaptation to Climate Change (Bhutan) and the National Communication on Climate Change Mitigation and Adaptation (India).

Avalanches in the Himalaya are another threat that need to be monitored and frequently reported. According to a recent research, winter temperatures in the north-western Himalayas have increased by an average of 0.65°C between 1991 and the present, which is higher than the global average increase of 0.44°C (Negi et.al., 2018). This warming trend has resulted in increased winter precipitation, with more rainfall and less snowfall. As a consequence, the risk of avalanches has increased since 1970. Monitoring the impact of climate change in the Himalaya is challenging due to the region's high altitude and rugged terrain. However, statistical modelling has shown that the rise in air temperatures in late winter and early spring is linked to a higher likelihood of avalanches. The study concludes that the transformation of dry snow packs into wet snow packs may trigger release of snow avalanches in the region. Snow with more water is less stable and more likely to cause wet snow avalanches, which can also travel greater distances due to reduced friction.

Another potential risk in the Himalayan region is earthquake which pose a significant danger to the area. This is due to the ongoing collision between the Indian and Eurasian plates that has formed the mountains, which continue to push the Indian plate northwards at a rate of 2 cm per year (USGS). As a result, pressure builds up over time and is eventually released as earthquakes. The entire Himalayan-Hindukush mountain region is located in zones 4 and 5 on the Richter Scale, indicating high seismic activity. However, human activities such as dam construction, dynamite blasting, and deforestation have increased the likelihood of earthquakes in the region by adding to its already unstable geological conditions.

The Uttarakhand Space Application Centre is well-equipped with information on landslides, glaciers, and glacier lakes. Regular reports on the status of glacier lakes and potential risks are produced by institutions such as ICIMOD. However, there is a gap in the dissemination of this scientific knowledge to implement policy making, planning, and subsequent monitoring of

recommended solutions for areas that have been identified as high-risk. This is comparable to the role of SASE, which provides frequent updates on avalanche threats to relevant organisations.

Permafrost Pathways in the Himalayas

Permafrost, also known as frozen ground, is a type of soil or rock that remains below 0°C for two or more consecutive years. Permafrost is widely found in the Himalayan region in the high-altitude, cold regions of the mountains. However, the changing climate has brought significant changes in permafrost dynamics making it one of the most sensitive indicators of climate change. Permafrost degradation can lead to soil instability and slope instability increasing the likelihood of landslides and rockfalls. As permafrost thaws, it also releases trapped greenhouse gases such as methane and carbon dioxide that further contribute to climate change.

Moreover, permafrost degradation in the Himalayas also affects the region's water resources. The melting of permafrost can lead to the formation of glacial lakes, which pose a significant threat to downstream communities leading to the event of a GLOF. The permafrost thawing can also cause changes in the hydrological cycle, leading to changes in the timing and quantity of water supply, which can impact agriculture and hydropower production.

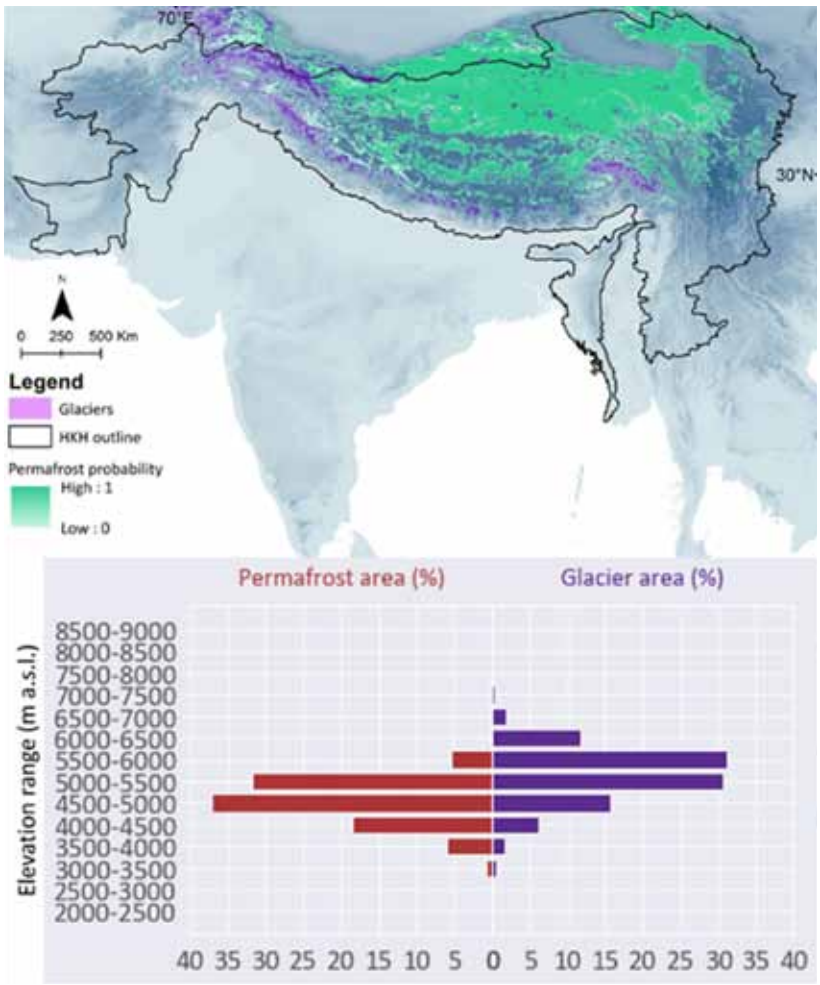
Permafrost degradation in the Himalayas is crucial for predicting and mitigating the impacts of climate change in the region. This requires a multidisciplinary approach that incorporates both natural and social sciences to develop appropriate adaptation and mitigation strategies.

People of the Hindukush Himalayan Region

With a population of approximately 210 million, the HKH area is primarily inhabited by agrarian communities who heavily depend on local natural resources and engage in small-scale farming (Murthy et al., 2016). These communities are among the poorest in the world and are particularly vulnerable to rapid environmental and socioeconomic changes. Climate change is already having an impact on the region, with loss of pasture, forest fires, drying up of springs, and deforestation all taking a toll on the mountain ecosystem. Additionally, migration is becoming increasingly common in the region, which is seen as both a challenge and an opportunity for development. Research shows that many households affected by climate change in the HKH region are using labour migration as an adaptation tool with remittances sent back home to be used for disaster risk reduction.

The Antarctic

Antarctica, the southernmost continent on Earth, is experiencing the consequences of climate change. The impact of global warming is evident in the significant increase in the rate of volume loss of ice shelves in the deeper south of Antarctica. According to a study, the volume loss rate of ice shelves has increased tenfold from 25 cu km per year during 1993-2003 to 310 cu km per year during 2003-2013 (Paolo et al., 2015).



Permafrost and glacier distribution in the HKH. In the given map, the permafrost probability map (Obu and others, 2019) is used for indicating permafrost probability distribution and the Randolph glacier inventory 6.0 (rgi, 2017) is used for indicating glacier distribution. The graph (above) shows percent-wise distribution of permafrost and glacier in different elevation ranges in the HKH.
Source: Mongabay Series, Climate Connections, 16 June 2022

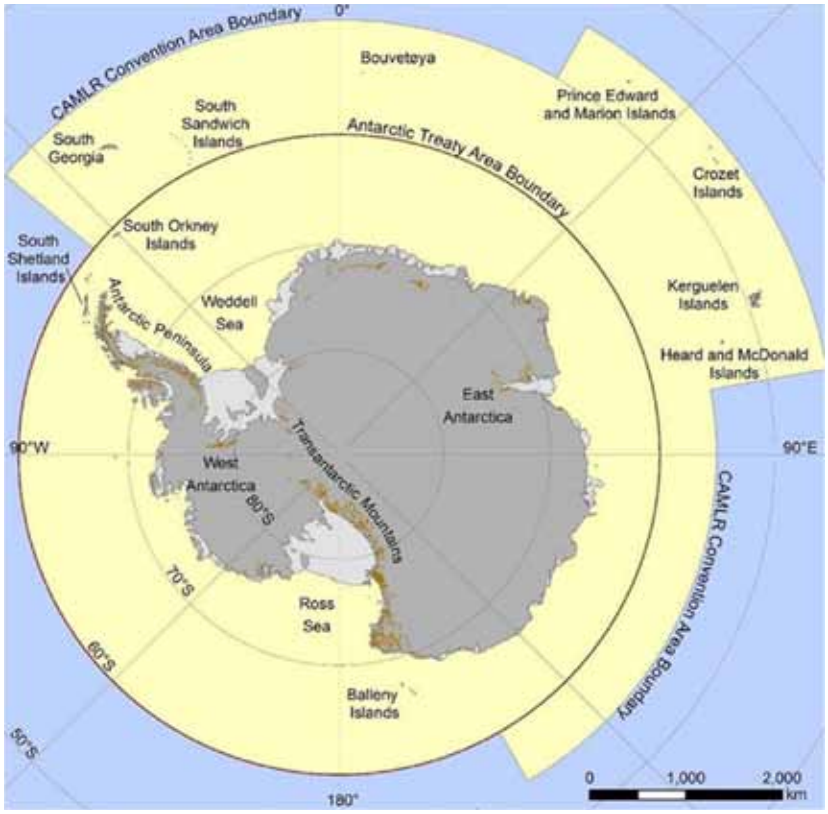
While rapid ice sheet thinning has been observed in West Antarctica and on the Antarctic Peninsula, the same has not been observed around East Antarctica (Pritchard, 2009). On the contrary, some parts of the East Antarctic ice sheet have been thickening, particularly deep in the interior (Davis et al., 2005). This observation stands in sharp contrast to the rapid thinning of the West Antarctic ice sheet. Despite this anomaly, the overall melting of ice sheets observed is significant, hence effects of global warming in Antarctica cannot be ignored. A similar example can be observed in Karakoram Himalayas.

Antarctica is divided into sections by overlapping territorial claims from seven nations, including Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom, which are currently in abeyance. Recently in October 2021, India ratified the conservation of Antarctic Marine Protected Areas to prevent overfishing of krill at CCAMLR. However, China and Russia vetoed this effort in 2022 (The Hindu, 2022). India does not participate in fishing for krill. While commercial mining has never been the focus in Antarctica due to a moratorium on it until 2048, the situation is quite different in the Arctic. With nations holding sovereign rights to the icy high-north realms, exploration has almost always been part of the national plan of most of the Arctic nations.

Antarctic Treaty

Antarctic Treaty, signed in 1961, has been successful in preserving Antarctica as a scientific preserve by allowing freedom of scientific investigation and banning any military activity. The Treaty has been praised as one of the most successful Treaties of modern times and has been used as an example for treaties related to oceans and space. The Antarctic region is believed to be rich in resources, making it controversial in terms of geopolitical relations. The relationship between science and politics is complex in the frozen realms of the Antarctic and Arctic, where science is the strategic front. Scientific activities have played a significant role in supporting the political engagement of Antarctic Parties with the continent. The seven states that maintain territorial claims in Antarctica all operate research stations within their own zones, and non-claimant states have used scientific activities and expeditions as a means to deny territorial claims. However, science has also provided the motive and means to negotiate and adopt the Antarctic Treaty, which has been successful in developing an effective and enduring regime for Antarctica despite the Cold War. (Chaturvedi, S., 2014).

The Antarctic Treaty of 1959 has developed into a complex governance system called the ATS, which deals with important issues such as the effective implementation of the Madrid Protocol, tourism regulation, biological prospecting, and climate change. The ATS has become more complicated due to the diverse membership and growing governance agenda, and this requires a focus on the changing role of Antarctic Science and a critical examination of existing power dynamics. The Treaty was created to promote peace and scientific cooperation in Antarctica, but security concerns continue to influence the laws and policies governing the region (Hemmings and Rothwell 2012).



Map of the Antarctic region, showing the Antarctic Treaty and CAMLR Convention areas.
Source: Hughes, et al.2018

Antarctica's Resources and Governance

In the early 1970s, initiatives for a minerals regime in Antarctica were considered unlikely and unfeasible due to economic, technological, and geopolitical constraints. However, by the 1980s, as the global population grew and the oil crisis intensified, the potential for commercial activity in Antarctica became more appealing. India, Brazil, China, and Uruguay formed a lobby to promote the interests of third-world countries in mineral negotiations, while the ATCPs faced dilemmas regarding the reconciliation of the legal status quo with equitable plans for mineral resource development. Despite this, the ATCPs reiterated that their respective positions on territorial claims in Antarctica could not be compromised.

In 1988, the CRAMRA was opened for signature. It prescribed tough procedures for exploration and development, including provisions related to environmental protection. However, the prospects of CRAMRA dimmed when the Australian government refused to sign

it in 1989, citing environmental conservation concerns. Australia instead sought international support for a comprehensive environmental protection convention and an Antarctic Wilderness Park. This decision was supported by France, leading to the eventual collapse of CRAMRA.

The crisis of consensus in the ATS exposed the dubious and disputed ownership crisis of a continent with abundant resources. The ATS, despite its legal and geopolitical innovation, had made the pursuit of science and scientific knowledge a 'permanent hostage' to the colonial legacy of territorial claims and counter-claims. However, the US decision to sign the Protocol on Environmental Protection to the Antarctic Treaty in 1991 restored dialogic politics and consensual diplomacy to the ATS and reaffirmed the state and status of Antarctica as a global knowledge commons.

The Greenpeace movement and other environmental groups played a significant role in opposing mining in Antarctica, leading to the emergence of a new non-state contributor and claimant to knowledge production, value addition, and representational practices in the ATS, eventually becoming the ASOC.

Protection of Antarctic Environment

The Protocol on Environmental Protection to the Antarctic, established in 1991, designates the region as a natural reserve dedicated to peace and science, with strict guidelines for the protection of its environment, including wilderness, aesthetics, and scientific research. The protocol prohibits any activities related to mining resources, except for scientific research. The Committee for Environmental Protection, comprising all signatories to the protocol, is responsible for monitoring and compliance with its provisions. Inspections are conducted individually and collectively under the Antarctic Treaty. While the protocol does not alter the special legal and political status of the region, it raises questions about the protection of the Antarctic environment and the changing nature of Antarctic science. The emergence of new ecological and environmental sciences operationalises the environmental standards established by the protocol, and the increasing prominence of new biological sciences raises complex questions of access, ownership, equity, and benefit-sharing. Bioprospecting, targeting the materials and processes in plants, animals, and microorganisms, pose a significant challenge to the common good principle of global knowledge commons, with commercial self-interest conflicting with the interests of fundamental science. The role of science and scientists in Antarctic bioprospecting will require a formal mechanism to preempt conflicts of interest. Marine scientific research may also raise security concerns, and disputes over access, equity, and rights in connection with the exploitation of biological resources cannot be ruled out. The Antarctic regime must continuously reinvent itself to meet new challenges. In April 2022, the Government of India passed the Indian Antarctic Act, 2022, adding a further commitment to its continued scientific endeavours in the region.

The Deep Ocean Mission

India required a deep ocean mission to explore and harness the vast resources in 2.2 million sq km of its EEZ. The Deep Ocean Mission was launched in 2018 to help explore the deep-sea beds and also to understand the ocean's role in climate change and provide important data for disaster management and early warning systems. This integrated operation is spearheaded by the MoES and technologies to harness both living and non-living resources from the deep ocean are intended to be developed. The programme is well underway and has been given a revised budget of INR 6.5 billion. India is now capable of mining underwater and has joined other elite nations such as the USA, Russia, Japan, France, and China in deploying manned titanium submersible vehicles. This would enable collaborations with nations of the high-north and help take exploration plans forward.

MATSYA 6000

The MATSYA 6000 is a manned submersible vehicle currently being developed with the support of organisations such as ISRO, IITM, and DRDO. It has been designed to accommodate three people (if needed) and can reach depths of up to 6,000 m. Equipped with advanced scientific sensors and tools, it promises to enhance our understanding of the deep ocean.

Samundrayaan

In October of last year, India launched its first manned deep ocean mission-Samundrayaan, putting it in the company of nations such as the USA, Russia, Japan, France, and China which have also developed underwater vehicles for subsea activities. Samundrayaan is designed to explore the deep ocean and investigate non-living resources like polymetallic manganese nodules, gas hydrates, hydrothermal sulphides, and cobalt crusts that are found at depths ranging from 1,000 to 5,500 m. This cutting-edge technology holds great promise for deep-sea exploration.

Blue Economy

Oceans contain 97 per cent of the Earth's water and sustain the environment by absorbing 30 per cent of global carbon emissions. The oceans are a great source of economic development with 3-5 per cent of global GDP contribution and supporting about 80 per cent of global trade (Indian Ocean Rim Association, 2017). Additionally, about 40 per cent of the world population lives near coastal regions with 3 billion people regularly accessing the oceanic resources for livelihood (Ghosh and Sridharan, 2023).

The growing consciousness about the dynamic importance of oceanic waters for environmental, economic and security purposes and its protection and conservation through sustainable usage has become a popular phenomenon among nations. Blue economy is generally understood as an economic system that conserves marine and freshwater resources (living and non-living) while also using them in a sustainable manner for economic growth.

Thematic representation of MATSYA 6000.
Source: The Week, May15, 2022

Prof Gunter Pauli at United Nations University, Japan, introduced the concept of Blue Economy in 1994, envisioning a sustainable economic model using locally available oceanic resources (Trainings, 2017). Further developments took place in the Rio Earth Summit of 2012, where the Small Island Developing States highlighted the gap between green and blue economy as the summit incessantly focussed on the former as the sustainable model of developmental growth. To address the gap between green and blue economy, institutions such as the UNEP drafted the report on 'Green Economy in a Blue World' and it placed Blue Economy as a significant dimension of the Green Economy model of growth (UN Economic and Social Council and Sustainable Development Solutions Network, 2014).

Contributions made by international legal frameworks are important in the development of practices of the blue economy. For example, the WTO's Agreement on Fisheries Subsidies in 2022 prohibited subsidies for illegal, unreported, and unregulated fishing. Likewise, the Kunming-Montreal Global Biodiversity Framework of December 2022 is also important in building consensus among marine nations in protecting oceanic and freshwater resources through biodiversity preservation. Recently, the UNCLOS (on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (also called BBNJ or the High Seas Treaty), concluded on March 3, 2023 is regarded as a milestone for extending marine life protection and sustainable development to the high seas.

India has a vast coastline and an exclusive economic zone (EEZ) of 2.02 million sq km, providing ample opportunities for the development of its blue economy. However, the development of India's blue economy has significant geopolitical implications, as the Indian Ocean is a critical strategic and economic region. India's maritime interests are closely linked to its national security, energy security, and trade. The country has been actively engaged in the IORA and the IONS, aimed at promoting regional cooperation and security.

India has also been developing its maritime infrastructure, including ports, shipbuilding, and offshore industries. This has increased its strategic influence in the Indian Ocean region, as it has been able to provide logistics and support to other countries in the region. India has also been cooperating with other countries in the region, such as Japan, the United States, and Australia, to maintain security and stability in the region.

Northern Sea Route and the Indo-Pacific Region

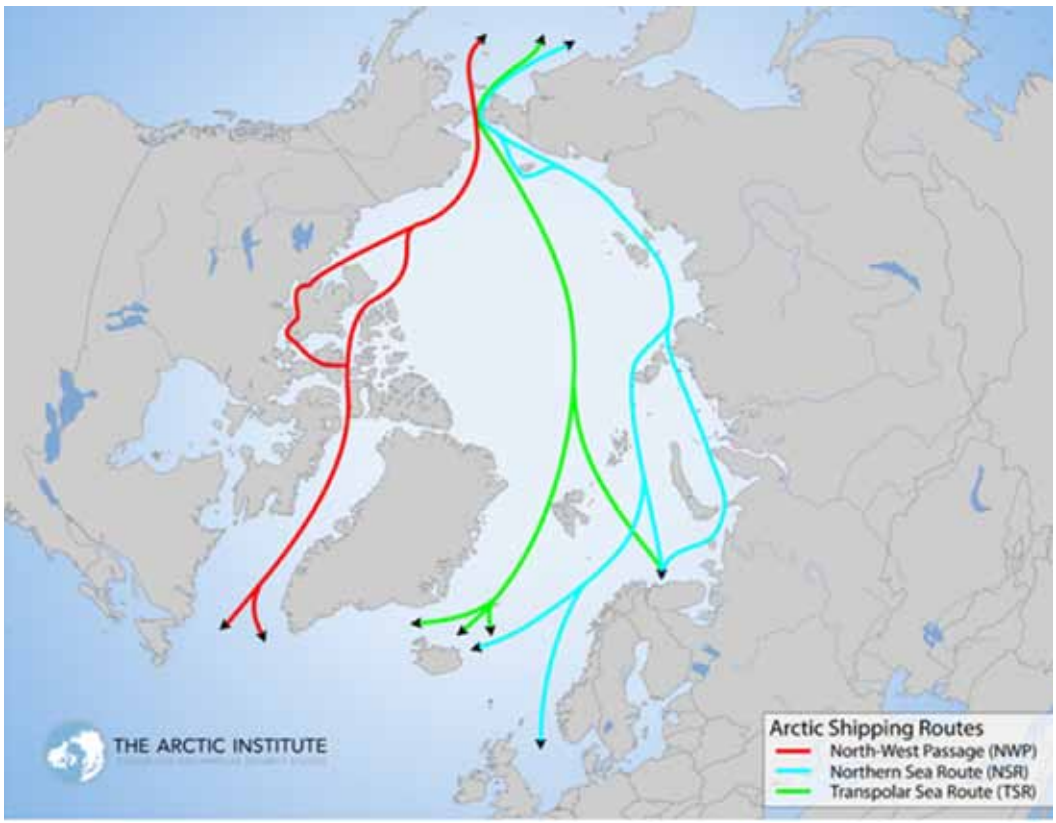
Throughout the human history, nations have always been intrigued by opportunities for resource exploration. The unfrozen Arctic region, which makes up one-sixth of the world's landmass, is currently experiencing what is known as the 'Cold Rush' (Briggs, 2021). As a result, there is a geopolitical competition between various nations, including China which has claimed to be a 'near Arctic' state. This competition is likely to bring about a range of challenges at multiple levels.

The Arctic region offers vast volumes of unexplored resources, including fossil fuels such as petroleum oil, natural gas, and gas condensates, as well as base metals, rare earth elements deposits, and gemstones (Boyd et al., 2016). However for these resources to be

sustainable, they must be commercially and environmentally viable, as well as easily accessible and transportable.

The Russian plan to establish a year-round navigation system in the Northern Sea Route by the 2030s could greatly benefit exploration efforts in the Arctic region leading to a significant increase in marine traffic, which would require the development of infrastructure such as ports, railways, roads, and pipelines. Areas such as Murmansk, Novaya Zemlya, Taymyr Peninsula, and Yamal Peninsula in Russia are likely to see significant development in this regard. The development of this route could also have broader strategic implications, as it would provide a shorter and more economical alternative to the existing Indian and Pacific Ocean marine traffic routes.

Bypassing the chokepoints such as Malacca, Suez, and Panama, this new route could save 10-15 days in travel time. This would have far-reaching consequences, beyond just cargo transportation. However, the Arctic region is sparsely populated and faces multiple stressors, presenting unique governance challenges. India has ratified all major treaties, including the UNCLOS and is actively involved with international bodies working on the Arctic. India's new Arctic Policy focuses on six key areas: science and research, environmental protection, economic and human development, transportation and



Map showing the Northern Sea Route, the Northwest Passage and the Transpolar Sea Route.
Source: The Arctic Institute

connectivity, governance and international cooperation, and national capacity building for involvement. India's continued interest in the Arctic region is therefore assured, and a calibrated approach is necessary to fully understand the region's changing potential. By focusing on these key areas and working collaboratively with other Arctic nations, India can contribute to the sustainable development of the Arctic region while ensuring its own strategic interests.

Conclusion

The significant and widespread changes that are taking place in the polar regions have created a pressing need for ongoing research to enhance our comprehension of local, regional, and global processes. These changes extend beyond man-made geographical boundaries, necessitating the involvement of multiple nations and communities on a global scale, each with their own set of interests and constraints. As a result, it is crucial to establish an interface between science and geopolitics in the Arctic and Antarctica. Although there are several forums for sharing scientific or geopolitical findings, an interface between them is rare. The principles that govern the polar regions are based on science but also require the involvement of multiple countries and communities. Therefore, it is necessary to hold discussions on platforms such as SaGAA, where various interdisciplinary issues can be discussed.

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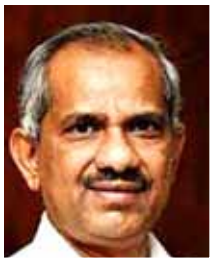

Dr M Ravichandran is the Secretary to the MoES, New Delhi. He was the Director of NCPOR, Goa (2016-2021). He has worked as a scientist at IITM in atmospheric sciences, NIOT in ocean observing systems (marine meteorology), and INCOIS in the ocean observing system and ocean modelling. His research interests include atmospheric physics and ocean dynamics, marine meteorology and air-sea interaction, ocean observing systems, and ocean modelling.

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Shri Sanjay Verma assumed the Secretary (West) post at MEA in 2022. He joined the Indian Foreign Service in 1990, and his overseas assignments have included: Ambassador to Spain and Andorra; Ambassador to Ethiopia, Djibouti, and the African Union; Consul General, Dubai; Counsellor (Economic and Commercial), Indian Embassy, Beijing; Spokesperson and Counsellor (Press, Information, and Culture), Indian Embassy, Kathmandu; Second Secretary (Press and Political), Indian Embassy, Manila and Economic and Commercial Officer, Hong Kong. Shri Verma's assignments at the MEA have included: the China Desk; Aide (OSD) to the Spokesperson; Joint Secretary (DG), Energy Security, and Chief of Protocol. He graduated in economics from Mumbai University's Jai Hind College. He did his post-graduation in international studies at JNU, New Delhi, and held a Fellowship in International studies from the University Grants Commission of India.

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Dr Goel was awarded Padma Shri in 2001. He has received several awards including Lifetime Achievement Award from the Aeronautical Society of India and Distinguished Scientist Award from ISRO. He is a fellow of Indian Academy of Sciences, Bangalore; National Academy of Sciences, Prayagraj; INSA, New Delhi; Institution of Electronic and Telecommunication Engineers, New Delhi; ASI, Bangalore; and Third World Academy of Sciences. He has recently been honoured with a Fellowship from Indian Society of Systems for Science and Engineering. He has authored over 100 research papers in referred journals and conferences.

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books for Springer on Climate Variability and Change over the Indian region and Societal and Economic Impact of Earth Sciences. He is a Fellow of all three Science Academies of India and an Academician at the International Academy of Astronautics, Paris. He is currently an Expert Member of the Research Board of the UN/WMO, Geneva.

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Dr Rasik Ravindra is the current Chairman of the Society of Earth Scientists (of India), the Senior Vice President of LIGHTS, and a Member of the Research Advisory Committees of WIHG and NCPOR. He held the position of the Director of NCPOR (2006-2012) after relinquishing the post of Deputy Director General in GSI in 2005. Dr Ravindra participated in Indian Expedition to Antarctica in 1987-1988 for the first time and subsequently led Ninth Antarctic Expedition in 1989-1991, revisiting the icy continent in 1996-1997, 2003-2004, 2007, 2009, and 2010 in various capacities for specific assignments, contributing to different facets of Antarctic science, logistics and policy. He led the first Indian Expedition to the South Pole in 2010 and the first Indian Arctic Expedition in 2008. Dr Ravindra was Chairman of the DST constituted Program Monitoring Committee on Dynamics of Himalayan Glaciers (2007-2012) and was appointed Chair, Panikkar Professor, in October 2012 by MoES. He has served as an elected Member of the UN Commission on Limits of Continental Shelf for the 2014-2017 Term. He has received the SCAR Medal for International Coordination, the National Award for Polar Sciences and Cryosphere-2013, the National Mineral Award-1990, the Antarctic Award-2002, H. N. Siddiqui Gold Medal from IGU in 2011, Prof Prem Bahadur Verma Memorial Lecture Award, Prof R C Mishra Memorial Gold Medal 2017, Life Time Achievement Award from Paleontological Society of India, and Dr W D West Oratory Award, 2018.

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Prof Naresh Chandra Pant, a geologist by profession, has made significant contributions in establishing the extension of East African Orogen in east Antarctica, described high-pressure metamorphism from Indian Archean craton (Bundelkhand), applied innovative and uncommon application of Electro Probe Micro Analysis for estimating the bulk composition of selected micro-domains, inferring sub-ice geology of east Antarctic shield from proximal marine sediments and many others. He is involved in Indian Antarctic activities for last three and a half decades out of which last ten years have been in management activities of the science programme of Indian Antarctic Expeditions. Besides, he has been a chief officer of the Geosciences of SCAR for the last ten years and currently is the Deputy Chief Officer. He is also a member of the SCATS. He currently Chairs the INSA national committee on SCAR. He has contributed to establishing, developing, and nurturing micro-domain characterisation laboratories in India and propagating chemical geochronology in the country. He recently retired as Senior Professor from the University of Delhi, and prior to that he has served in GSI and IIT (Kharagpur). He has received National Mineral Award (1996), the Antarctic Silver Jubilee Award, and the British Council Innovation Award in the form of ICECAP-2 project (2015-2017). Prof Pant has over hundred international and national research publications and has produced 10 doctoral students out of which three have been awarded PhD's on their work on Antarctica.

Dr Sulagna Chattopadhyay
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Dr Sulagna Chattopadhyay is the founder-Editor of ISSN and RNI accredited Geography and You (G'nY), a journo-magazine focusing on climate change, development, and the environment in particular, being published since 2001. She has been working for nearly three decades in the field of climate change, polar studies, disaster management, and biodiversity. She has been involved in various research and outreach programmes and has co-authored two books, *Climate Change and the White World; Science and Geopolitics of the White World: Arctic-Antarctic-Himalaya* published by Springer along with six other books on varied topics. She is also a founding member of LIGHTS and has been the convenor of national and international conferences/ seminars, notable being the round table conclave on seas and oceans around India, SaGAA in 2011, 2012, 2015, 2017, 2019 and 2020. She has been a member of the National Biodiversity Authority, FICCI Geospatial Award Jury and is in the Advisory Body of CEMAS, Mumbai University, and has engaged in various efforts toward conservation and climate change. She has a deep interest in polar studies and policy and has built a think tank SaGAA for policy and advocacy of the three poles. She also won an Environmental Documentary Short Film Contest, STL-2 : 2015 for her short film titled *O Bhai Saab*. She was awarded Business Excellence and Innovative Best Practices Academia Award, 2019 by NDIM.

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Dr Ramana Murthy is the Director of the NCCR, Chennai. He was a Senior Engineer at Vishakapatnam Port Trust before joining the ICMAM - Project Directorate, Chennai as a scientist (1999-2009). He is a National Expert on Climate Resilient Coastal Protection and Management Project, CWC, and served on many national committees, including the Research Advisory Committees of CMLRE and NCESS and Governing Council of NIOT. He served as the President of the Ocean Society of India (2016-2018) and is a Member of the IAHR and the IEEE. He has

successfully implemented several research projects such as the establishment of desalination plants in Lakshadweep, beach restoration at Pondicherry and the Kadalur Periyakuppam, Urban Flood Warning System (I-Flows) for Mumbai and Chennai, offshore wind development in Gujarat and Tamil Nadu and monitoring the health of coastal waters to meet SDG 14. Dr Murthy was awarded the National Award of Excellence in Ocean Technology, MoES, in 2021; the National Geo Science Award in 2010; and Outstanding Contribution in Disaster Management, Ministry of Mines, among others. Dr Ramana has published over a hundred papers in national and international referred journals and proceedings, produced over twenty technical reports, and delivered over fifty talks in national workshops and international working groups.

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Dr Rahul Mohan is the Group Director and Scientist at NCPOR. His research interests include paleoclimatology and paleoceanography using archives from Antarctica, Southern Ocean and the Arctic. He is a Member of the National Committee (India) for SCAR and IUGS (INSA). Dr Rahul represents India as Alternate Delegate to SCAR. He is a Member of the SCAR CBET Committee and is the National Coordinator for the Asian Forum for Polar Sciences. He is passionate about outreach and international cooperation and looks after Antarctic science coordination, polar sciences, outreach and international cooperation. He and his group members have published over 100 peer-reviewed publications and has successfully nurtured a group that looks into multiple microfossils from the polar regions.

Dr K J Ramesh
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Dr K J Ramesh is the former Director General of Meteorology at India Meteorological Department (IMD). He specialised in Numerical Weather Prediction that includes hazard and climate risk assessment and early warning. He has worked on model diagnostics, monsoon dynamics and disaster mitigation modelling. He was involved in monsoon research at IIT Delhi for ten years followed by Group Head position in NCMRWF and Head Disaster management Unit of the Government of Andhra Pradesh. In the Ministry of Earth Sciences, he was heading Atmospheric Science Services and Climate Change Research Programme Development before taking over as DGM, IMD. He is an elected Fellow of Andhra Pradesh Academy of Sciences, an elected Member of National Academy of Sciences, Prayagraj and has more than 50 papers in peer-reviewed journals to his credit.

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Dr B Meenakumari is the Chairperson of Research Advisory Committee of ICAR-CIFRI, pursuing initiatives in societal applications in fisheries research and committed to the conservation of bioresources and their sustainable use in the country. She is the former Chairperson of NBA, Chennai under the MoEF&CC. She was Deputy Director General (Fisheries) of ICAR, New Delhi prior to joining NBA. She is the first woman scientist to occupy this prestigious position. Earlier to this, Dr Meenakumari, who has more than three decades of service in ICAR, was the Director of ICAR-CIFT, Cochin. Her areas of research include development of newer fishing gear for coastal and deep sea fishing, conservation of fishery resources, upgradation of gear systems for reservoirs and responsible fishing, introduction of eco-friendly fishing methods, pollution monitoring, environment impact assessment, marine corrosion, and bio-fouling. In all her research programmes and projects, gender mainstreaming was an inevitable component. She is the recipient of prestigious awards

like Young Scientist Award of Kerala Science and Technology (1989), Women and Technology Innovation Award (2007), Panjab Rao Deshmukh Agricultural Scientist Award (2002), VASVIK Award (2003), Marie Curie Mahila Vijnana Puraskar (2010), R C Dalela Oration Award (2009), Dr M S Randhawa Memorial Award (2012) and Society of Fisheries Technologist Award (2015). She has been conferred D.Sc by Vidyasagar University (2016), West Bengal for her study on the 'Innovations in Fishing Technology'. She has made significant contributions as a scientific administrator and in promoting scientific research through both publications and outreach programmes in the field of fisheries and biodiversity conservation. She has more than 150 research publications to her credit.

Dr M Sudhakar
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Dr M Sudhakar has served two premier research institutions of the country—NIO and NCPOR in Goa. He took charge as Director, CMLRE, Kochi in 2018 till 2020. A veteran oceanographer, he has occupied various positions such as project leader and scientist and has spent more than 1,500 days at sea on-board research vessels, as leader of expeditions to the Southern Ocean and Antarctica. He represented India at the Preparatory Commission for the United Nations Law of the Sea (PrepCom) and was an Elected Member of the Legal and Technical Commission of the ISBA for the term 2007-2011 and (2012-16). Dr Sudhakar was also a member of SCOR, ICSU, serving for the second term until 2014. He was a visiting scientist to the Aachen University of Technology, Germany; a Resource Person of the International Ocean Institute, Malta; Member, National Steering Committee for Science and Astronomy Olympiads and Member, Scientific Committee, International Geological Congress 2020. He was the 'Commissioner General' of Government of India for the Yeosu (World) Expo 2012 held in the Republic of Korea.

Dr Ajit Tyagi
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Dr Ajit Tyagi is Senior Advisor at IRAD, New Delhi and Member of Monsoon Panel of WMO. His areas of expertise are high impact weather, disaster risk reduction, public weather service and climate change. He has served as Koteswaram Chair Professor with the MoES, Director General of Meteorology, IMD and Assistant Chief of Air Staff (Meteorology), IAF. He was Permanent Representative of India (2009-2013) with the WMO and member of its Executive Council. He has served on the Governing Councils of SAARC Meteorological Research Centre, Indian Institute of Meteorology and NARL. Prof Tyagi played a key role in modernisation of IMD and brought significant improvements in weather forecasting and warning of high impact weather events in the country. He was a member of the Core Group constituted by the NDMA engaged in preparing guidelines for the management of tropical cyclones and urban flooding. He has been Chairman of Governing Board of SAARC Meteorological Centre, Dhaka and played an important role in capacity building in the south Asian region and organising South Asian Climate Outlook Forum. As a member of the Executive Council of WMO, Dr Tyagi has contributed to the cause of promoting weather, environmental and climate services worldwide. He has been involved in strategic and operational planning of WMO and developing the Global Framework of Climate Services. Dr Tyagi has been conferred with Vishistha Seva Medal by the President of India for his distinguished services and leadership. Dr Tyagi has been actively involved in operational meteorology and has about hundred research papers and technical reports to his credit.

Mr S Bal Shekar
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Shri S Bal Shekar has a rich experience of over three decades in the Administrative/ Executive/ Legislative/ Committee services in the Indian Parliament including being Chief of Protocol and Conference Branch involving event management and visits to various countries on conference duty as Secretary to Parliamentary delegations. He has rendered advice on various matters of Parliamentary practice and procedure to the Hon'ble Speaker and to the Lok Sabha. Being the head of the Lok Sabha Secretariat, he has handled all aspects of administrative work of the Secretariat consisting of about 3,000 employees. He has been a Permanent Faculty Member of the Bureau of Parliamentary Studies and Training, which is an institution under the Lok Sabha imparting training to members of parliament, speakers, and officers of parliament from various countries all over the world. He has organised several international and national level conferences on parliamentary matters, apart from organising various ceremonies and functions in the Central Hall of Parliament including arrangements for addresses by international dignitaries such as the US President, amongst others.

Dr Narmadeshwar Prasad
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Dr Narmadeshwar Prasad is the Founder Director of PARI, New Delhi. He has a vast experience in parliamentary procedures and has worked in different capacities in Rajya Sabha Secretariat in Department-related Parliamentary Standing Committees on Commerce, Home Affairs, Science and Technology, MoEF&CC, etc. He has drafted over fifty Parliamentary Reports during his stint at Rajya Sabha for over two decades. He took VRS from his service in 2017 and founded PARI with a view to impart training on various aspects of parliamentary procedures, public policy management, public health policy administration, mental health systems development, preventive vigilance, vigilance management, protocol and privileges, etc. to officers of the government, PSEs and Autonomous bodies under the Central Government. He has successfully entered into collaboration with International Institutions/Universities viz Dods Parliamentary

Communications, London, the UK; The School of Population and Global Health, University of Melbourne, Australia; The John Curtin Institute of Public Policy, Curtin University, Perth, Australia; and International Anti-Corruption Academy, Vienna, Austria and has completed around 70 capacity building courses so far. He has been editing a Hindi magazine on Environment and Development titled *Bhugol Aur Aap* since 2002 and has authored a book *Towards World Parliament: A Saga of Inter Parliamentary Union, A Study in the International Organisation*.

Dr Abul Amir Khan
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Dr Abul Amir Khan is Head and Assistant Professor in ACAPC and ACOAST respectively at Amity University, Haryana. His research interest revolves around the hydrosphere-cryosphere-atmosphere interaction, stable isotopes, physical and chemical properties of aerosols, and air pollution. Previously, he has worked as a project scientist in an International Project with IAEA, Vienna, Austria. In the last ten years, Dr Amir had carried out extensive field work in some of the difficult terrains in the Himalayas and Ladakh. He has also visited several Indian Himalayan glaciers including Gangotri, Satopant and Bhagirathi Kharak in the upper Ganga basin of central Himalayan and Hamtah and Patsio glaciers of western Himalayan region. He was invited as a field expert and Instructor in Earth and Space Exploration Programme held in Leh-Ladakh and adjacent regions in 2021 and 2022. He has published several International/National papers and book chapters in reputed journals and books.

B

THE PEOPLE

The Speakers/Panelists*

**arranged alphabetically*

Mr Hjalti Ómar Ágústsson
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Mr Hjalti Ómar Ágústsson is the Project Manager for the Gender Equality in the Arctic Project, Phase III and a Special Advisor at the Directorate for Equality in Iceland. He has an ML degree in law and a diploma in Polar Law from the University of Akureyri. Mr Hjalti has been working on human rights issues since his graduation in 2014 through teaching and community engagement in Akureyri before joining the Gender Equality in the Arctic Project and the Directorate for Equality.

Dr M A Atmanand
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Dr MA Atmanand is a Visiting Professor at the Indian Institute of Technology, Madras. He has more than three decades of experience in the field of Ocean Technology and he is the former Director of National Institute of Ocean Technology (NIOT), Chennai. His areas of interest include development of underwater systems, ocean observation systems, components for deep sea applications, blue economy, project management, and teaching students deep sea technology, ocean instrumentation, deep sea mining etc., based on his long practical experience in this field.

Dr Atmanand has done pioneering work in deep sea technologies in India. He led a team of engineers for the design and development of underwater crawler for deep sea operation. He and his team developed the in-situ soil tester which was tested at a depth of 5,200 m in the Central Indian Ocean Basin. He has also guided various indigenisation programmes for Ocean observation and underwater systems. He is nominated as Chair, Marine Systems Panel, Naval Research Board, DRDO, Government of India; Chair of IEEE Oceanic Engineering Society Technology committee on Cables and Connectors; Founder Chair of IEEE Oceanic Engineering Society in India. He is the Governor's nominee to the

Planning Board of Bharathidasan University. He is elected as a member of SUT Council.

In view of the pioneering work done in the area of deep-sea technologies in 2020, Dr Atmanand received the prestigious MoES National Award of Excellence in Ocean Technology, Life time achievement award from IEEE Madras for 2021, the Dr D Srinivasan Endowment Award for the year 2021, instituted by the Ocean Society of India (OSI), for outstanding contributions in the areas of Ocean Engineering and Technology, the International Society for Ocean and Polar Engineers award in 2020, IEEE Oceanic Engineering Society, Presidential Award in 2016 etc. Dr MA Atmanand has published more than 160 papers in international journals, international and national conferences, book chapters, and others. He has delivered more than 300 invited lectures at conferences.

Dr Stuti Banerjee
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Dr Stuti Banerjee is a Senior Research Fellow at ICWA, New Delhi. At the Council, she is engaged in research on North America, Latin America, the Caribbean, the Indo-Pacific, and the polar regions. This includes producing analytical articles on politics, strategy and security with emphasis on US and Indian foreign policy, and the polar policy of the two nations. Prior to joining the ICWA, she was an Associate Fellow at CAPS, New Delhi where she was a part of the Nuclear Security Project and was studying the development of nuclear energy in countries within Asia. She has worked as a Research Intern at ORF.

Shri Sanjay Baveja
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Shri Sanjay Baveja is Chief General Manager for Business Development and Regional Head for Asia Pacific at ONGC Videsh. He has over three decades of wide experience in upstream oil and gas sector. His interests include petroleum play analysis, petroleum policy along with alternate/new energy sources, energy scenarios and environmental impact. He has done Executive Programme in 'International Petroleum Management' from school of Business, University of Alberta, Canada. An active Member of various national and international professional associations of exploration geosciences, he has been awarded the prestigious National Mineral Award in 2003. Shri Baveja has been actively associated with the preparation of document on non-traditional sources of energy as part of a draft approach paper on Energy Security for Government of India. He has also been associated with structuring the 'India Energy Portal', an India centric energy portal developed by TERI. His international exposure to Oil and Gas M&A activities span for over eight years including a stint of foreign assignment as Country Head at Myanmar. He has been key person for M&A related activities of Americas, Russia and Asia Pacific and has evaluated projects for Arctic Regions of Alaska and Russia.

Ambassador Guðni Bragason
Ambassador of Iceland to India
Embassy of Iceland, New Delhi

Ambassador Guðni Bragason is the Ambassador of Iceland to India, Sri Lanka and Nepal with residence in New Delhi. Prior to this, he was Permanent Representative and Ambassador to the Organisation for Security and Cooperation in Europe and the International Atomic Energy Organisation, Vienna; Chief of Protocol, Ministry for Foreign Affairs, Reykjavík; Director for Natural Resources and the Environment, MFA, Reykjavík; Senior Advisor, Department for Fisheries and Acquaculture, Food and Agriculture Organisation of the UN in Rome, Italy. He has been conferred with a score of honours such as Honorary Officer of the Order of the British Empire 1990; Chevalier de la Legion d'Honneur 1990;

Verdienstorden 1. Klasse 1995; Commander of the Order of the Lion of Finland 2001; and Commendatore di Ordine della Stella della Solidarieta Italiana.

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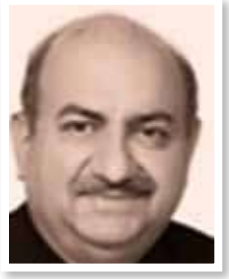

Dr Sanjay Chaturvedi is Professor in International Relations, and Dean, Faculty of Social Sciences at South Asian University. He has authored two, co-authored three and co-edited eight books including *Climate Terror: A Critical Geopolitics of Climate Change* (Palgrave, 2015, with Timothy Doyle). During early 1990s, he received Nehru Centenary British Commonwealth Fellowship, followed by the award of Leverhulme Research Grant, to pursue post-doctoral research on 'Polar Regions in International Relations' at Scott Polar Research Institute, University of Cambridge, England. During his stay at Cambridge he published Polar Regions: A Political Geography (John Wiley, 1996), and travelled to Antarctica lecturing on board MS Alla Tarasova during November-December 1994. He has remained engaged with both the Polar Regions in his research pursuits and has served on several Indian delegation to ATCMs. President of IORG, an Observer to IORA, he is the Chief Editor of the Journal of the Indian Ocean Region and serves/has served on editorial/advisory board of Geopolitics, Political Geography, Cooperation and Conflict, Journal of Borderland Studies, Strategic Analysis, The Polar Journal, and India Quarterly: A Journal of International Affairs. He is the recipient of several fellowships abroad including Curtin University, Australia; University of Wurzburg; India-China Institute, The New School; The University of Adelaide; University of Durham; and ISEAS Yusof Ishak Institute, Singapore. He has served on the Steering Committee of the IGU Commission on Political Geography, and was a Lead Author for Chapter 10: (Asia) of the Working Group II Contribution to the IPCC Sixth Assessment Report (2019-2021).

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Bhaswati Das is an Associate Professor (Population Studies) at JNU. Her area of interest includes study of population in the context of development. Her recent research focuses on health issues, migration, ageing among others. She has published more than thirty articles in journal of national and international repute and as chapters in edited books. She has authored two books and edited one book on population issues. She is the Associate Editor of Journal of Health and Population: Perspectives and Issues (HPPI) of National Institute of Health and Family Welfare, Ministry of Health and Family Welfare, Government of India. She is also a member of Internal Ethics Review Board of JNU and external member of IAIP of IIHMRU, Jaipur.

Dr Archana Dayal
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Dr Archana Dayal is a postdoctoral researcher at Aberystwyth University in the United Kingdom and works on an NERC-funded project. Her areas of research include the glacial ecosystem, biogeochemistry and microbial ecology. She is a recent inaugural recipient of the IASC-Prince Albert II Monaco Foundation Fellowship, where she represents the UK on IASC's Terrestrial Working Group. Dr Archana has conducted extensive fieldwork in Longyearbyen, Svalbard (High Arctic) for four months. She was selected as the only student researcher for the 33rd Indian Scientific Expedition to Antarctica (33-ISEA) in 2013. Archana spent nearly five months in Antarctica working on her project, *Biogeochemical studies of blue ice regions in coastal East Antarctica* and the collected samples led to several publications at NCPOR. As a guest speaker, Dr Archana has presented several talks and posters at national and international conferences (Arctic Frontiers in Norway, Arctic Science Summit Week in Austria, Polar2018 and APECS Summit, Switzerland, IGS Kyoto Symposium, Japan, APECS Summit in Bulgaria).

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Dr Manasi Debnath is an Assistant Professor in Department of Geography at Nagaland University since 2022. She has done several field surveys in different parts of the Himalayas (such as, Changme Khangpu glacier, Gurudongmar glacier and lakes in Sikkim Himalaya, Beas kund and Hamtah glacier in Himachal Himalaya). She has presented several research papers at national and international levels such as at 10th International Conference on Geomorphology in Portugal (2022), International Geographical Union in Paris (2022), APECS (2020), INQUA in Dublin (2019), IGI in India (2019), AGU (2018), ICG (2017) and IAMG (2014). She has been awarded as the 'Best Young Geomorphologist' at the 31st Indian Institutions of Geomorphologists Conference 2019 and 'Best Alpine presentation Award' at the 6th APECS International Online Conference (2020). She is an active Member of IGI, EGU, Individual Council Member of APECS. Currently, she is the President of IGF. She has jointly published eight articles and few book chapters.

Dr Paul Dodd
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Dr Paul A Dodd is a Physical Oceanographer at NPI specialising in the circulation of the Arctic Ocean. He is committed to providing the long-term observations needed to study ongoing changes in the Arctic Ocean and has participated in 19 Arctic research expeditions since receiving his doctoral degree from the University of East Anglia in 2007. Dr Paul has previously led the Norwegian Polar Institute's Fram Strait Arctic Ocean Outflow Observatory during 2010-2014 and the Fram Centre's Arctic Ocean Flagship Programme during 2020-2022. He currently leads a Fram Centre Research Programme called Sustainable Development of the Arctic Ocean (SUDARCO).

Ms Kunzes Dolma
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Ms Kunzes Dolma is pursuing her PhD through the UNESCO GRO GTP scholarship at Reykjavik, Iceland and is the first woman from India to be selected for Iceland's UNESCO GRÓ Geothermal Training Programme. After completing her engineering, she worked at the Ladakh Renewable Energy Development Agency where she worked on customising technologies for the local communities, reducing their dependence on natural resource extraction, improving ecosystem services, providing clean energy, and improving access to facilities, infrastructure, and information. Her concern about gender parity in the energy sector led her to open a WING India chapter. Ms Kunzes was awarded the WING *Courageous* Award 2019 and the Green Activist Award by the Indian Federation of Green Energy also in 2019. She has been the Vice-Chairperson of the Sustainable Development Forum of Ladakh since 2022, which conducted the Sustainable Mountain Development Summit in Ladakh in 2022.

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Dr G Latha is Head of Ocean Acoustics and Scientist G at NIOT. Her area of expertise includes ocean acoustics and modelling of ocean processes. The team under her leadership developed an autonomous system for noise measurements and deployed it in the coastal/deep waters of the Indian Seas and in the Arctic. The Arctic System has been operational since 2015. She has been awarded two patents. She has published more than eighty papers in peer-reviewed journals of high repute. She has received the MS Narayanan Memorial Lecture Award from Acoustic Society of India for her contribution to the Ocean Acoustics field. She is a member of the Committee on IQOE under SCOR of the USA. She was deputed to attend the UN meeting on 'Anthropogenic Underwater Noise' in New York, USA in June 2018, as the expert from India.

Dr Jenson V George
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Dr Jenson V George is working as a Scientist D at NCPOR. He is an observational physical oceanographer and obtained his post graduation in Oceanography from CUSAT and PhD on marine science from Goa University. He conducted his post-doctoral research in the Centre for Atmospheric and Ocean Studies, IISc, Bengaluru. His area of expertise is the biophysical coupling in ocean and turbulence. Presently, he is working on the Air-Ice-Sea interaction in Antarctic coastal waters. He is a member of several national and international scientific working groups like SOOS, the SCOR, Indian Meteorological Society, and Ocean Society of India.

Dr Santonu Goswami
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Dr Santonu Goswami is an Associate Professor at the Center for Climate Change and Sustainability, APU, Bengaluru. His current research focuses on understanding climate change impacts across various sectors in India. Dr Goswami also leads a virtual community called 'Community Climate Lab,' where young researchers from across the country come together to learn about research and collaborate to carry out various projects using data-driven approaches to find viable solutions in the climate and environmental space. Before his tenure at APU, he worked as a Senior Scientist at NRSC, ISRO, Hyderabad, where he established the first Indian Permafrost Study Site in Svalbard at 79-degree northern latitude as part of the Indian Arctic Expeditions. Before working in India, Dr Goswami was a research scientist at the Center for Urban Science and Progress at New York University. He developed baseline scenarios for New York City neighborhoods by analysing urban data sets. Over the years, Dr Goswami has conducted extensive fieldwork in the Arctic, Antarctic, US southwest desert, and Coastal India, totaling several years of actual field presence.

Dr Gopal Raman Iyengar
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Dr Gopal Raman Iyengar currently Adviser and Scientist G at Ministry of Earth Sciences where he is involved in the planning and coordination of atmospheric science programmes. His area of expertise includes weather and climate modelling. Prior to joining MoES, he has worked at National Centre for Medium-Range Weather Forecasting (NCMRWF) from 1990 to 2015 in various scientific positions. He obtained his M.Sc in Physics from Savitribai Phule Pune University. He has several research papers in many international and national peer-reviewed journals to his credit.

Dr Miriam Jackson
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Dr Miriam Jackson is a Senior Cryosphere Specialist in the Action Area on reducing cryosphere and water risks at ICIMOD based in Kathmandu, Nepal. She has performed fieldwork on Whillans Ice Stream and Kamb Ice Stream in West Antarctica. She has worked as a glaciologist for the Norwegian Water Resources Energy Directorate. Her work here included responsibility for leading research in the unique Svartisen Subglacial Laboratory located under 200 m of glacier ice in northern Norway. She established glacier mass balance measurements in Bhutan and led the joint Norwegian – Indian project INDICE - The response of the hydrological system in India to climate change. Working in Antarctica, Norway and Bhutan, she has also performed glaciological fieldwork in Greenland, Alaska, Nepal, Iceland and Svalbard. Dr Jackson is a lead author in the High Mountains Chapter of the IPCC Special Report on Oceans and Cryosphere in a Changing Climate.

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Dr Anand Jain is a Project Scientist at NCPOR, working in the Arctic ecology and biogeochemistry division. His research interests include microbiology and microbial ecology of the High Arctic Region. He has been to the Arctic five times and has been studying the role of microbes in the changing Arctic. He did PhD in microbiology from Goa University, while he was working as a research fellow at the CSIR-NIO, Goa. To pursue post-doctoral research, he moved to the School of Biotechnology, Dublin City University, Ireland. After the successful completion of post-doctoral research, he moved back to India as a 'Quick Hire fellow' at CSIR-NIO, Goa. Dr Jain has published over twenty research publications and contributed one book chapter.

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Dr Sharad K Jain is Visiting Professor in Civil Engineering Department at IIT Roorkee. Earlier, he has served as a scientist and Director at the NIH, Roorkee. He has more than four decades of R&D experience. He was a post-doctoral fellow in Japan, Visiting Professor at Louisiana State University, USA for one year, and NEEPCO Chair Professor at IIT Roorkee (2009-12). He was also Director General of National Water Development Agency, Government of India. Dr Jain has co-authored five books, written 25 book-chapters, published more than 290 technical papers, organised more than 30 short-term courses, and has worked on more than 40 research and consultancy projects. Dr Jain is a member of editorial boards of three international journals and one National Technical Journal. He was the Chairman of Expert Appraisal Committee (River Valley and Hydroelectric Projects), MoEF&CC; Member - Project Appraisal and Monitoring Committee, Ministry of Earth Sciences and Member of many scientific committees.

Dr Tanu Jindal
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Prof Tanu Jindal is working as Group Pro Vice Chancellor (R&D) and Founding Director of many environmental Institutes including Amity Centre for Antarctic Research and Studies at Amity University and has launched various doctoral, post graduate and graduate programmes. She has completed 12 projects with various national and international funding agencies in the area of the Antarctic; oceans, surface and groundwater; air and land pollution; toxicology studies; environmental health impact assessment; sustainability; etc. She has travelled extensively across the globe presenting over 120 papers in prestigious conferences. She has organised several conferences, webinars and trainings on environmental protection and sustainability. She has several publications in refereed journals and six books to her credit with Springer Publishing House. She has filed ten patents for eco-friendly technologies. She is a Fellow of the National Environmental Science Academy and has been conferred 'Scientist and Environmentalist of the Year Award' along with many others.

Ms Tiina Jortikka-Laitinen
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Ms Tiina Jortikka-Laitinen is working as Ambassador for Polar Issues in the Foreign Ministry of Finland and as Head of the ATCM Host Country Secretariat. Previously, she has served as Finland's Ambassador to Spain and Andorra (2017-2021) and to Tunisia and Libya (2010-2013). She has also served as Ambassador at large for Euro-Mediterranean issues and MENA region (2015-2017), as Foreign Minister's Special Envoy for Ebola and as Ambassador for Countering Radicalisation, Violent Extremism and Terrorism. She has been the Director of the International Environmental Policy in the MFA (2007-2010) and Deputy Director of the Civilian Crisis Management (2005-2007). She has done post-graduate studies in École National d'Administration in Paris. She is a member of the Finnish and Nordic Women Mediation Networks.

Rear Admiral Monty Khanna
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Rear Admiral Monty Khanna, AVSM, NM (Retd) is appointed at the NSCS in New Delhi as the Assistant Military Adviser and has been officiating as the Military Adviser since September 2022. His afloat commands include Indian Naval Submarine Sindhuvijay and the Frigates Krishna and Gomati. In addition to tenures as Naval Assistant to the VCNS and Flag Officer Commanding-in-Chief, Western Naval Command, he was also the Naval Attaché at the Embassy of India, Washington D C. He was awarded the Nao Sena Medal in 2000 and the Ati Vishisht Seva Medal in January 2017. He has published over 20 articles in professional journals that include ORF issue briefs, maritime affairs, and the United States Naval Institute proceedings. He also regularly delivers lectures on a wide variety of subjects that include Leadership, Naval and Military Strategy, Geo-Politics of the Indo-Pacific, Developments within the PLA Navy, Ship Building and Restructuring our Armed Forces.

Dr Nalan Koc
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Dr Nalan Koc has been serving as Research Director at the NPI since September 2011. Dr Nalan has over three decades of experience with climate interpretations from polar marine sediment cores and has participated in as well as led many cruises in the Nordic Seas, Arctic Ocean and the Southern Ocean. She has also participated in several Ocean Drilling Programmes and Integrated Ocean Drilling Programme cruises. She has extensive experience in polar climate research and management through her previous positions at NPI as leader of the Polar Climate Programme (2004-2009) and as head of the Centre for Ice, Climate and Ecosystems (ICE), NPI (2009-2011) and in her present position as research director. She has also served on several international science panels (i.e., CLIVAR, ESSAC, EPB, FARO).

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Dr Raghavan Krishnan is the Director of IITM, Pune. He specialises in climate modelling studies relating to climate change, the Asian monsoon, and the water cycle. Under his leadership, the CCCR at IITM, Pune, developed the first Earth System Model from India and contributed to the Coupled Modelling Intercomparison Project- Phase 6 (CMIP6) and the IPCC Sixth Assessment Report (AR6). He was the coordinating lead author in the IPCC AR6 WG1 report (Chapter-8: Water Cycle Changes) and a drafting author in the IPCC AR6 Summary for Policymakers. He is a Member of the Joint Scientific Committee, the WCRP, WMO. Dr Krishnan and his team from CCCR-IITM published the First National Climate Change Assessment Report of the MoES in 2020. He is a Fellow of the Indian Academy of Science, Bengaluru, the INSA, New Delhi, and the Indian Meteorological Society. Dr Krishnan was honoured with several awards for his scientific contributions, notably the Frontier Outstanding Research Award by the FRSGC, Japan, in 2000 and the 2021 National Award for Excellence in Atmospheric Science and Technology, MoES, Government of India. He has published over 150 scientific articles/papers.

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Dr Avinash Kumar serves as a Scientist E at NCPOR. His research is centered on exploring sea ice and climate dynamics-related studies in the Polar Regions that employ advanced remote sensing techniques and field observations. His noteworthy contributions to the field include discovering the mechanism of Arctic and Antarctic sea ice variability and dynamics, developing a model for forecasting the future position, and estimating the ice shelf change rate based on satellite passive-microwave measurements. Apart from his expertise in sea ice and climate dynamics, Dr Avinash Kumar is also proficient in coastal dynamics and geomorphological studies utilising remote sensing and GIS techniques. He led the 35th

Indian Scientific Expedition to Antarctica, where he conducted an aerial/field reconnaissance study to analyse the ice shelf morphology and changes in coastal regions. He has also spearheaded several geological and geophysical surveys in the Indian Ocean as a chief scientist.

Dr T Srinivasa Kumar
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Dr T Srinivasa Kumar is the Director of INCOIS where he has been responsible for implementing several important projects including the Potential Fishing Zone Advisories, Multi-Hazard Vulnerability Mapping, Coral Reef Bleaching Alert System, satellite coastal and oceanographic research, amongst other responsibilities. He has made impactful contributions to the field of operational oceanography and coastal multi-hazard early warning systems. Post the 2004 tsunami, he coordinated the successful establishment of the Indian Tsunami Early Warning System, as a multi-institutional project. The tsunami early warning centre, based at INCOIS is identified as one of the Tsunami Service Providers under the IOTWMS framework of the IOC of UNESCO. Between October 2016 and August 2020, he worked with the IOC-UNESCO as Head of the IOTWMS Secretariat in Perth, Australia. During this time, he was instrumental in strengthening the regional Tsunami Early Warning System in active collaboration with 28 Member States, global harmonisation of tsunami watch operations and implementation of the Tsunami Ready Community Recognition Programme. He is also the Vice Chair of the IOC for Region IV, Co-chair of the IOC - WMO Joint Collaborative Board and Chair of the Ocean Decade Tsunami Programme Scientific Committee.

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Dr Vijay Kumar is Scientist G at MoES where he is responsible for monitoring and coordination of programmes related to Polar Science and Cryosphere (comprising Arctic, Antarctic and Himalaya) as also the programmes on Southern Ocean, water cycle, ocean survey and Mineral Resources (Geo-scientific studies of the Exclusive Economic Zone, Delineation of India's Continental shelf, Gas Hydrates Exploration, Poly-Metallic Nodules, and Studies on Hydrothermal Sulphides) etc. His area of research includes groundwater modelling, analysis of hydro-meteorological variables, climate change, spatial modelling, lake hydrology etc. Prior to joining MoES, he has worked in NIH where he contributed significantly in many consultancy and sponsored several projects. He has conducted many specialised training courses on hydrological aspects for field engineers. He has published more than 100 papers in various International and National journals, conferences etc. to his credit.

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Commodore Debesh Lahiri is the Executive Director at National Maritime Foundation, New Delhi. An alumnus of the Naval Engineering Course, Naval Engineering College, INS Shivaji, Lonavala and College of Defence Management, Secunderabad, he was commissioned into the Indian Navy on November 25, 1988. He is a Marine Engineer by profession and has completed his MTech from IIT, Chennai. He has completed a World Bank Programme on Alternate Dispute Resolution-Arbitration, Conciliation and Mediation. He was the Deputy Naval Attaché at the Embassy of India, Moscow, and has been at the helm of two Naval Ship Repair Yards, at Port Blair and Karwar respectively.

Dr Parvinder Maini
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Dr Parvinder Maini is serving as Scientific Secretary at the Office of Principal Scientific Advisor to the Government of India, where she is responsible for enlarging the R&D ecosystem in the country, formulating policies for science, technology and innovation and creating regulatory mechanisms, forging collaboration among the industry, academia and government for delivery of citizen centric solutions. Her role also requires her to engage with various International agencies to continuously discuss and develop common frameworks for addressing contemporary global S&T policy issues as they come along and to also explore areas of S&T collaboration aligned with the national priorities of the country. Her research interests include monsoons, downscaling techniques, forecast evaluation studies, socio economic benefits of weather and climate-based services. She is an Executive Committee Member of the IGU and life member of the IMS and Association of Agrometeorologists. She has several publications across national and international journals. In 2009, Dr Maini moved to MoES Headquarters to spearhead the Atmospheric Science Programs of MoES. She has also represented India in the Belmont Forum as a Steering Committee member and initiated negotiations of funding calls.

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Dr Kenichi Matsuoka is a senior research scientist at the NPI primarily investigating Antarctic glaciology. He received his PhD from Hokkaido University, Japan in 2002 and became a Research Assistant Professor at University of Washington, USA in 2005. He moved to NPI in 2010 and qualified as a full professor in 2013. Throughout his career, Dr Kenichi worked on seasonal snow, mountain glaciers, and polar ice sheets. At NPI, he has worked in both coastal and inland regions of East Antarctica with many international collaborators

including those from National Center for Polar and Ocean Research. He has served on the SCAR as the Norwegian representative to its Physical Science Group, a co-founder of a SCAR map product Quantarctica, and the founding chair of the RINGS Action Group.

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Dr Rajeev Kumar Mehajan is an atmospheric scientist with more than three decades of experience in weather forecasting, scientific research and project management. His career commenced as a Military Aviation Meteorologist with IAF. He has been the Director-Forecasting and Communication at Ministry of Defence and Programme Director-Atmospheric and Ocean Divisions at MoES. He has also served the UN as Chief Meteorological Officer in Democratic Republic of Congo. He has organised many national level seminars and conferences and has been Chairman, Board of Studies for Meteorological Division of Bharthiar University, Coimbatore as well as Research Guide for Meteorology and Management. He has also been Editor-in-Chief of a national meteorological journal Vatavaran and author of a few coffee table books. He is member of many National Committees in the arena of Earth and Atmospheric Sciences. He has been conferred with various national and international awards during his service career.

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Dr Thamban Meloth is the Director of the NCPOR, Goa. His field of specialisation includes cryosphere and palaeoclimatology. His current research focuses on Antarctic ice core studies, polar snow biogeochemistry and Himalayan glaciology. He was instrumental in establishing India's first and state-of-the-art Ice Core Laboratory at NCPOR in 2005, and also pioneered the Antarctic snow and ice core studies at NCPOR. He was also a member of the first Indian Scientific Expedition to the South Pole in 2010. He has conducted several expeditions to Antarctica, Arctic, Southern

Ocean and Indian Ocean. In recognition of his scientific contributions, he has been awarded National Geoscience Award by Ministry of Mines, NIPR Visiting Scientist Award by the National Institute of Polar Research, Japan; Prof Naganna Gold Medal by the Mineralogical Society of India; START Young Scientist Award by International Geosphere Biosphere Programme; and Young Scientist Award, by the Indian Science Congress Association (ISCA). He is a Fellow of the National Academy of Sciences, India and has more than 120 papers in peer-reviewed journals to his credit.

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Dr Nisha Mendiratta is Advisor and Head of Women in Science and Engineering and Climate Change Programme at Department of Science and Technology. She has worked in NRSA, Hyderabad, IIRS, Dehradun and NCMRWF, Noida. She has led a major programme at NRDMS, a division of DST. She is recipient of the meritorious PG fellowships of IARI. She is serving as an Expert Member of a number of national/ International level committees on climate change and related issues. Dr Nisha has published many research papers and articles and co-authored a number of departmental technical documents. She has edited a book on Bio-geo data entitled Guidelines for BIOGEO Database Creation and Sustainable Watershed Development Planning in Himalayas.

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Dr Om Prakash Mishra is the Director of NCS. Previously, he worked with IDRC-Canada in a joint venture project with CMPDIL, Coal India (1992-1995). Dr Mishra has served at the GSI for two decades (1995-2014). He has worked with SAARC Disaster Management Centre, New Delhi, as the Head / Director and at GRC-Japan as the Foreign Visiting Guest Professor. He has represented India as a SAARC Member State to various UN agencies (UNDP, UNESCAP,

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Dr Sandip Rasmikant Oza is Scientist-G and presently heading the Cryosphere Sciences Division at SAC, ISRO. He has vast experience in utilisation of space borne data for resource applications, including vegetation dynamics and cryosphere studies, along with sound knowledge of image processing and GIS. He established the state REmote SEnsing and COmmunication (RESECO) centre, currently known as BISAG. He has also participated in the Indian Antarctic (2008-09) and Arctic (2016) scientific expeditions. ISRO has recognised his contribution by considering his name for ISRO Team Excellence Award for two times (2008 & 2012).

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Dr Vimlesh Pant is a Professor at Centre for Atmospheric Sciences, IIT Delhi. He participated in several national and international scientific expeditions over land, sea, and airborne platforms, including the 24th Indian scientific expedition to Antarctica (Summer, 2004). Dr Pant has worked in the area of physical oceanography at INCOIS, MoES during 2009 - 2011. He led two scientific cruises as a Chief Scientist

onboard research vessels Sagar Nidhi and Sagar Kanya in October-November 2009 and 2010, respectively. Deployments/recoveries of RAMA buoy and deployments of ARGO profiling floats, XBTs, CTD, etc., were carried out along the cruise track. Dr Vimlesh Pant served as Scientist-C at Aryabhatta Research Institute of Observational Sciences (an autonomous institute under DST, Govt. of India) for a period of one year before joining IIT Delhi in May 2012. His current research interests are regional ocean modelling, air-sea interaction, ocean biogeochemistry, and sea-ice dynamics in polar regions. He received the INSA medal for young scientists in 2014 by the Indian National Science Academy.

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Dr R P Pradhan is a Professor at the Department of Humanities and Social Sciences, BITS Pilani KK Birla Goa Campus. He also serves as a Distinguished Fellow- Political Economy at the Center for Public Policy Research, Kerala. As a Political Economist, he teaches courses like international relations; maritime studies and blue economy; international trade and development; development economics as well as international migration and labour economics. Teaching at a Science and Technology Institute, Prof Pradhan has developed a unique digital data lab that maps all the seaports of the World (over 8,000 ports) along with vessel traffic mapping in them on daily basis. He has been a Member Expert for Commonwealth Fellowship, MHRD, Government of India during 2007 – 2011 and served as a Member of the Board of Trustees, The International Centre, Goa. He has jointly edited a book *Coastal Zone Management in Goa*, 1999 and he regularly writes in Indian newspapers on several themes of International Relations and issues of Economic Development. Apart from delivering several lectures in most Indian universities, he has also delivered UGC SWAYAM Lecture at Madras University on Politics of Foreign Assistance in two parts in May 2018.

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Dr Waliur Rahaman is an isotope geochemist working at NCPOR. His research primarily focuses on understanding the earth's surface and oceanic processes at modern to geological time scales, paleoclimate, and paleo-oceanography. He uses various stable and radiogenic metal/metalloid isotopes as a tool to understand these processes and quantify them. He joined the NCPOR in 2012 and established a new metal-free clean chemistry laboratory, ISOTRACE which is equipped with state-of-the-art instruments in the field of isotope geochemistry, such as Multi-Collector ICMS (MC-ICPMS), ICPMS (Quadrupole) for the analysis of trace elements, radiogenic and stable isotopes. With the addition of these new analytical facilities, the ISOTRACE laboratory at NCPOR has become one of the well-reputed isotope geochemistry laboratories, reflected in publications in reputed journals. Currently, he is heading the Isotope Geochemistry Section at NCPOR. His group has been actively involved in cutting-edge research in the field of non-traditional stable isotopes and their applications in paleo-oceanography. He was awarded Alexander von Humboldt Fellowship by Humboldt Foundation, Germany in 2011.

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Dr S Rajan is a former Director of NCPOR, Goa. He has over four decades of scientific and administrative experience in various facets of geosciences, initially in the GSI and subsequently at NCPOR, from where he retired in 2015. Dr Rajan has been involved in marine geoscientific studies and continental margin research specialising in maritime boundary delineation since 1984. The leader of the Indian Continental Shelf Programme between 1999 and 2012, he is currently India's elected representative to the UNCLCS. On the polar front, He was a member of the four-member team which visited Antarctica during 2003-04 to identify a site for India's new Antarctic research base. He has also been an integral part of the Indian

scientific endeavours in the Arctic and had been the principal investigator of a project to study the seasonal and annual responses of an Arctic fjord to climate variabilities. Dr Rajan is the recipient of the National Geoscience Award 2010 for his contributions to the field of Ocean Development as well as the Dr H. N. Siddiquie Medal of the Indian Geophysical Union (2014) for his contributions to the field of Marine Sciences.

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Dr G A Ramadass is the Director of NIOT, Chennai. His research areas include deep sea technology, deep sea mining, underwater acoustics and marine instruments. Presently, he is coordinating a project for the development of Indian manned scientific submersible 'MATSYA 6000' which is intended to carry three scientists/engineers to 6,000 m depth in the ocean. Since the inception of NIOT, he has been leading different technology development projects. In 2010, he won the National Geoscience Award under the Exploration of Oil and Natural Gas category and NRDC award for the year 2017. He led NIOT team during the 34th Indian Scientific Expedition to Antarctica in February- March 2015. He has been the Chief Scientist of several cruises and scientific explorations on-board various research vessels. He has a number of publications in the international journals, international conferences and four international patents.

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Shri M Koteswara Rao is an Adviser/Legal consultant to MEA. Prior to this, he has held positions of Counsellor and Legal Advisor at the Permanent Mission of India to the UN, Legal Advisor to the Government of Seychelles, First Secretary (legal) from India to WTO. He has been an Assistant Editor for the Indian Journal of International Law. He also has rich negotiating experiences concerning

India's stand with respect to Investment Treaties, Preferential Trade Agreements and Free Trade Agreements with other countries and unions like MERCOSUR. He has authored several books on International Law and Corporate Laws including Heading Reports for the MEA, Government of India. He was elected and functioned as the Secretary-General of the Indian Society of International Law, New Delhi during 2019-2021. He has delivered guest lectures at the Indian Society of International Law, Foreign Service Institute of the MEA, and Indian Institute of Foreign Trade.

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Prof Shakil Ahmad Romshoo is the Vice-Chancellor of the IUST, Kashmir. He has more than three decades of research and academic experience. His areas of research include hydrology, glaciology and climate change with a geographical focus on the Western Himalaya. Prof Romshoo is a member of a score of policymaking committees and working groups on environment, water, climate change, and disaster management at the state, national and international levels. He is the Elected Fellow of the Indian Academy of Sciences, Indian Society of Remote Sensing and Indian Society of Geomatics. He is the Elected Vice-President of the Indian Society of Geomatics. He has won more than a dozen of national and international awards for his academic achievements and notable among these are the Satish Dhawan Award from ISRS in 2019, ISG President's Appreciation Medal for the promotion of Geomatics in India in 2015, Best Research Award (Geospatial Science) conferred by Shri Narendra Modi, as Chief Minister of Gujarat in 2010 amongst others. Dr Romshoo has published more than 260 papers in the peer-reviewed national and international journals.

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Captain Sarabjeet Singh Parmar is a serving Indian Naval Officer who has written and spoken extensively on maritime security and strategy issues at various national and international conferences including the Arctic and Antarctic. He was a member of the 11th Indian Antarctic Summer Expedition in 1991. He has been a Research Fellow at the MP-IDSA and worked in the Indian Navy's strategic apex-level offices where as a part of the core team, he published the Indian Navy's unclassified maritime security strategy document titled *Ensuring Secure Seas: Indian Maritime Security Strategy* in 2015. He also carried out regional maritime assessments and completed the doctrine development plan. He was the Executive Director of the National Maritime Foundation during 2019-2022. He is presently a Senior Fellow at the NMF and looks at maritime strategy and security-related aspects, piracy, and international maritime law, focussing on lawfare.

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Dr Vijay Sakhuja is a former Indian Navy officer and served for over two decades in various ranks and positions. He was Director at National Maritime Foundation, New Delhi; Director at Rashtriya Raksha University, Gandhinagar, Gujarat; and Director (Research), Indian Council of World Affairs, New Delhi. He specialises in Indo-Pacific affairs, International Maritime Law, blue economy, Arctic politico-strategic dynamics, and 4th Industrial Revolution technologies. His current focus is on seabed critical materials, and maritime energy transition. He has published over fifty books, edited volumes and monographs including Fourth Industrial Revolution and Maritime/Naval Operations (2021), Asia and the Arctic: Narratives, Perspectives and Policies (2016), and Arctic Perspectives (2015).

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Cmde Sujeet Samaddar is the Founder and Secretary of SAMDeS, New Delhi and proprietor of a consultancy firm on defence, space and sustainability projects apart from being on the governing council of a few think tanks. He is an Advisor to the Material Recycling Organisation of India where he pursues his passion for the promotion of the Circular economy and sustainable economic growth. After being commissioned into the Indian Navy in 1980, he held various staff appointments and commanded four warships before taking an early retirement in 2009 in the highly prestigious appointment of Principal Director Naval Plans, Naval Headquarters, New Delhi responsible for acquisition, infrastructure and budget of the Indian Navy. He is recipient of the CNS Commendation and the Nau Sena Medal. He is an alumnus of the highly prestigious National Institute of Defense Studies, Tokyo and of the University of Madras, Chennai. He has also been a Visiting Fellow at the United Services Institution, New Delhi and at the Japan Institute of International Affairs, Tokyo. He has seved as a Senior Consultant (Industry) at NITI Aayog, Government of India where he was in-charge of the policy verticals of the national aero and defence industry, blue economy, circular economy, recycling, civil aircraft program, shipbuilding until January 2019. He was the Member Secretary of the NITI AAYOG Task Force on Drafting India's first comprehensive National Maritime Policy. He also drafted India's first comprehensive and integrated National Material Recycling Policy. His paper on *Establishing a National Development Bank for Shipping and Shipbuilding* is under consideration of the Ministry of Shipping. He is presently on the board of a space technology company using AI and Earth Observation for a range of applications – particularly maritime. He has several publications and has published two books on Defence Development and National Security and Minerals Markets and Maritime Strategy.

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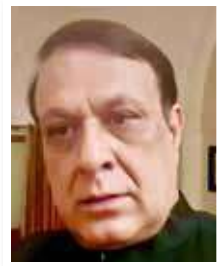

Major General BK Sharma, AVSM, SM and Bar (Retd) is the Director General of United Service Institution of India, established in 1870. He is a recipient of three military awards by the President of India for rendering exceptional distinguished national service and displaying courage. He was conferred the National Award for nation building by the Confederation of Educational Excellence of India. He served as a Senior Faculty Member at the National Defence College, served as UN Military Observer in Central America, and India's Defence Attaché in Central Asia. He specialises in strategic net assessment methodology, scenario building and strategic gaming. He has participated in several international conferences, Track 2 dialogues, edited several books and authored sixty seminal papers. He has lectured at a score of prestigious policy think tanks and literature festivals in India and abroad.

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Dr Parmanand Sharma has been working at NCPOR as a Scientist since 2012. Some of his significant contributions involved pioneering the mass balance studies in the Indian Himalaya using a steam drill to understand glacier–climate interrelationship. He has also undertaken more than twenty expeditions to the Arctic and Himalaya as station coordinator and team leader along with making substantial contributions to the field of glacier studies in the Himalaya. He is also a member of the IASC-CWG. He has more than forty publications in peer-reviewed national and international journals in his name and published many proceedings papers, book chapters and books. He has significantly contributed to establishing India's first field research lab named Himansh at an altitude more than 4,000 m in a remote location of Himalaya to monitor Himalayan glaciers.

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Dr Sateesh Shenoi is currently the Chair of IUGG's Union Commission for Data and Information since 2014 and the national Vice-president of Vijnana Bharati since 2022. His research interests include dynamics of the waters around India, the role of the Indian Ocean on the monsoon, observational oceanography, ocean circulation, sea level variability and satellite oceanography. His recent research includes the discovery of intraseasonal barotropic oscillations in sea level in the tropical Indian Ocean. He is an elected Fellow of Indian Academy of Sciences (2007), National Academy of Sciences, India (2009), Indian Geophysical Union (2011), Andhra Pradesh Akademi of Sciences (2014), and Telangana State Academy of Sciences (2015). Indian Geophysical Union awarded him with Dr H.N. Siddiquie Memorial Lecture Award (2011). AMET University, Chennai conferred him the Honorary Degree (Honoris causa) of Doctor of Science (2016), and Ministry of Earth Sciences awarded him the National Award for Ocean Science & Technology (2018). He has served as Director of INCOIS, NIOT and as the Vice-Chair of the Intergovernmental Oceanographic Commission (IOC) of UNESCO in 2019-2021, Co-chair of the International Indian Ocean Expedition-2 Steering Group (IIOE-2 - SG) during 2015- 2022, Chair of the Indian Ocean Global Ocean Observing System (IOGOOS) during 2017-2021, Member of the Executive Council of International Association for Physical Sciences of Ocean (IAPSO)/IUGG in 2011-2015 and in 2015-2019.

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Dr Aparna Shukla is a Scientist at MoES and has been actively involved in remote sensing as well as field-based cryospheric research since 2005. Her research specialisations are remote sensing, digital image processing and information extraction techniques for glaciology. Her research interests include developing robust methodologies for mapping of debris-covered glaciers, characterisation of supraglacial debris, glacier dynamics and remote sensing

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Dr Singh was conferred the title Adjunct Professor in 2007 in recognition of his contribution to Murdoch University, Perth, Western Australia. He served as a Board Member of Greening Australia from 2007 - 2009. Dr Singh was awarded the prestigious UNESCO Young Scientist Award (1988) for his outstanding contribution in the field of renewable energy. He has more than 70 publications in his credit published in reputable international journals and further, he edited newsletters, proceedings of international conferences.

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Dr Sunil Kumar Singh is the Director CSIR-NIOT since 2017. His research interests are in the field of Earth and ocean sciences and deals with low-temperature isotope geochemistry. He led the international GEOTRACES programme in India. GEOTRACES is an international programme to unravel the distribution of micronutrients and other trace metals in the global ocean to assess their impact on the global carbon cycle. He is leading this ambitious multi-institutional programme successfully in the Indian Ocean, a least-study ocean basin. He has been awarded the most prestigious Shanti Swarup Bhatnagar Prize for Earth, Planetary and Ocean Sciences in 2016. He received the Ministry of Mines, the National Geoscience Award in Basic Geosciences (2012), the Eminent Mass Spectrometry Award (2014) and the MoES National Award for Ocean Sciences (2021). He has been honoured

with a Doctor of Engineering (Honoris Causa) degree by NIOT, Goa in 2019 for his outstanding research contributions. He is the Elected Fellow of all the three major Academies of India: the Indian Academy of Sciences, Bangalore; the Indian National Science Academy, Delhi and the National Academy of Sciences, India. Very recently he has been recognised by the DST as one among the "75 Under 50 Scientists Shaping Today's India". Dr Sunil Kumar Singh is on the editorial board of many of the recognised international/national journals. He served as associate editor of the journal Chemical Geology. Currently, he is serving on the editorial board of the journal Frontiers in marine biogeochemistry. He is a member of the General Body of the Current Science Association. He has served as a Member of the research planning committee of the second International Indian Ocean Expedition (IIOE-2), SCOR and currently, he is the Chairman of the National Committee for SCOR. He is the Chairman and a Member of Governing Councils, Research Councils, Research Advisory Councils, and the senate of many Indian institutions and universities. His research findings are published in about 75 research publications mostly in reputed international peer-reviewed journals and are well appreciated with about 4,000 citations with 35 h-index.

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Dr Virendra M Tiwari is Outstanding Scientist and JC Bose National Fellow at CSIR-NGRI. His research interests primarily focus on deciphering subsurface mass distribution and mass transport relevant to a wide range of scientific and societal applications such as elucidating structure and dynamics of Indian lithosphere, quantifying water storage over Indian subcontinent, and mapping sub-basaltic sediments. Besides many well-cited research papers in leading national and international journals, he has contributed to the important R&D projects for the groundwater and the oil and mineral industries in India. He is an elected Fellow of all three science academies of India viz Indian National Science Academy, National Academy of Sciences India; Indian Academy of Sciences; and Telangana Academy of Sciences and he is also conferred with several awards and honours for his contributions in the field of geophysics.

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Dr Sarat Chandra Tripathy has been working as a senior scientist with the Ocean Sciences Group of NCPOR, Goa since 2011. Before joining NCPOR, he was carrying out post doctoral research at Nagoya University, Japan. He has over two decades of post-MSc research experience and has published more than 60 research papers in several peer-reviewed journals of national and international repute. Presently, he is working towards understanding the productivity potential and biogeochemistry of the Indian sector of Southern Ocean and Arctic fjords of Svalbard by actively involving in the scientific expeditions to the polar waters. His research interests include study of harmful algal blooms, phytoplankton productivity and physiology, ocean color remote sensing, nutrient dynamics in estuarine and coastal environment, bio-optics and bio-physical interaction studies to understand the ocean biogeochemistry. Dr Tripathy is Co-Chair of the Southern Ocean Indian Sector Regional Working Group (SOIS-RWG) of SOOS, and the national representative of the Scientific Standing Group-Life Sciences for SCAR.

Mr Sonam Wangchuk

Educator and Inventor

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Er Sonam Wangchuk, a Mechanical Engineer by education, has been primarily working in the field of educational reform for more than three decades. In 1988, just after Er. Wangchuk finished his engineering and founded SECMOL to support Ladakhi children and youth in educationally challenging and culturally confusing times. In 1994 he was instrumental in launching Operation New Hope - a triangular collaboration among the government, village communities, and civil society to reform the government school system. The programme involved the formation of Village Education Committees to take ownership of state schools, training teachers in child-friendly ways, and re-writing

and publishing localised textbooks for Ladakh. As a result, the pass percentage in 10th grade (matriculation) rose from the dismal 5 per cent to 55 per cent in seven years and presently stands at 75 per cent. For students who failed their state exams, he founded the SECMOL Alternative School Campus near Leh, where the admission criteria is a failing grade. However, with the supportive and creative environment at the school, the so-called failures have excelled in their chosen fields and risen to international acclaim as entrepreneurs, filmmakers, politicians, and teachers. As an engineer, Er. Wangchuk has been teaching innovation at the SECMOL Alternative School, where, together with the students, he designed and built solar-heated buildings that are low cost, made of earth/mud but maintain +15°C even when the outside temperature is -15°C in Ladakhi winters. In order to solve the water crisis facing mountain regions due to climate change and fast melting glaciers, he invented the Ice Stupa artificial glacier, which stores the unused stream waters in winter in the form of giant ice cones or stupas and releases the water in late spring as they melt; when farmers need water. Er. Wangchuk has been granted several awards and titles, such as the Magsaysay Award from the Philipines (Asian version of the Nobel Prize), 2018; The GQ Men Of The Year Award for Social Entrepreneur of the Year in 2017; the Global Award for Sustainable Architecture, Paris 2017; The Rolex Award for Enterprise 2016 in Hollywood USA; The Terra Award 2016 for World's Best Earth Buildings in Lyon France; The UNESCO Chair for Earth Architecture for India in 2014; Real Heroes' Award by CNN IBN Channel in 2008; 'Green Teacher' Award by Sanctuary Asia Magazine in 2005; Ashoka Fellowship by Ashoka: Innovators for the Public in 2002; 'Man of the Year' by The Week magazine in India in 2001 and the Governor's Medal by the J&K State Government in 1996.

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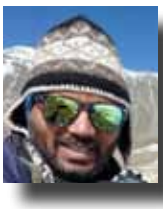

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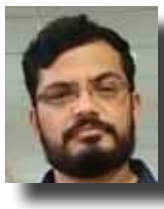

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Glossary

Acronym	Expanded Form
ACAPC	Amity Centre for Air Pollution Control
ACOAST	Ocean Atmospheric Science and Technology
AEC	Arctic Economic Council
AGU	American Geophysical Union
APECS	Association of Polar Early Career Scientists
APU	Azim Premji University
ARCI	International Advanced Research Centre of Powder Metallurgy
ASI	Aeronautical Society of India
ASOC	Antarctic and Southern Ocean Coalition
ATCM	Antarctic Treaty Consultative Meeting
ATCP	Antarctic Treaty Consultative Parties
ATS	Antarctic Treaty System
CAPS	Centre for Air Power Studies
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CIFRI	Central Inland Fisheries Research Institute
CIFT	Central Institute of Fisheries Technology
CLIVAR	Climate and Ocean Variability, Predictability and Change
CRAMRA	Convention on the Regulation of Antarctic Mineral Resource Activities (
CSIR	Council of Scientific and Industrial Research
CUSAT	Cochin University of Science and Technology
DRDO	Defence Research and Development Organisation
DST	Department of Science and Technology
ECORD	European Consortium for Ocean Research Drilling
EEZ	Exclusive Economic Zones
EGU	European Geophysical Union
EGU	European Geophysical Union
ENSO	El Niño-Southern Oscillation
EPB	European Polar Board
ESSAC	ECORD Science Support and Advisory Committee
FRSGC	Frontier Research System for Global Change
GEOTRACES	An International Study of the Marine Biogeochemical Cycles of Trace Elements and Isotopes
GSA	Gujarat Science Academy
GSI	Geological Survey of India
IAATO	International Association of Antarctica Tour Operators
IAEA	International Atomic Energy Agency
IAF	Indian Air Force
IAHR	International Association for Hydro-Environment Engineering and Research
IAIP	Institutional Academic Integrity Panel
IAMG	International Association for Mathematical Geosciences
IARI	Indian Agricultural Research Institute
IASC	International Arctic Science Committee
ICAI	Institute of Chartered Accountants of India
ICAR	Indian Council of Agricultural Research
ICIMOD	International Centre for Integrated Mountain Development

ICMAM	Integrated Coastal and Marine Area Management
ICWA	Indian Council of World Affairs
IEEE	Institute of Electrical and Electronics Engineers
IGC	International Geological Congress
IGF	Indian Young Geomorphologists Forum
IGSTC	Indo-German Science and Technology Centre
IGU	Indian Geophysical Union
IHR	Indian Himalayan Range
IIG	Indian Institutions of Geomorphologists
IIHMRU	Indian Institute of Health Management Research University
IIRS	Indian Institute of Remote Sensing
IISC	Indian Institute of Science
IMD	India Meteorological Department
IMS	Indian Meteorological Society
INCOIS	Indian National Centre for Ocean Information Services
INSA	Indian National Science Academy
INSTC	International North–South Transport Corridor
IOC	Intergovernmental Oceanographic Commission
IOCINDIO	Intergovernmental Oceanographic Commission Regional Committee for the Central Indian Ocean
IONS	Indian Ocean Naval Symposium
IORA	Indian Ocean Rim Association
IORG	Indian Ocean Research Group
IOTWMS	Indian Ocean Tsunami Warning and Mitigation System
IPCC	Intergovernmental Panel on Climate Change
IQOE	International Quiet Ocean Experiment
IRAD	Integrated Research and Action for Development,
ISBA	International Seabed Authority
ISEAS	Institute of Southeast Asian Studies (now SEAS Yusof Ishak Institute)
ISPRS	International Society of Photogrammetry and Remote Sensing
ISRO	Indian Space Research Organisation
IUGC	International Undergraduate Geophysics Competition
IUST	Islamic University of Science and Technology
JNU	Jawaharlal nehru University
LIGHTS	Learning in Geography, Humanities, Technology and Science
LLOF	Landslide Lake Outburst Flood
M&A	Mergers and Acquisitions
MEA	MInistry of External Affairs
MoEF&CC	Ministry of Environment, Forest and Climate Change
MP-IDSA	Manohar Parrikar Institute for Defence Studies and Analysi
NARL	National Atmospheric Research Laboratory.
NBA	National Biodiversity Authority
NCESS	National Centre for Earth Science Studies(
NCMRWF	National Centre for Medium Range Weather Forecasting
NDIM	New Delhi Institute of Management
NDMA	National Disaster Management Authority
NIAS	National Institute of Advanced Studies

NIH	National Institute of Hydrology
NIO	National Institute of Oceanography
NMSHE	National Mission for Sustaining the Himalayan Ecosystem
NPI	Norwegian Polar Institute
NRDC	National Research Development Corporation
NRDMS	Natural Resources Data Management System (Now called National Geospatial Programme Division)
NRSA	National Remote Sensing Agency
NSCS	National Security Council Secretariat
OECD	Organisation for Economic Co- operation and Development
ORF	Observer Research Foundation
PARI	Parliamentary and Administrative Research Institute
SAARC	South Asian Association for Regional Cooperation
SaGAA	Science and Geopolitics of Arctic and Antarctic
SAMDeS	Society for Aerospace Maritime and Defence Studies
SASE	Snow and Avalanche Study Establishment
SCAR	Scientific Committee on Antarctic Research
SCATS	Scar Committee on Antarctic Treaty System
SCOR	Scientific Committee on Oceanographic Research
SDFL	Sustainable Development Forum of Ladakh
SDG	Sustainable Development Goals
SECMOL	Students' Educational and Cultural Movement of Ladakh
SICMSS	School of Integrated Coastal and Maritime Security Studies
SPLICE	Strategic Programmes Large Initiatives and Coordinated Action Enabler
SROCC	Special Report on the Ocean and Cryosphere in a Changing Climate
SWERA	Solar and Wind Resource Assessment
TERI	The Energy and Resources Institute
TIFR	Tata Institute of Fundamental Research
TWAS	The World Academy of Sciences
UNCLCS	United Nations Commission on the Limits of the Continental Shelf
UNDP	United Nations Development Programme
UNECAP	United Nations Economic and Social Commission for Asia and the Pacific
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organization
USERC	Uttarakhand Science Education and Research Centre
USIEF	US-Indian Education Foundation
USISTEF	U.S-India Science and Technology Endowment Fund
VNCS	Vice Chief of the Naval Staff
VRS	Voluntary Retirement Scheme
WCRP	World Climate Research Programme
WIHG	Wadia Institute of Himalayan Geology
WING	Women in Geothermal
WMO	World Meteorological Organisation
WTO	World Trade Organisation

पृथ्वी विज्ञान मंत्रालय
Ministry of Earth Sciences
Government of India (www.moes.gov.in)

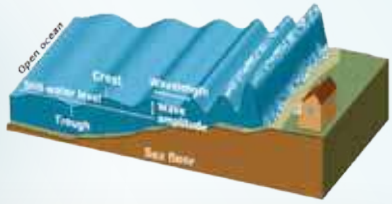
Indian National Centre for
Ocean Information Services, Hyderabad

Our Mission

To provide ocean data, information and advisory services to society, industry, the government and the scientific community through sustained ocean observations and constant improvements through systematic and focused research in information management and ocean modelling.

Tsunami Early Warning System

- Detection and Early Warnings for Indian Ocean Tsunamis
- Operational 24x7
- INCOIS is recognised as a Tsunami Service Provider by IOC-UNESCO to provide Tsunami advisories for India and 25 Indian Ocean Rim countries.

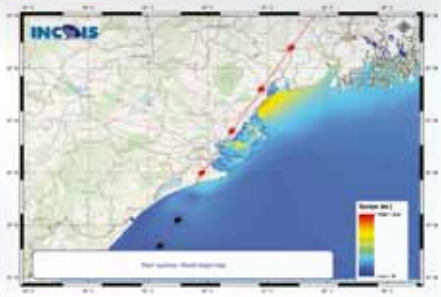


Potential Fishing Zone Advisory (PFZ)

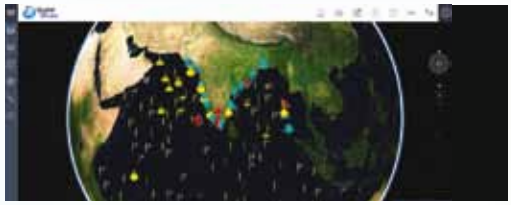
Since established, INCOIS provides a reliable service on availability of fishes as Potential Fishing Zone (PFZ) and Tuna-PFZ advisories to Indian Fishing Community.

Ocean State Forecast

- High Wave Alerts • Oil Spill Trajectory
- Storm Surge Early Warnings • Marine Search and Rescue



Dissemination of Ocean Data and Information



- INCOIS also maintains various open-source platforms for publishing specialized data with interactive mapping applications on the web, such as Live-Access-Server (LAS), OMNI-RAMA Joint web portal, Earth System Science Data (ESSD) portal, Digital Ocean, etc.
- Designated as the National Oceanographic Data Centre (NODC) under the International Oceanographic Data Exchange (IODE) Programme of IOC/UNESCO. INCOIS also serves as the National Argo Data Centre and Regional Argo Data Centre of the International Argo Programme

Connecting India to the Global Ocean Science-scape

- ITCOocean - International Training Centre for Operational Oceanography established in 2013
- A Category-II Training Centre recognised by IOC-UNESCO with world- class state-of- art e-class room and online education infrastructure

MINISTRY OF EARTH SCIENCE

National Centre for Seismology

Considering the importance of earthquake monitoring and seismological research in India, since long it has been realized that a dedicated institute is required. Accordingly, the Seismology Division and Earthquake Risk Evaluation Centre of India Meteorological Department, have been merged with the newly created National Centre for Seismology (NCS) in August 2014, as an attached office of the Ministry of Earth Sciences. In addition to earthquake monitoring NCS is involved in providing seismic microzonation of mega cities lying in seismic hazard zones. maps of a few selected cities, and seismological research.

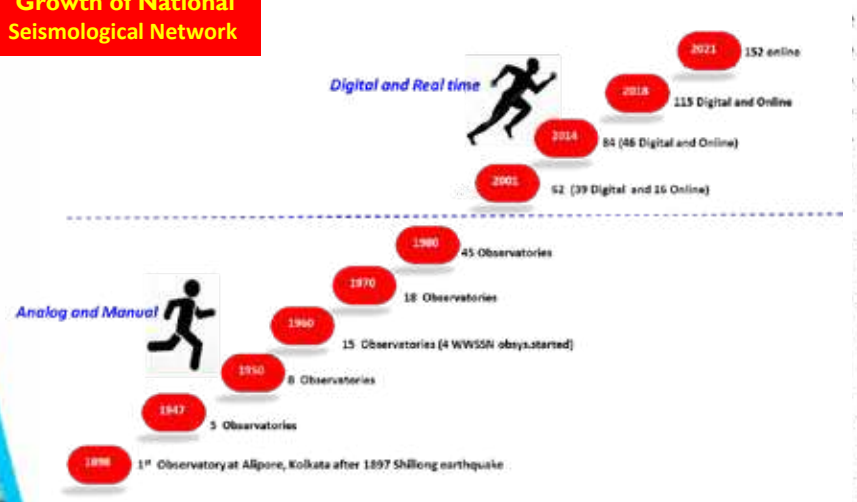
Vision

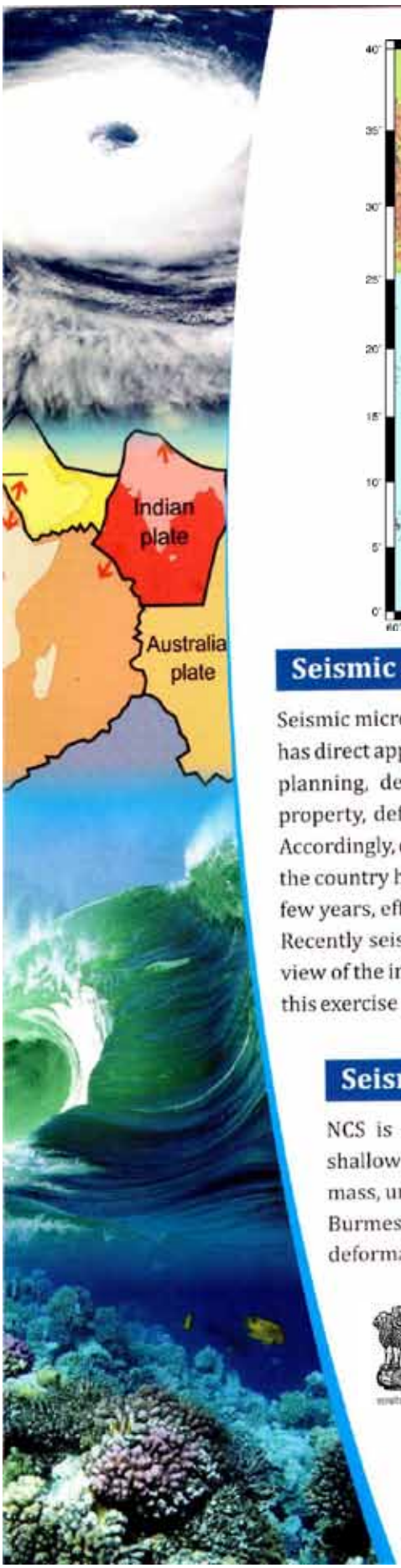
Understanding earthquake processes and their effects through monitoring and seismological research for cause of earthquake safe society.

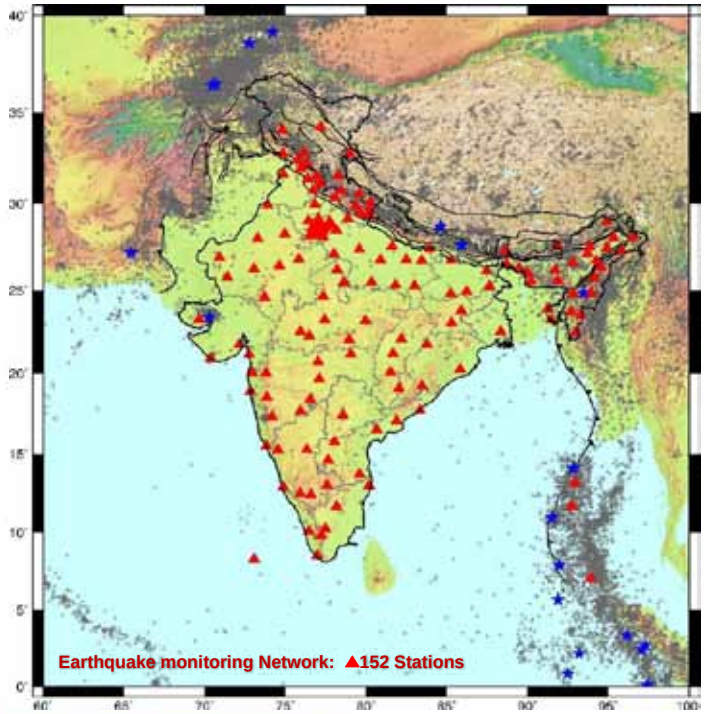
Earthquake monitoring

Earthquakes in the Indian subcontinent occurs due to the northeastward movement of Indian plate and its interaction with the neighbouring Eurasian plate in the north and Sunda plate in the east. Majority of the earthquakes occur in the plate boundary regions, however, a few damaging earthquakes have occurred in the plate interior regions as well. A few damaging earthquakes in the plate boundary regions are, 1897 Shillong plateau, 1905 Kangra, 1934 Nepal-Bihar, 1950 Assam (now Arunachal), , 2004 Sumatra Andaman, 2005 Kashmir and 2015 Gorkha earthquakes. In the plate interior regions, damaging earthquakes occurred in 1993 at Killari, 1997 at Jabalpur, and in 2001 at Bhuj.

Growth of National Seismological Network







Seismic microzonation

Seismic microzonation is a multi-disciplinary and multi-institutional effort, which has direct application in disaster mitigation and management, urban development, planning, design and construction, and risk assessment to existing life and property, defence installations, heavy industry and public utilities and services. Accordingly, development of seismic microzonation maps of major urban centres in the country has been recognized as one of the priority areas in NCS. During the last few years, efforts have been made to take up microzonation studies in a few cities. Recently seismic microzonation (1:10,000 scale) of Delhi has been completed. In view of the importance of the seismic microzonation in mitigating future disasters, this exercise has been initiated for 30 important cities of India.

Seismological research

NCS is actively involved in seismological research related to estimating shallow and deep crustal structure in various tectonic domains of Indian land mass, understanding earthquake occurrence processes in the Himalaya, Indo-Burmese and Andaman Sumatra arc and also in plate interior regions, crustal deformation measurements in the plate boundary and plate interior regions.

National Centre for Seismology
Ministry of Earth Sciences

Brief History

Initially, the Institute was founded as a distinct unit of the India Meteorological Department (IMD) under the name of Institute of Tropical Meteorology (ITM) on 17 November, 1962 at Pune by the Government of India with support from the World Meteorological Organization (WMO). On 1st April 1971, the Institute was given an autonomous status under the present name. Later in 1985, the Institute was brought under the Department of Science and Technology (DST) of the Ministry of Science & Technology. Now, since 12th July 2006, IITM has been functioning under the direct administrative control of the specially formed Ministry of Earth Sciences (MoES), Government of India.

About IITM

IITM is recognized as a national centre for basic and applied research in Meteorology and Atmospheric Sciences. The Institute is having state-of-the-art world-class infrastructure and facilities. IITM is working dedicatedly on these subjects with emphasis on Tropical Meteorology and Monsoon Studies.

IITM, as a vibrant and dynamic research institute, is committed to the better understanding of land-atmosphere-ocean system and to the development of improved skills in monsoon predictions. The Institute is constantly evolving to meet the new challenges and changing national and international demands. Institute's scientific expertise has potential applications in country's agriculture, economics, health, water resources, transportation, communications, etc.

Broad areas of Research and Development

Tropical Meteorology and Atmospheric Sciences including Climatology, Palaeoclimatology, Dendroclimatology, Hydrometeorology, Monsoon Studies, Weather Modifications, Climate Predictions and Weather Forecasting, Climate Change, Boundary Layer, Global Atmosphere and Ocean Modelling, Satellite Meteorology, Atmospheric Chemistry, Atmospheric Electricity, Cloud Physics, Aerology, Instrumentation for Observational Techniques, Theoretical Studies, land-Ocean-atmosphere Processes and interactions, Satellite and Radar Meteorology, etc.

climate change and projections

GHG studies

cloud physics and dynamics

cloud seeding

Vision

"To Make IITM a World Centre of Excellence in Basic Research on the Ocean-Atmosphere Climate System required for improvement of Weather and Climate Forecasts"

thunder storm

air quality forecast: SAFAR

ocean studies

monsoon studies

prediction

variability

extended range

seasonal

short-term

palaeo

land

Atmo-sphere

ocean

modeling

theoretical studies

obser-vations

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IITM

Indian Institute of Tropical Meteorology

www.tropmet.res.in

Aspiring for Better Prediction of Weather and Climate

Major Thrust Areas

- Tropical Weather and Climate
- Climate Change Research and Projections
- Monsoon Prediction at Different Scales
- Physics and Dynamics of Tropical Clouds
- Airborne Research
- Air Quality Research and Forecast
- Academic and Training Activities

Strengths

IITM has strong expertise in theoretical and observational meteorology, oceanography, climate change and modelling with special reference to Asian monsoon variability and predictability.

Infrastructure and Facilities

IITM has excellent infrastructure and facilities for advanced research in Atmospheric Sciences and Climate. The advanced labs and instruments include: High Performance Computers (HPCs) with high processing capacity, mobile multi-parameter Doppler Radars, GPS Radiosonde, X-Band, Ka-Band and C-band Radars, Mobile LIDAR Wind Profiler, Hyper-spectral Microwave Radiometer, Sky Radiometer, Dual Polarisation Micro Pulse LIDAR, Stable Isotope Mass Spectrometer, Urban Air Pollution Measurement Network and Forecasting System, Thunderstorm Forecasting System, Dendroclimatology Lab with advanced Densitometry for tree rings, Laser Remote Sensing & Aerosol lab, High-end Multimedia Training Facility, Fluid Dynamics Lab, etc. A well-equipped High Altitude Observatory for aerosol-cloud interaction studies at Mahabaleshwar, Maharashtra is established.

IITM Main Gate

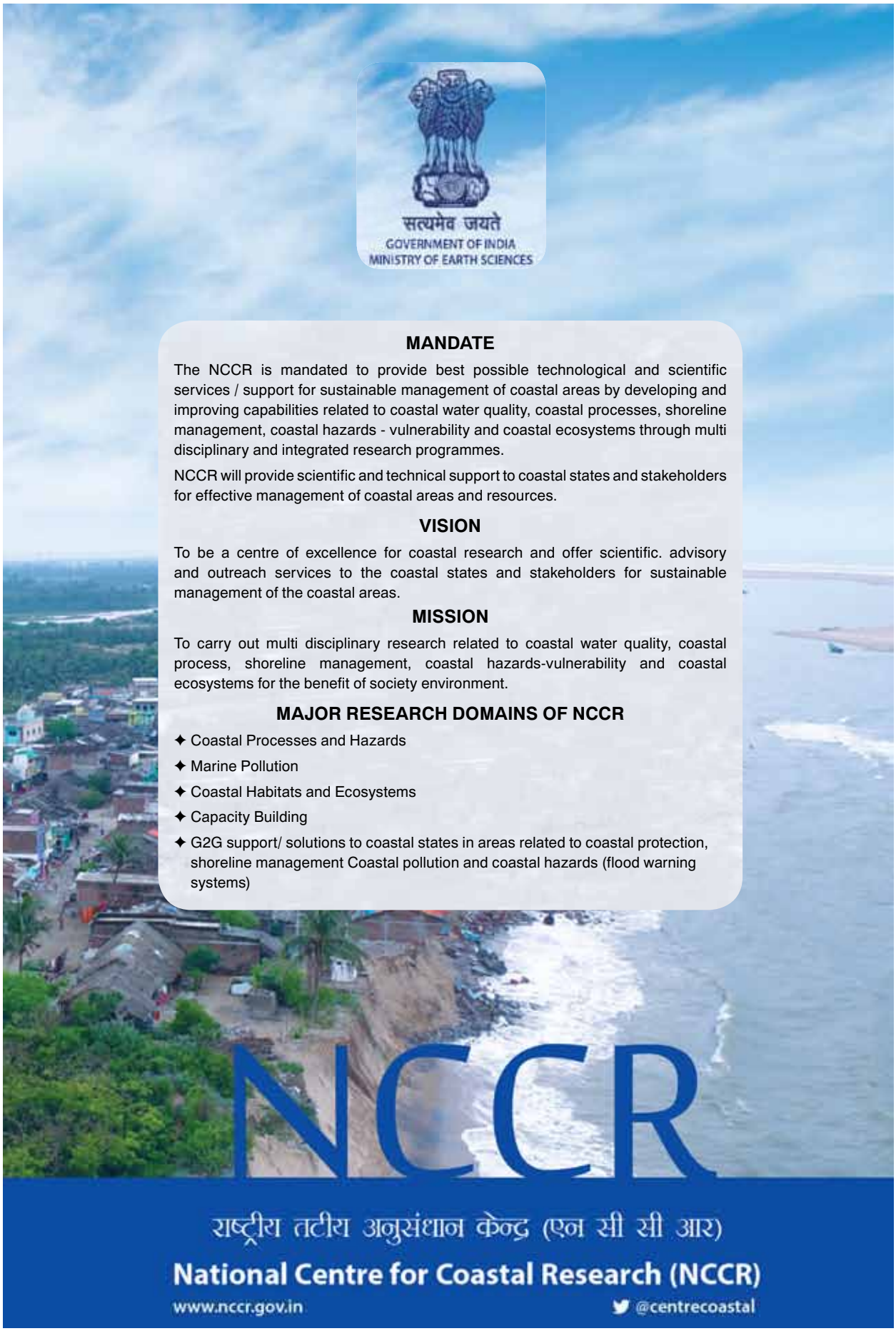
Meghdoot Complex

HACPL, Mahabaleshwar

IITM Library Building

New Delhi Branch Office

Prithvi Hall of Residence


सत्यमेव जयते
GOVERNMENT OF INDIA
MINISTRY OF EARTH SCIENCES
MANDATE
The NCCR is mandated to provide best possible technological and scientific services / support for sustainable management of coastal areas by developing and improving capabilities related to coastal water quality, coastal processes, shoreline management, coastal hazards - vulnerability and coastal ecosystems through multi disciplinary and integrated research programmes.
NCCR will provide scientific and technical support to coastal states and stakeholders for effective management of coastal areas and resources.
VISION
To be a centre of excellence for coastal research and offer scientific. advisory and outreach services to the coastal states and stakeholders for sustainable management of the coastal areas.
MISSION
To carry out multi disciplinary research related to coastal water quality, coastal process, shoreline management, coastal hazards-vulnerability and coastal ecosystems for the benefit of society environment.
MAJOR RESEARCH DOMAINS OF NCCR
✦ Coastal Processes and Hazards
✦ Marine Pollution
✦ Coastal Habitats and Ecosystems
✦ Capacity Building
✦ G2G support/ solutions to coastal states in areas related to coastal protection, shoreline management Coastal pollution and coastal hazards (flood warning systems)
NCCR
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Ministry of Earth Sciences
Government of India

NATIONAL CENTRE FOR POLAR AND OCEAN RESEARCH

An Autonomous body under the
Ministry of Earth Sciences, Government of India

Indian Gateway to Polar Regions


Himadri, Arctic


Himansh, Himalaya


Bharati, Antarctica

The mandate of the institute is to plan, promote, coordinate and implement scientific research in the polar regions and surrounding realms.

Besides organizing expeditions, NCPOR also maintains the Indian research bases in Antarctica (Maitri & Bharati), Arctic (Himadri) and Himalayas (Himansh).

THRUST AREAS OF RESEARCH

Expedition & Operations
- Antarctica
- Arctic
- Southern Ocean
- Himalayas
- Management of research vessels

Polar Sciences
- Polar Cryosphere and Ice core studies
- Polar Micropaleontology
- Paleo-oceanography
- Polar Remote Sensing
- Himalayan Cryosphere

Geoscientific Studies
- Indian Ocean Discovery Program
- Indian Ocean Geoid low
- Extended Continental shelf Program

Deep Sea Exploration and Mapping
- Mapping of the EEZ
- Hydrothermal Studies
- Cobalt Crust

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The 7th Conference on Science & Geopolitics of

ARCTIC-ANTARCTIC

The Future of Arctic Ice

An Indo-Pacific Connect

PRE-CONFERENCE MATERIAL
April 2023

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Contents

Section A

Ideating the Conference

SaGAA 7 2023
Post pandemic efforts of the organising committee to put together an event of national and international significance

Ideating SaGAA 2023

Science and Geopolitics of Arctic and Antarctic acronymed SaGAA, began its journey in 2011 as a bi-annual conference and was formalised as a think tank in 2015. It works under the aegis of LIGHTS Research Foundation, a not-for-profit organisation, registered under the Registrar of Societies Act, 1860. SaGAA addresses challenging issues facing the global community today, i.e., understanding the science behind the melting of the poles and the geopolitics around it. It is also the first in India to focus solely on cryospheric issues. SaGAA's mission is to jointly undertake policy initiatives on all matters related to science and geopolitics of the Poles, act as an advocacy body for the Indian government, forge alliances with relevant national and international bodies so as to enhance and accelerate research capabilities in various associated disciplines in the Polar domain, serve the industry by forging globalisation efforts in relation to the Polar regions, encourage and inspire universities, colleges and schools and other educational institutions towards expanding academic research and policy pursuits on polar sciences and finally, develop various consultation fora/platforms leading to policy interventions. Till date, SaGAA has organised 6 conferences between 2011 to 2020, worked towards policy alliances with NSCS for the Arctic Policy, authored 3 academic books, published 5 issues dedicated to Polar concerns in the 'Geography and You' magazine, and 9 newspaper articles.

The ideation of SaGAA 7 began about 9 months ago, in July, 2022 with the commencement of the LIGHTS governing body meeting with Dr Rasik Ravindra, Chairman, SaGAA and Senior Vice President, LIGHTS, at its helm. Professor NC Pant, Fmr Prof Geology, Delhi University, was invited to join the SaGAA organising committee as its Co-Chairman, to help in the preparation of the vision outline, as well as contribute to the overall mission, goals, scope and objectives of the SaGAA think tank. India's new interest in the Arctic, partially due to the possibility of engaging beyond science with the Arctic nations and the increasing commercial viability of the Northern Sea Route has contributed towards shaping the objectives of SaGAA 2023. The Conference being central to the activities of the think-tank, the nature of the seventh SaGAA event was determined and the platform was envisaged to throw up new ideas of collaborations.

With a resoundingly positive response from the Ministry of Earth Sciences, the National Security Council Secretariat, and the Ministry of External Affairs, SaGAA embarked on furthering the conference platform after a three-year hiatus since the pandemic. The organising committee upheld the dynamism and the urgent need to rebuild the SaGAA forum and engage in multifarious domains. The SaGAA 7 panel of patrons advised proactively through the ideation period and attended several online meetings. Members of the organising committee came together in several in-person meetings to build a methodology based on the advice of the patrons and identified key issues to be discussed during the SaGAA 7 conference.

The members brought to focus various online and offline meetings, workshops and seminars that were organised between 2021-2022 related to the poles and the Southern Oceans. The topics from these events were curated, analysed and contextualised for contemporary and regional relevance. Thereafter a list was prepared with 35 topics. Armed with a list of topics, the patrons and organising committee attempted to put a face and name to each of these ideas. Thus emerged the list of identified experts who were to be invited for this special edition of SaGAA 7. The SaGAA secretariat then went on to write personalised letters to each of these invited speakers, outlining their areas of synergy with the topic selected for them. SaGAA 7 stands today with a total of 67 eminent speakers, including 6 secretary level officers, 17 Heads of the Departments from 7 nations including India and representatives from more than 38 institutes, universities and organisations, working in the areas of geology, geography, climate science, technology, policy, security, exploration, geopolitics and environmental sciences.

However, the limitations of the SaGAA 7 two-day event, sans a parallel session format, imposed a time-constraint. All 35 topics were unable to be accommodated but a sizeable number, 26, is being addressed during the event. From the list of 26 topics, majority (more than 24) of the papers are being presented on the polar regions of Arctic, Antarctic, and the Himalaya, primarily focusing on the issues of energy, climate change and disaster risk mitigation. In all 6 papers are being presented on India's Deep Ocean Mission, and about the same number of speakers and panellists will be discussing topics pertaining to the maritime security, Arctic-Indo-Pacific Connect, especially with regard to the narratives around Northern Sea Route and the Strait of Malacca. Deliberations on new areas of research in this sector pertains to indigenous communities in cryospheric realms, gender perspectives and youth participation in polar affairs. SaGAA 7's list of finalised talks are listed in this book of abstracts.

The future events of SaGAA will, additionally focus on encompassing more papers, presentations and discussions on the topics of permafrost, blue and green economy, climate change and the disasters in the Arctic, Antarctic and Indian Himalayan region, and its impact on people's livelihood.

Section B

The Discourse

SaGAA 7 2023
2 Plenary;
5 Technical Sessions;
3 Panel Discussion;
On geopolitics;
climate change
and science of the
polar regions

The Gender Equality in the Arctic (GEA)

Mr Hjalti Ómar Ágústsson
Special Advisor, Directorate of Equality, Iceland

The 2030 Agenda for Sustainable Development Goals affirms that gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world; in fact, realising gender equality and the empowerment of women and girls will be a crucial contribution to progress across all the Goals and Targets. In 2021, The Pan-Arctic Report on Gender Equality in the Arctic, a product of the Arctic Council Sustainable Development Working Group, embraced these principles and highlighted the necessity of cooperation across the Arctic on gender. The Report identified shared challenges and gaps, and put forward suggestions and recommendations, including gender-based analysis and gender mainstreaming as necessary strategies for promoting and ensuring gender equality including social and economic development in the Arctic. This presentation will highlight the importance of recognition and appreciation of diversity and balanced participation in leadership and decision-making both in the public and private sectors. It will do so by presenting some of the lessons learned about engagement, collaboration and inclusion during the inception, writing, reviewing and disseminating of The Pan-Arctic Report on Gender Equality in the Arctic.

Technological Innovations

Dr M A Atmanand
Former Director, National Institute of Ocean Technology, Chennai

The discussion will cover the following points:

1. **Global need for minerals vis a vis development of technology for deep sea mining including associated environmental concerns.**
2. **UN decade of ocean science for sustainable development, lack of general awareness for public in terms of influence of ocean on climate change, and need for more ocean observations.**
3. **Need to motivate youngsters to take up ocean-based career, including more of SDGs like SDG 14 in curriculum for making youngsters aware of need to protect and conserve the oceans.**

Selected Values of UNCLOS in Indo-Pacific Maritime Security Trade and Transport

Dr Stuti Banerjee
Senior Research Fellow, Indian Council of World Affairs, Sapru House, New Delhi

The Indo-Pacific is a multi-polar region, a home to the most dynamic economies of the world, the most populous nations of the world and important sea lines of communication. The region accounts for the three largest economies of the world-China, Japan and the United States, and some of the fastest growing economies of the world-India, Indonesia and Vietnam are also located in this region. Forty-two per cent of global trade and sixty per cent of global maritime trade flows through its waters. The region is home to sixty-five per cent of the world population and sixty-three per cent of the world's GDP. In this geo-strategically important region maritime security and connectivity are two important factors that are common to the global narrative that is visible in the Indo-Pacific strategies from around the world. The stress on a free, open and rules based Indo-Pacific highlights the need to maintain maritime security and the value of the UNCLOS to address both challenges and enhance opportunities. This not only means that States must prioritise safeguarding the freedom of commercial and military vessels to transit international waterways but also ensure they can exercise all the rights and uses of the sea and airspace recognised under international law. More broadly, it means unimpeded lawful commerce, respect for international law, and the peaceful management of disputes. As nations look to the oceans for economic opportunities, it increases the need for more sustainability and a robust mechanism to define the scope of maritime entitlement of nations.

Dr Sulagna Chattopadhyay
President SaGAA, Editor in Chief, Geography and You.

Northern Sea Route

Global shipping traffic between western nations and east Asia passes through three primary routes, the Suez Canal-Malacca Strait, the Cape of Good Hope-Malacca Strait, and the NSR. Of the three, the first two bear high-value global traffic and hold enormous strategic appeal. The third, however, is becoming a viable alternative hastily, remaining open for extended periods due to global warming. The Trans-Arctic Sea Route comprises three sea routes: Northwest Passage along the northern coast of Canada, the Transpolar Sea Route running from the Atlantic Ocean to the Pacific Ocean across the center of the Arctic Ocean (unusable now due to pack ice), and the NSR. The NSR is a 5,600 km shipping route that runs along the northern coast of Russia between the Barents and Kara Seas and ends in the Bering Strait. The NSR is primarily utilised by tankers and dry cargo ships, accounting for 82 per cent of all the transits, while transit constituting passengers, cruise, and research ships account for a mere 5 per cent. The NSR holds time and emission reduction possibilities for countries such as China. Reducing time from Shanghai to Kirkenes, in Norway, to merely 22.5 days instead of 32-38 days through Malacca, China hopes to develop Kirkenes as the first port on call in Europe. A wider adoption of NSR will, of course, require navigation competency over the still present sea ice, which constitutes a hazard for navigation, more cargo ports along the NSR, higher insurance premiums, sufficient coverage of charts, search and rescue facilities, and more days available for navigation (<155 days per year). With the Arctic sea ice extent decreasing every decade, NSR may account for 4.7 per cent of the future global trade by 2030s assuming the route is open all year round. However the volume, the nature of cargo, its value, and strategic advantage of the NSR need a thorough review in the Indian context.

Contradictions and Hollowing of the Antarctic Treaty System

Dr Sanjay Chaturvedi
Professor in International Relations and Dean, Faculty of Social Sciences, South Asian University, New Delhi

Against the backdrop of discursive scientific transformation of the Antarctic throughout the decades – the 1950s to 1970s – followed by the intense resource-driven geopolitics of 1980s and the crisis of consensus that preceded the 1991 Madrid Protocol, I argue that the resilience, responsiveness and adaptability shown by the ATS over the past six decades cannot be taken for granted, especially at a time when rivalries and mutual mistrust among some of the major powers, which are also the key players in both polar science and Antarctic geopolitics, seem to be at their zenith. Be it the concerns expressed over the future intentions of China or climate change impacts or possible resumptions of intense resource geopolitics from 2048 – when the Madrid Protocol comes up for a review – onwards, or the prospects of legally frozen territorial claims being more assertively promoted, the following proverbial million/billion-dollar question demands and deserves serious attention: who is fearful/insecure about what/whom, when, where and why? With Antarctic geopolitics and related scenarios oscillating between hope and fear – both at the risk of being unfounded – and posing a challenge to the power of human agency, 'futures' are not inevitable and thus avoidable, provided there is a will to seek and follow unconventional pathways.

A Home no More: Climate Change and Migration in Selected Himalayan Tribes

Dr Bhaswati Das
Associate Professor, Centre for the Study of Regional Development, School of Social Sciences, Jawahar Lal University, New Delhi

The Lepchas are a unique Himalayan community in the remote reaches of the Myal Lang, or the Kanchenjunga National Park. The community has been granted scheduled tribe status in 1956 and as per the 2011 Indian Census, the total population of Lepchas of Sikkim is 42,909. Today, the Lepchas are losing ground to climate change which is causing cultural erosion. Loss of land and biodiversity as a result of climate change is damaging the traditional practices such as nature-worshiping. The Lepchas believe that mountains, peaks, rivers, and lakes are organic entities that live and breathe. Their rituals call for the involvement of the environment around them and they are deeply dependent on the natural world for not only physical sustenance, but for their mental well-being too. The Janjati can potentially lose their nature-inspired deities caused by climate-change induced migration, displacement, territorial dispossession, and deletion of 'inherited heritage-knowledge through innumerable generations'. There is a need to delve into the foundations of the sacredness of the region to highlight its bio-cultural diversity and provide a way forward in ecosystem conservation through climate change preparedness. The Lepchas are the keepers of the region's unique biodiversity. They can be a great aid in providing nature-based solutions to the survival of the population of India and the world. Additionally, the Lepchas can be a great asset in mapping and monitoring of water bodies within the Lepchas reserve area to protect it from the possible threats of climate change.

Changes in the Arctic Ocean and the Need for Sustained Observations

Dr Paul Dodd
Scientist, Norwegian Polar Institute, Norway

The Arctic Ocean is undergoing rapid climate change. As the region warms and sea ice retreats, previously inaccessible areas become accessible paving the way for increased activity. The water column is changing in response to freshwater inputs, modulation of inflowing Atlantic water, and a reduced sea ice cover. Observing and understanding the changes occurring in the surface layer of the Arctic Ocean is critical for its appropriate management as processes here influence primary productivity and ecosystem dynamics in the photic zone. Moreover, the changing sea ice regime directly affects the surface layer with increasing light availability but also increased stratification and nutrient limitation is expected as the sea ice retreats. The rapid pace of change means our current understanding of the Central Arctic Ocean is outdated and needs updation to enable effective management. Although the Arctic is warming, it remains an extreme environment-cold, dark and ice-covered for much of the year, making comprehensive studies extremely challenging. However, the retreating ice cover and availability of powerful new research vessels have allowed a new sustained observing system to be established in the Central Basins.

Engaging the Youth in Polar Knowledge-Why Polar Studies is Even an Option

Dr Archana Dayal
Postdoctoral Researcher, NERC Cryo365, Aberystwyth University, UK

The rapid transformations occurring in polar regions due to climate change have far-reaching global implications, necessitating increased public awareness and knowledge. Although seemingly distant from the polar regions, India is significantly affected by changes in the Polar regions and its resultant consequences, such as sea-level rise, extreme weather events, and alterations to monsoon patterns. Thus, understanding the processes and impacts of polar changes is crucial to addressing these challenges. In addition, Polar research offers valuable insights into global environmental processes and sustainable development strategies, which can benefit a diverse range of sectors in India. This presentation will draw from the speaker's personal experiences of having started with a career in Polar research in India, with a progression to PhD and postdoctoral positions in the UK and elsewhere. The presentation will present national and international opportunities to pursue polar studies as a viable career path. By showcasing diverse opportunities in the field, ranging from scientific research and environmental management to policy-making

and international collaboration, the talk will aim to inspire the youth to consider polar studies as an exciting and meaningful option for their future. In conclusion, engaging the youth in polar knowledge goals is essential for addressing the global challenges of climate change and promoting a broader understanding of environmental issues. Furthermore, by presenting Polar Studies as an attractive educational and career option within India, we can foster a new generation of dedicated polar professionals who will contribute to the preservation and sustainable development of these fragile regions while benefiting India's national interests.

Understanding Glaciers and Glacial Lake Responses across the Sikkim Himalayas

Dr Manasi Debnath
Assistant Professor, Nagaland University
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The west-east glacier anomaly over the Hindukush Himalayan Region, a part of third pole, is well visualised. The Sikkim Himalaya, a part of eastern Himalayas, have different topography than western part of Himalaya which further provide combined varied conditions of local topography and climate response on glacier and glacial lakes. The satellite-based data and limited field-based data have been used to monitor glacier and glacial lake variability since five decades in Sikkim Hiamalaya. It has been identified by the researchers that the glacier area loss in Sikkim is much higher ranging from 20 per cent to 30 per cent at different basin level. Among many glaciers, East Rathong, South Lohnak, Gurudongmar, and Kangchengayo glaciers have showed much faster glacier recession. The development of new glacial lakes adjacent to the receded mother glaciers and expansion of existed lakes have drawn critical attention. The basin and local level glacial lake area monitoring research work in Sikkim Himalaya identified varied result, such as 8 per cent to 35 per cent of lake area expansion based on remote sensing and GIS based data. Exceptional case of lake area reduction also has been identified in Sikkim Himalaya signifying lake water breaching event and varied behaviour of supraglacial lake. Some of the enlarging glacial lakes are South Lohnak lake, Gurudongmar Lake, Khangchung Tsho, Tenbawa Kangse, etc. Regular monitoring and hazard prevention methods employed over the South Lohnak Lake has reduced the water level and hence minimised the risk factor. Further, a synthesis work combined with palaeo-glacier variability, present glacier-glacial lake responses and future trend modelling is required to understand the complex climate-glacier-glacial lake interaction at regional level.

Ms Kunzes Dolma
India Ambassador, WING India Ambassador /GRÓ GTP PhD Fellow Iceland / Vice Chairperson-SDFL

Technological Innovations in Geothermal Energy: Learnings from Iceland

Iceland has been an international leader in geothermal energy for the past century and is now a major exporter of the technology. This presentation is on the types of geothermal systems used in Iceland, the strategies for utilising geothermal energy for heating and electricity production, and the environmental and economic benefits of geothermal energy. Furthermore, the challenges that have been faced in the development of geothermal energy in Iceland and the solutions that have been implemented to overcome them will be discussed. Finally, the potential for the development of geothermal energy in India and the transfer of knowledge from Iceland to facilitate this will be discussed.

Dr Jenson George
Scientist D, National Centre for Polar and Ocean Research, Goa

Exchange of Mass/Particle across Air-Ice-Sea Interface in Southern Ocean

Rapid sea-ice variability observed in the Antarctic coastal waters in the last decade is alarming and puzzling for the scientific community. In a climate-change scenario, the interconnected physical, biological, and chemical ocean-ice/snow-atmosphere system is now transitioning to an unprecedented and uncertain regime, including the seasonally ice-free conditions in the Southern Ocean. Sea ice is a substrate for algal growth influencing nutrient dynamics, water column stratification, and light availability. Sea ice melting during spring-summer generates extensive phytoplankton blooms controlling the carbon dioxide draw-down as part of the carbon pump. The ecological consequences of rapidly declining sea ice are unsure, as this will result in earlier and further close-to-coast phytoplankton blooms. The lack of proper representation of processes active in the air-sea-ice interface, vertical mixing, and biogeochemical processes in climate models is attributed to the weak predictability of change in the polar system. In this presentation, we will discuss the data gathered from the Indian Southern Ocean and Antarctic expeditions to understand the exchange of mass/particles and energy across the air-ice-sea interface and its climate relevance.

Permafrost Pathways in the Arctic and the Himalaya

Dr Santonu Goswami
Associate Professor, Azim Premji University, Bangalore

Permafrost, a layer of soil that remains frozen for at least two consecutive years, is a critical component of the Arctic and the Himalaya. Its degradation due to climate change has a far-reaching impact on the environment and human societies. In the Arctic, permafrost is thawing at an accelerating rate, releasing stored carbon and other greenhouse gases into the atmosphere contributing to global warming. Permafrost pathways research in the Arctic aims to understand the complex physical, biological, and biogeochemical processes that occur in permafrost environments and the feedback to the global climate system. Similarly in the Himalaya, permafrost is an essential component of the high-altitude ecosystems and plays a critical role in regulating the water supply to millions of people living downstream. Permafrost degradation in the Himalayas can lead to increased landslides and glacial lake outburst floods, which pose a significant risk to local communities. Permafrost pathways research in the Himalaya should aim to understand the pathways of water, nutrients, and energy through permafrost which are critical for the functioning of these ecosystems and their responses to environmental change. Permafrost pathways research in the Arctic and the Himalayas integrates observations, experiments, and modeling to advance our understanding of permafrost processes and their vulnerability to environmental change. Permafrost pathways research also has important implications for climate change mitigation and adaptation strategies as it provides insight into the vulnerability of permafrost ecosystems and the potential for feedback to the global climate system.

Dr Miriam Jackson
Senior Cryosphere Specialist
International Centre for Integrated Mountain Development, Kathmandu, Nepal

Early warning Systems for Glacial Lake Outburst Floods

GLOFs, can be defined as the sudden release of water from a lake that is in contact with a glacier. Climate change has led to rapid changes in glaciers which in turn has led to the expansion of glacial lakes or the formation of new ones. Many GLOFs have occurred where there is no historical evidence of such floods occurring previously. GLOFs can be huge, and the flood water can carry significant amounts of sediment and other debris. However, how dangerous a GLOF can be depends on whether there are settlements or infrastructure downstream in the flood zone. In the Hindu Kush Himalaya, major damage can occur in areas far from the glacier itself, and people affected may not have been aware of the existence of the lake before it burst. Lowering the lake level can either make the lake much less likely to flood or make the volume of such a flood much lower and hence much less damaging. However, doing this kind of mitigation in remote areas and at high elevation is often prohibitively difficult. In such cases, early warning systems can give communities the chance to get away from the flood zone before the flood water arrives. The distance from the glacial lake is often far enough that sufficient warning time can be given as soon as a lowering in lake level or increase in discharge is noted. It is imperative that such warning systems are established in close agreement with the local community. Although such warning systems cannot save infrastructure, they can help greatly in saving lives and reducing injury.

India's Expanding Role in Arctic Science

Dr Anand Jain
Project Scientist, National Centre for Polar and Ocean Research, Goa

It all started in 2007 when a team of Indian scientists, led by the former Director of NCPOR (erstwhile NCAOR) Dr Rasik Ravindra embarked on a journey to the Northernmost research base on earth. The following year (2008), India's first high Arctic research station Himadri was opened in the International research town at Ny-Ålesund, Svalbard. Since then, India has constantly been sending teams of Indian scientists to the Arctic to not only evaluate the teleconnection between the Indian monsoon and the Arctic climatic variabilities but also to contribute to a better understanding of climate change and its consequences on the atmospheric-land-sea processes. Although India is the youngest among all other nations to join Arctic research but has contributed immensely to Arctic research in the form of publications. To date, Indian scientists have contributed more than 150 research publications related to the Arctic. Moreover, in 2014 India joined the club of elite nations that can deploy and operate an underwater laboratory (IndARC mooring) for long-term monitoring of Kongsfjorden. To study atmospheric variabilities of the high Arctic region, India in the year 2015 established a Northmost atmospheric lab in the Ny-Alesund, Svalbard. India is also a member of the SIOS. The year 2022 was very significant since India unveiled its 'Arctic Policy,' and in the same year, a team of Indian Scientists landed on the geographical North Pole for the first time. To obtain a holistic understanding of the Arctic region India, under the pan-Arctic approach, is expanding its research portfolio in the other part of the Arctic, especially the 'Canadian High Arctic.' In this presentation, we will discuss India's achievements in the Arctic in the last decade and future perspectives.

Climate Change and Adaptation in the Himalayan Region

Dr Sharad K Jain
Visiting Professor, Indian Institute of Technology, Roorkee, Uttarakhand

The Himalaya refer to a large area consisting of large mountains, snow covered peaks, and valleys. From east to west, the Himalaya stretch to more than 2,500 km and have wide variations in climate and precipitation. Since Himalaya have the largest storage of snow outside the poles, they have been rightly named The Third Pole and this implies that global warming will impact the region immensely. Himalayas are also known as The Water Towers and this signifies that changes in the components of hydrologic cycle here will have large impacts on water management, ecosystems and society dependent on them. In addition to climate change, some other changes driven by rising population, land use and cover, and developmental activities such as agriculture and industries, will also impact water, land, and living beings. Thus, adaptation in the Himalayan region will have to address sustainability issues, disasters, restoring ecosystems, and livelihood. Southern slopes of Himalayas straddle across six countries and display large variabilities. Therefore, it will be good to develop adaptation strategies in a regional context by adopting a transdisciplinary approach and by involving local governments, researchers, professional, NGOs and the society.

Green and Blue Growth: Prospects of the Southern Ocean Biomass

Dr Tanu Jindal
Pro Vice Chancellor, R&D, Director, Amity Institute of Environmental Toxicology, Amity University, Noida

Bioprospecting of green and blue bioresources from Southern Ocean offers plethora of bioresources. Southern Ocean has physio-chemical factors that have a bigger impact on life as compared to other marine ecosystems. As a result, Southern Ocean is home to a diverse range of microorganisms that can adapt to harsh environments. Extremophiles have a part to play in this because of their capacity to flourish in conditions with extreme temperatures, light, carbon doxide levels and metal concentrations as well as acidic or alkaline pH. Extremophiles are a diverse group of creatures that live in habitats with unusual habitat ranges. These organisms are exceptionally good at adapting to such settings, which guarantees their optimum growth. Certain groups of the Kingdom Protista appear to be more tolerant of extremophilic environments than other taxa, according to analysis of the evolutionary relationships of the known extremophiles. They have distinctive defence mechanisms as well as strong enzymatic and biocatalytic systems, both of which could be advantageous in a range of industrial applications. A number of multinational teams are currently applying genetic engineering technology as an alternative to the utilisation of extremophilic microalgae to enable land plant

crops to manufacture the beneficial LC Omega-3 oils. Fungal adaptations to low temperatures in Antarctic marine habitats result in the creation of structurally unique enzymes and secondary metabolites that provide them a competitive edge over other microbes. Fungi can serve as a significant source of bioactive compounds that have lately sparked interest in exploring various research due to their potential medicinal benefits. Using the extremophiles, contaminants can be actively degraded and changed into less hazardous compounds. Extremophiles have the potential that can be used in a variety of industrial and biotechnological applications because of their strong enzymatic mechanisms. Amity Southern Ocean Isolate 01(ASOI-01), bacterial isolate was found to be beneficial in surfactant degradation of detergent. While the potential of extremophilic microflora is being investigated, more work still has to be done in the areas of physiology, molecular biology, metabolic engineering and outdoor cultivation bioprospecting.

Revisiting Antarctica's Need for Being Fully Protected

Ms Tiina Jortikka-Laitinen
Ambassador (Polar Issues), Head, ATCM Host Country Secretariat, Ministry for Foreign Affairs of Finland

The Antarctic Treaty signed 1959 declares that "in the interest of all mankind", Antarctica would be "demilitarised and allowed to be used only for peaceful purposes". Science was placed as the cornerstone of peaceful coexistence and cooperation in the international community. The Treaty has provided a solid mechanism for governing the Antarctic and over the years, the ATS has expanded and new legal instruments have been developed such as the Protocol on Environmental Protection. The increased accessibility of Antarctica, however, has brought up a number of issues that did not need to be considered in the early years of the Treaty; the effects of rapidly advancing climate change, growing tourism and use of natural resources are examples of new challenges. Has the Treaty the capacity to cope with these challenges? This presentation will discuss the main goals of the next ATCM meeting to be held in Helsinki on May 29–June 8, 2023.

India's Arctic Outlook for a Decade Ahead

Rear Admiral (retd) Monty Khanna
Assistant Military Advisor, National Security Council Secretariat, New Delhi

The talk will be focussed on the following points:

1. Activities undertaken towards India's engagement in the Arctic post promulgation of the Arctic Policy since Mar 2022.

2. Way ahead to increase our engagement.

Climate Change and the Arctic Sea Ice: Lessons learned and Future Strategies

Dr R Krishnan
Director Indian Institute of Tropical Meteorology, Pune

The global mean temperature in 2022 has been estimated to be about 1.15 [1.02 to 1.28] °C above the 1850-1900 pre-industrial average. As the Earth's surface temperature continues to rise, the rapidly warming signal in the Arctic during the recent decades is among the most profound regional manifestations of global climate change. This rapid warming of the Arctic is associated with strong reductions in the Arctic sea-ice extent and decrease of poleward temperature gradient, which in turn have impacted weather extremes over the Northern Hemispheric mid-latitudes. Additionally, increases in surface heat and fresh water fluxes in the North Atlantic appear to have slowed down the ocean thermohaline circulation, also known as the AMOC. According to the IPCC AR6 projections, the Arctic Ocean will likely become practically sea ice free during the seasonal sea ice minimum for the first time before 2050 in all the considered SSP scenarios. Furthermore the Greenland Ice sheet has lost significant mass over the last three decades, due to increased surface melt and discharge. While it is virtually certain that the Greenland Ice Sheet will continue to lose mass throughout this century under all the considered SSP scenarios (IPCC AR6, 2021), the Greenland ice sheet

mass changes have implications for global sea level rise. Clearly, widespread and rapid changes are already occurring in the atmosphere, ocean and the cryospheric components of the Arctic, which are projected to further increase with continued global warming in the future. There are major gaps in our understanding of the influence of the rapidly changing Arctic climate on weather and climate extremes across different regions of the globe. This talk will provide an overview of climate change over the Arctic and discuss some of the key scientific issues based on the IPCC AR6 report; and also describe the ongoing Earth System Modelling efforts at the IITM to unravel the linkages between the Arctic and the Indian monsoon region in a globally changing climate.

Recent Antarctic Sea-Ice Record Low: Role of Ocean-Atmospheric Forcing

Dr Avinash Kumar
Scientist E, National Centre for Polar and Ocean Research, Goa

Over the coming century, Antarctic sea ice is projected to decline drastically in response to increasing global temperatures. Antarctic sea ice expansion and recession are asymmetric, with regional and temporal variations. For many years, scientists have studied and conducted research on Antarctic sea ice, keeping track of its extent and behavior through satellite measurements and other methods. Since 1979, the decade-long overall increase in Antarctic sea ice extent until 2015 shows a rapid decline in recent years. The present study focuses on determining the ocean-atmospheric forcing and climate fluctuations responsible for the lowest SIE record in 2022 and 2023. The SIE reached a record low of 2.16×10^6 sq km in February 2022, which was 43 per cent lower than the mean extent of the previous February months since the satellite era. However, in the austral summer of 2023, the sea ice extent was about 30 per cent less than anticipated for February. The record-low SIE occurred due to the positive polarity of the SAM, intensification of the ASL pressure center, and strengthening of the stratospheric polar vortex. In addition, the global ocean temperature is reported to be one of the warmest on record. Hence, ocean-atmospheric warming and climatic indices modify Antarctica's pressure and wind patterns resulting in low sea ice. Further, these low sea ice conditions significantly impact the stability of ice shelves and, eventually, the rate of sea level rise. Overall, it is crucial to constantly monitor the patterns and ocean-atmospheric factors that influence sea ice variations.

Ocean Advisory

Dr T Srinivasa Kumar
Director, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad

The talk will be focussed on the following points:

1. Opportunities provided by the oceans.

2. Challenges being faced by the oceans.

3. Ocean Value Chain - ocean observations, modelling, information and advisory services.

4. How operational oceanography is central to achieving our blue economy aspirations and UN ocean decade outcomes.

Strategic Importance of the Indo-Pacific Region and Climate Change

Cmde Debesh Lahiri
Executive Director, National Maritime Foundation, New Delhi.

It is amply evident that the strategic and economic centre of gravity has shifted from the Euro-Atlantic to the Indo-Pacific region despite the present focus on the 'ongoing special military operations' of Russia in Ukraine which is more than a year old with no immediate end in sight. The 'great game' is undoubtedly going to play out in the Indo-Pacific region in the next several decades. The region is home to the four most populous nations, the three largest democracies, and the three largest economies. The Indo-Pacific is responsible for 60 per cent of the world's GDP and two-thirds of the present global economic growth. Militarily, seven of the world's ten largest armies, five of the world's declared nuclear nations, and some of the most sophisticated navies reside in the Indo-Pacific. Additionally, the sea lanes are extremely busy, supported by the world's nine largest ports. Every day, half of global container cargo and 70 per cent of ship-borne energy supply flows through this area. The gradual opening of the NSR and potential of the Chennai-Vladivostok maritime corridor would infuse added dynamism in the geopolitical, geoeconomic and geostrategic contours of the

region. The Indo-Pacific region is not an anomaly, but an idea whose time has come. The recently released Synthesis Report of the IPCC Sixth Assessment Report (AR6) in its 'Summary for Policymakers' has clearly stated that human activities, principally through emissions of greenhouse gases, have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 levels in 2011–2020. Global greenhouse gas emissions have continued to increase, with unequal historical and ongoing contributions arising from unsustainable energy use, land use and land-use change, lifestyles and patterns of consumption and production across regions, between and within countries, and among individuals. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. Human-caused climate change is already affecting many weather and climate extremes in every region across the globe. This has led to widespread adverse impacts and related losses and damages to nature and people. Vulnerable communities, which have historically contributed the least to current climate change are disproportionately affected. These adverse effects of climate change will manifest in a wide spectrum of 'felt-impacts' in the short-, medium- and long-term, ranging from water scarcity and food insecurity to forced human migration, and stresses on coastal and marine infrastructure.

IndArc Ocean Data

Dr G Latha
Head- Ocean Accoustics and Scientist G, National Institute of Ocean Technology (NIOT), Chennai

This talk will focus on the acoustic and oceanographic data measured in the Kongsfjorden, Svalbard , Arctic since 2015 and analysed to understand sea ice melting, seasonal variabilities and causative factors. Different types of melting including ice calving, ice bobbing and ice bubbling identified from acoustic data are studied. Soundscape of the Kongsfjorden Arctic consisting of geophonic, anthropogenic and biophonic sources are presented. Interannual variability of the noise field is studied.

Dr Kenichi Matsouka
Scientist, Norwegian Polar Institute, Norway

Antarctic RINGS Addresses a Critical Knowledge Gap that IPCC Identified for Future Sea-Level Rise Projections

The coastal zone of the Antarctic Ice Sheet where this vast ice mass meets the Southern Ocean and warmer air masses, is fundamental to our understanding of the links between Antarctica and the global climate system. This coastal zone contains multiple tipping mechanisms that lead to large, rapid, and possibly irreversible changes in the coming centuries, which must be better understood to predict future sea-level rise. The Antarctic Ice Sheet constitutes the largest source of uncertainty in future sea-level projections. This uncertainty is mainly rooted in poorly known bed topography under the ice sheet in the coastal regions, which the IPCC identified as a critical knowledge gap. In 2021, Norway, Denmark, Italy, UK, and USA proposed SCAR to establish a new Action Group RINGS. RINGS is an international consortium to identify outstanding science, develop strategy for complete pan-Antarctic data coverage, and coordinate international efforts for airborne geophysical surveys all around Antarctica. Together with many other nations, India and Norway are working to carry out the first RINGS surveys in 2023-24 austral summer.

Dr O P Mishra
National Centre for Seismology, Ministry of Earth Sciences, Government of India

Developing an Early Warning System in the Himalayas

Earthquake is the most powerful event that generates gigantic seismic energy at the sub-surface source zone, causing a huge loss of lives and economic losses in the area. It is a proven fact that earthquake can neither be stopped nor be predicted with present state of knowledge in the field of science and technology due to complex processes involved into the physics of the earthquake. In order to reduce the worst impact of earthquake shaking on the structures and infrastructures, there is an urgent need of development of plausible earthquake risk mitigation model for the region, which can be achieved either through the development and implementing the earthquake Early Warning Dissemination System (EEWDS) or by constructing the earthquake risk resilient structures by applying advanced seismic microzonation based risk resilient building design codes. The Himalayan region is one of the most earthquake prone and disastrous regions in the world because of its intricate seismotectonic settings and the development of EEWDS will be a way forward to alert the people to take precautionary steps ahead of the disastrous seismic phase (S-wave and surface wave)

arrival to the site just after on-set of the P-arrival on the rupture initiation at the source zone as quickly as possible. The role of NCS-MoES has become paramount in sense of using several advanced tools and technology for EEWDS with the deployment for the region by exploiting the advantages of big analytics, fast algorithms, and superior communication tools in the real-time mode, which would be discussed during the presentation.

Forthcoming ATCM

Dr Rahul Mohan
Scientist and Group Director, National Centre of Polar and Ocean Research, Goa

The Antarctic Treaty, with only 14 articles and 54 signatories, is the shortest legal Treaty that has stood test of the time (since 23rd June 1961). The Treaty which is registered pursuant to Article 102 of the Charter of the United Nations has made a provision under Article 9 envisaging that "representatives of the Contracting Parties meet at suitable intervals and places, for the purpose of exchanging information, consulting together on matters of common interest pertaining to Antarctica." Hence the ATCM is organised each year at different venues of the Consultative Parties, generally, in alphabetic order. The ATCM and the meetings of the CEP are held together with active support of the Antarctic Treaty Secretariat. The latter is mandated to take care of the operational part of the Treaty and coordination among the Treaty nations. The work of the ATS is funded by the Consultative Parties who approve its budget each year at the ATCM. The First Meeting of the Contracting Parties was held in Canberra and subsequently 45 such meetings have been held since then. India had the privilege of holding 30th ATCM at New Delhi in 2007 when among other important decisions taken, a proposal on responsible tourism and the proposal for construction of India's third permanent Station in Antarctica were approved. The 44th ATCM held in Berlin in 2022 approved holding of its 46th meeting in 2024 in India. While the detailed Agenda for the 46 ATCM will be finalised under relevant Agenda Item at Helsinki, Finland, during the 45th ATCM, some of the general issues of continued interest are expected to be discussed under three Heads i.e. CEP, Working Group 1 (on policy, legal and institutional issues), and Working Group 2 (on operations, science and tourism). The usual issues that will come up for discussions are: tourism and its impact on the Antarctic environment, management plans for ASPA and ASMA, any new proposal for ASPA/ASMA, Scientific issues pertaining to climate change response, biological prospecting, impact and consequences of global climate change on Antarctic environment, environmental management, and environmental remediation, implementation of Annex 6, liability issues, and safety of Operation, etc. The ATCM is attended not only by the Contracting Parties, but also by observers and invited experts. These include all the Consultative Parties; the non-Consultative Parties; Observers such as the SCAR, the CCAMLR and COMNAP; and Invited Experts,

such as the ASOC and the IAATO are likely to participate in the 46th ATCM. The MoES/ NCPOR has initiated preparations for holding the ATCM by putting in place a National Committee and a Local Organising Committee and work for identification of a suitable venue for the Meeting has already commenced.

Anthropocene and the Antarctic

Prof N C Pant
Co-Chairman; Professor (Fmr), Department of Geology, University of Delhi, New Delhi.

Anthropocene, the geological epoch marking the significant influence of humans as the third division of the Quaternary period, is a contested idea. One of the reasons for this may be uncertainty of whether we are in the beginning of the Anthropocene, towards the end of it or transitioning. This is so because all the geological epochs have been marked after these were over which is definitely not the case with Anthropocene. This idea essentially entails that the human (Homo sapiens) activities have overtaken the control of geological processes. Antarctica along with other stores of 'old' ice such as Greenland is very important in this context. This is so because these icesheets are not only very sensitive but preserve the best imprints of human activities in form of aerosols (e.g. overground nuclear bomb tests from 1950-1986 resulting in a spike of beta radioactivity; CH 4, CO 2 , industrial sulphur activity taking over the natural sulphur cycle in Greenland; increased nitrate concentrations etc.) and atmosphere of the past. Also concentrations of lead increased by a factor of over 200 over the Holocene base level in Greenland icesheet. Besides these, a range of non-natural chemicals including POP also preserve strong human imprints in the recent past in the ice cores retrieved from the icesheets. The Antarctic icesheet being too remote displays only some of these marking the Anthropocene epoch. However, it is extremely relevant in defining this third sub-division of the Quaternary period as well as crucial for the survival of Homo-sapiens. However, it would be premature to describe fully developed Anthropocene as the icesheet records suggests at best the transition stage for the Anthropocene.

Dr Vimlesh Pant
Professor, Centre for Atmospheric Sciences, Indian Institute of Technology, New Delhi

Sea-Ice Dynamics in the Arctic Using a Multi-model Ensemble Approach

The large-scale Arctic sea ice and glacial melt impact the oceanic thermohaline structure, biogeochemistry, and atmospheric dynamics. The regional differences in the sea ice and its variability in the Arctic would, therefore, influence oceanic and atmospheric parameters and processes at different spatiotemporal scales contributing to the 'Arctic Ocean Amplification'. In the present study, we utilised a diagnostic model intercomparison project curated to assess sea-ice modeling named SIMIP as a part of the sixth phase of Coupled Model Intercomparison Project (CMIP6). Twelve CMIP6 models were selected based on their performance and availability of sea-ice parameters. The ensemble analysis of twelve climate models with multiple realisations shows regional differences in the sea-ice parameters within the Arctic and the inter-model bias, mainly over higher temporal variability regions. Trends in sea ice concentration, heat content, sea surface temperature (SST), and sea surface salinity are calculated spatially over the Arctic and the seven area-averaged zones (marginal seas) in the Arctic Ocean. The maximum variability of SST (September) is seen over the Barents Sea, Beaufort Sea, and Chukchi Sea. Sea ice concentration has the highest variability in the East Siberian and Laptev Seas. However, the Beaufort Sea has a large variability due to sea ice drift. Surface freshening (up to 3 psu) of near-surface waters is noticed compared to past climate (historical). This freshening is attributed to the accelerated melting of sea ice and runoff through glacial melting. The mechanisms driving the regional differences in sea-ice concentration and thickness are explained using the heat content and budget analysis.

Arctic Ocean Common Heritage Mankind-CHM

Captain Sarabjeet S Parmar
Senior Fellow, National Maritime Foundation

Global Commons refers to resource domains or areas that lie outside of the political reach of any one Nation, State and hence can be considered as the common heritage of mankind (CHM). As per UNEP the four global commons are the High Seas, the Atmosphere, Antarctica, and Outer Space. As far as the maritime domain is concerned "the oceans reflect the classic model of a 'global commons', and the term is a useful metaphor for thinking about shared space". In the case of the Arctic, CHM pertains to the High Seas and the Area over which the spreading tentacles of nationalistic jurisdiction and control are increasing. UNCLOS article 87 lays down the aspects related to the freedom both coastal and land locked states enjoy in the high seas, which is defined as per article 86 as "all parts of the sea that are not included in the EEZ, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State." The Area has been defined in UNCLOS Part 1, article 1(1) as "….the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction", and in section XI, article 136, UNCLOS states that "The Area and its resources are the common heritage of mankind." UNCLOS article 137 (1) states that "No State shall claim or exercise sovereignty or sovereign rights over any part of the area or its resources, nor shall any State or natural or juridical person appropriate any part thereof. No such claim or exercise of sovereignty or sovereign rights nor such appropriation shall be recognised." Further as per article 137 (2) UNCLOS states that "All rights in the resources of the Area are vested in mankind as a whole, on whose behalf the Authority shall act." This authority, as per UNCLOS Part 1, article 1(1) is the International Seabed Authority (ISA). Insofar as the CHM related issues are concerned, two aspects stand out. Firstly, the melting of the ice and opening up of the northern and northwest passages have heralded a new maritime frontier. Secondly, the inhospitable environment, cost of extracting the available natural resources, and ISA strictures in force, presently, limits exploration and possible future exploitation. The growing strategic competition fuelled by the adversarial NATO/ Europe-Russia relations, differences in opinion over maritime jurisdictional claims resulting from varying interpretations of UNCLOS that is leading to modicum of control over sea areas, and growing militarisation are impacting the status of the Arctic Ocean as a CHM. This talk will analyse the various factors impacting this status and attempt to suggest a way ahead to protect that status.

Arctic Melting Ice: Examining NSR-Indo-Pacific Circular Transport Corridor Prospect

Dr R P Pradhan
Associate Professor, Department of Humanities and Social Sciences, BITS Pilani Goa Campus, Goa

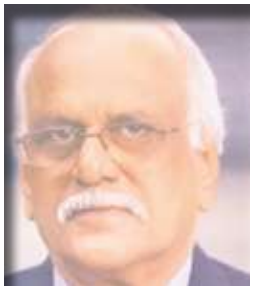
Arctic Ice is expected to make way for far greater shipping activities as early as 2030 to 2050. The Arctic Council to geopolitical stakeholders, including Chinese and Indian scientists are actively examining the scenario including mapping the prospect of NSR. In the event of NSR being more shipping friendly, the distance from London Port to Vladivostok Port will reduce by 40 per cent. Active NSR therefore is likely to change global shipping pattern in a major way which may directly affect IOR shipping pattern. The Russian Port of Murmansk (Western NSR Gate) and Dudinka Port already offer nearly round year shipping, eight more ports offer an average of five months of shipping. NSR Vessel traffic has indeed increased over the years. NSR stakeholders are also exhibiting climate sensitivity and correspondingly investing on Smart Port, Green Shipping and Net Zero Compatibility while further developing NSR. Chennai Port and Vladivostok Port have already signed Smart Port MoU in 2019. In the Western Coast of India, India's forward multimodal transport concepts like INSTC has already gone through ground testing level. Now, Armenia offering additional passage opportunity to INSTC, connecting Mumbai Port to St. Petersburg Port seems more feasible. In the larger context of Chennai-Vladivostok MoU in the east coast and Mumbai-St. Petersburg INSTC prospect in the West Coast, NSR could be a creative addition to deliver an NSR-IOR-IPR Circular Maritime Transport Corridor in the near future. In the context of this emerging transport module, and in the context Clydebank Declaration on Smart Port, Green Shipping, etc., this presentation shall examine real time prospect of an emerging NSR-IOR-IPR Circular Maritime Transport Corridor.

Dr Waliur Rahaman
Scientist E, National Centre for Polar and Ocean Research, Goa

Predicting Tipping Points for Future Collapse of the West Antarctic Ice Sheet and Sea Level Rise from Pliocene-Pleistocene Records

The WAIS is primarily marine-based and, therefore, sensitive to climatic and oceanographic changes. Over the past several decades, the WAIS has been undergoing dramatic mass loss contributing to sea-level rise faster than any other continental ice sheet on Earth. Model simulations predict a complete/ partial WAIS collapse soon resulting in a catastrophic sea-level rise of 3.3-4.3 m. However, model predictions can produce diverging results and have significant uncertainties associated with estimating the timing of the ice sheet collapse and sea-level rise. The IPCC (2007) 4th Assessment Report highlighted that the response of continental ice sheets to climate change and their contribution to global sea-level rise is the most significant unknown variable in predicting future sea-level change. In this study, we have reconstructed the Pliocene erosional history of West Antarctic using radiogenic isotopes of Nd (143Nd/144Nd) measured in the detrital phase of sediment core samples retrieved from the Amundsen Sea embayment during the IODP 379 expedition in 2019. Our results, together with the multi-proxy data from the sediment core enable us to test the hypothesis related to stability and dynamics (waxing-waning and collapse events) of the WAIS and its impact on sea level changes during the geologic period, i.e., Pliocene epoch - the most recent geological analogue for modern/or near-future climate (IPCC, 2013). The detrital 143Nd/144Nd record from the study site shows a dramatic shift from less radiogenic values during the warm Pliocene to more radiogenic values during the Pliocene-Pleistocene transition indicating erosional shift associated with the ice-sheet dynamics of the Pine Island and Thwaits glaciers. It indicates a dynamic ice sheet during the Pliocene and the sensitivity of the WAIS to the climate transition from the warm Pliocene greenhouse to Pleistocene icehouse conditions.

Conflicts and Law of the Sea



Dr S Rajan
Former Director, National Centre for Polar and Ocean Research, Goa

The discussion will be providing a short overview of some of the conflicts and ambiguities in the Law of the Sea vis-a-vis four of the maritime zones and how these can pose challenges to an effective ocean governance. The following points will be discussed.

1. **Seabed and sub-seabed beyond national jurisdictions. The environmental challenges, Nauru's 2021 declaration for its plans to seek mining approval, the mining code (or lack of it), the probable conflict between Seabed Authority's mandate and the new 2023 BBNJ Agreement.**
2. **Extended continental shelf beyond 200 miles and the backlog of submissions, Article 82 on royalty for exploitation of resources.**
3. **Continental shelves of the polar regions (Both Antarctic and Arctic).**
4. **The 2023 Agreement and the challenges in its implementation.**

Indian Inputs in the Technological Innovations in Deep Ocean Mission

Dr GA Ramadass
Director, National Institute of Ocean Technology, Chennai

About 70 per cent of the earth is covered by the oceans that makes 70 per cent of the earth resources still unexplored for the human use. Energy, fresh water, minerals and biomass are some of the non-living and living resources that can be harvested from the oceans. The development of reliable technologies for the sustainable exploration and harvesting of these resources is the need of the hour. India, with a long coastline and vast EEZs has realised the importance of the resources and launched a mission to develop the technologies needed and to harvest the resources in an environmental friendly way. In order to leverage the exploration activities, NIOT has developed seabed crawler based mining machine, work-class deep water remotely operated vehicles, and in-situ soil tester. After carrying out field demonstrations using crawler-based mining machine at about 500m water depth, the development of a 6,000m depth rated demonstrative polymetallic nodule mining machine is underway. Studies such as environmental impact assessment studies and upstream metallurgical processes are underway. Development and operation of unmanned submersibles like in-situ soil tester and deep water work class remotely operated vehicles, underwater drill up to a depth 5,500m placed India

in the in the select club of nations to achieve such technology. To further augment the exploration capabilities through direct human intervention and to empower the nation's capacity building in the strategic deep ocean human missions, development of a 6,000m depth rated manned scientific submersible is underway. Efforts of NIOT in this endeavour are presented in this presentation.

Climate change and its Impact on Water Cycle over South Asia

Dr KJ Ramesh
Former Director General, Indian Meteorological Department

The water cycle operates through water first evaporating from the Earth, rising into the atmosphere to form clouds and then falling again as rain or snow. The climate crisis is naturally speeding this process because warmer temperatures cause water to evaporate faster. Authentication of water cycle acceleration is carried out with the rate of change of sea surface salinity because sea water turns saltier as the fresh water evaporates, while already fresher water is further diluted by heavy rainfall. IPCC suggested that the water cycle could intensify by as much as 7 per cent for every 1°C of global warming (wet areas becoming 7 per cent wetter and dry areas 7 per cent drier under changing climate regime). When all clouds holding that extra warm-extra moist (wet) air precipitates, it drops extra rain or snow to the ground essentially suggesting a warmer world means experiencing heavier rain and thunder/snow storms. Water-related hazards like floods and droughts are increasing because of climate change. The existing systems for monitoring, forecasting and early warning support services for management of water resources is fragmented and inadequate. Increasing temperatures are resulting in global and regional precipitation changes, more so leading to shifts in rainfall patterns of South Asia and such changes, during principal agricultural seasons, could have a major impact on food security, human health and well-being of the region with highest population density. Water-related hazards have increased over the past two decades. Since 2000, flood-related disasters have risen by 134 per cent compared with the two previous decades. Most of the flood-related deaths and economic losses were recorded in Asia, where end-to-end warning systems for riverine and urban floods require strengthening. According to figures cited in the WMO State of Climate 2021-Water Report, 3.6 billion people had inadequate access to water at least one month per year in 2018. By 2050, this is expected to rise to more than five billion. In the past 20 years, Terrestrial Water Storage (TWS) – the summation of all water on the land surface and in the subsurface, including soil moisture, snow and

ice – has dropped at a rate of 1cm per year. TWS analysis over High Mountain Asia that is lifeline for highly populous South Asia is comprehensively examined. IWRM is vital to achieving long-term social, economic and environmental well-being. But despite some advances, 107 countries remain off track to hit the goal of sustainably managing their water resources by 2030. Overall, the world is seriously behind schedule on the UN SDG 6 to ensure availability and sustainable management of water and sanitation for all. In 2020, 3.6 billion people lacked safely managed sanitation services, 2.3 billion lacked basic hygiene services, and more than 2 billion live in water-stressed countries with lack of access to safe drinking water. Seventy-five countries reported water efficiency levels below average, including 10 with extremely low levels. The current rates of progress need to quadruple in order to reach the global targets by 2030.

Changing Priorities in the Antarctica

Dr Rasik Ravindra
Chairman, SaGAA Organising Committee, New Delhi;
Former Director, NCPOR, Goa

Antarctica has been able to maintain its enviable position as a natural reserve devoted to peace and science in spite of several upheavals in the international geopolitical scenario ever since the Treaty was signed in 1961. However, the world has changed considerably since the 1960s with emergence of a new world order where China and some Asian nations have become stronger in technological and financial arena to give a tough competition to original signatories. Though the domination of developed western world still continues in several policymaking platforms but future is bound to see growing assertions from others in pushing their own aspirations. With the year 2048 being at the back of mind, all the Consultative and Non -Consultative Parties will continue to strive hard to push their agenda forward. The growing impact of the climate change on the Antarctic environment forms part of several intercessional contact groups and long term projects of CEP. There is also a growing acceptance of contribution of scientific research in the matters of Antarctic environment and more collaborative projects and coordination among the nations will be a rule in future. Though all the articles of Treaty and Environmental Protocol remain crucial to the success of continuation of the Antarctic System, the Article 3 of the Environment Protocol which sets forth basic principles applicable to human activities in Antarctica and Article 7 that prohibits all activities relating to Antarctic mineral resources (except for scientific research) will continue to remain priority for all the time of the life of the Treaty as prohibition on mineral resource activities cannot be removed unless a binding legal regime on Antarctic mineral resource activities is in force (Art. 25.5). The requirement that protection of the environment shall be a fundamental consideration in the planning and conductance of all activities in the Antarctica will remain intact in the near future. The future ATCMs are likely to put extra pressure on the CPs for ratification of the Annex VI on Liability arising from the Environmental Emergencies

(adopted in 2005 but not yet entered into Force), as several CPs have not yet ratified it. The growth of tourism in Antarctica and its regulations to make it a responsible activity following the protocols of a non-invasive activity of non-native species – is also likely to receive continued attention.

Ground and Space based Monitoring of Cryosphere

Dr SA Romshoo
Vice Chancellor, Islamic University of Science and Technology, J&K

The concerns over the depletion of the Himalayan cryosphere have attracted the attention of scientists, decision makers, and policymakers the world over to understand the factors driving glacier recession. Direct measurements of glacier mass balance over the Indian Himalaya are available on a limited number of glaciers and mostly come from the period 1975-90. In order to observe the current status of the western Himalayan glaciers we selected eight benchmark glaciers from North western Himalayas for detailed in situ mass balance measurement (03 in the Kashmir Himalayas and 05 in the Zanaskar Himalayas). The glaciological mass balance observations obtained from all these glaciers revealed that there is a continuous surface mass loss as well as recession during the last seven years. However, the rate of mass loss varies among these glaciers. For example, the Kolahoi, Hoksar, Wakhalbal and Machoi are showing an annual mass balance of -0.84, - 0.96, -0.82 and -0.98 m.we a^{-1} respectively. Further, the ablation measurements obtained from the Lilong, Kangrez, Pansila and Drung Drung showed an annual mass loss of -0.65, -0.81, -0.58 and -0.77 m.we a^{-1} respectively. To understand the recent glacier dynamics, we estimated decadal glacier thickness changes over the entire Jammu, Kashmir and Ladakh using TanDEM-X and SRTM- C DEMs from 2000 to 2012. The study area is often divided in six mountain ranges: Pir Panjal range, (PPR), Greater Himalaya range (GHR), Shamaswari range, Zanaskar range, Ladakh range and Karakoram range(KKR), each with distinct climatic and topographic characteristics. More than 12,000 glaciers having 19,727 ±054 sq km area were investigated and it was found that the glaciers have thinned on an average −0.35 ±0.33 m a^{-1} during the period. The highest thinning of – 1.69 ± 0.60 m a^{-1} was observed in the PPR while as a marginal glacier thinning of – 0.11 ± 0.32 m a^{-1} was observed in the KKR. The observed glacier thickness changes indicated a strong influence of topographic parameters. Higher glacier thickness reduction was observed at lower altitudes (– 1.40 ± 0.53 m a^{-1}) and with shallower slopes (– 1.52 ± 0.40 ma^{-1}). Significantly higher negative glacier thickness changes were observed on the south slopes (– 0.55 ± 0.37 m a^{-1}). The thickness loss was higher on the debris-covered glaciers (– 0.50 ± 0.38 m a^{-1}) than the clean glaciers (– 0.32 ± 0.33 m a^{-1}).

Arctic and Industry 4.0 Technologies

Dr Vijay Sakhuja
Director, Rashtriya Raksha University, Gandhinagar

Industry 4.0 technologies such as AI, ML, Bigdata, Digital Twining, unmanned platforms and drones have a significant role to play in the Arctic. In particular, 4IR technologies offer enormous opportunities to gain deeper knowledge of the Arctic that is critical for studying impact of climate change. AI models are being developed to detect ice seals, polar bears, and other marine mammals to obtain better understanding of the Arctic marine ecosystem. As the Arctic gains greater importance and central role in global policy, diplomatic, military, transport, technology, and environmental issues, the future of the Arctic will be driven by Industry 4.0 technologies.

Marine Spatial Planning in Arctic Ocean

Commodore Sujeet Samaddar
Founder, SAMDeS

The Arctic Ocean is spread across 6 million square miles. Historically, most of the surface of the Arctic Ocean remained ice-covered all year round, but as a consequence of global warming this protective ice pack has contracted. Over the last two decades the surface area has nearly halved, the length of the ice melt season has grown by 39 days and the sea ice now starts melting nine days earlier and starts refreezing 30 days later than its historical average. The concern is that the Arctic ice cap's shining surface reflects 80 per cent of incident sunlight. With a smaller and decreasing surface area of the ice cap, sunlight reflection is reduced whilst sunlight absorption is increased leading to further warming of the ocean, which leads to more melting of ice, which leads to more warming, which leads to further reduction of the ice cap and the vicious cycle thereby propagates. This reduced ice cap also opens the Arctic to increased maritime activities such as shipping, fishing, tourism, undersea pipelines and cables, hydrocarbons exploration, naval operations etc. These activities, with their attendant energy and emission loads, promote localised warming and reduce the arctic ice cap still further. Many of these activities impinge positively and negatively on each other. From an environmental, economic and governance perspective the haphazard utilisation of the Arctic is bound to be sub-optimal and hugely detrimental, which if left unchecked and unplanned could lead to ocean slums thus jeopardising our common future which is so intrinsically linked to healthy oceans. Nowhere is this more significant than in the Arctic Ocean. Planning has the potential to establish rational use of marine space. Therefore, a Sustainable Ocean Plan, which is 'an 'umbrella' framework for ocean-related governance that aims to guide decision-makers and stakeholders on

how to sustainably manage maritime areas is a solution'. MSP is considered a key component of a Sustainable Ocean Plan. Unfortunately, there is no international convention on marine spatial planning, and there are no requirements under international law that marine plans, as such, should be prescribed by international law, treaty or agreement. MSP takes place within the national jurisdiction and is limited to the 200 nautical miles EEZ line. For the area beyond national jurisdiction, such as in the Arctic, the need for comprehensive spatial planning has been on the back burner but now it is a pressing necessity. Global activism for better ocean governance has been on the upswing. The recent agreement on Areas Beyond National Jurisdiction, the COP declaration to achieve the target of 30 by 30 and the G20 leader's statement reaffirming commitment to better ocean health are fine examples. In the Arctic region, some countries have undertaken marine spatial planning within the EEZs; for example, in Norway's part of the Barents Sea, Canada's part of the Beaufort Sea and the US has developed a marine spatial planning framework for its entire exclusive economic zone including its Arctic seas. This is a commendable initiative but the Arctic Ocean deserves much more planning and organisation due to its direct impact on life on earth. Thus, setting up a framework for the equitable marine spatial planning of the entire Arctic Ocean–which combines both areas under and those beyond national jurisdiction as one comprehensive package - for the benefit of humanity as a whole is now a crying necessity. This presentation will discuss the models of MSPs and the potential role that India could play in saving the Arctic from further damage.

Changing Glaciers and its Implication on Hydrology in Western Himalaya

Dr Parmanand Sharma
Scientist F, Himalayan Cryosphere Studies, Polar Science Division, National Centre for Polar Research, Goa

Over the last few decades, many Himalayan glaciers have been losing substantial glacier mass in response to climate change and have been predicted to decline further over the next few decades. Decline in glacier mass eventually alter the local and regional hydrology in Himalaya by potential shift in discharge regime and also rapidly increase in the number and size of glacial lakes. Glacier meltwater contribution to river flows is scale dependent and varies considerably across the basin scale. Although no substantiated trends is observed in discharge for any basin in Himalaya, our studies on Chandra basin revealed a potential shift in discharge regime. The mean annual discharge has noticeably increased by 50 per cent during last five decades. Initially a decadal increment of summer discharge was limited to 3-13 per cent, however it was significantly enhanced during last two decades. Similarly an increased spring runoff potentially changed the hydrological behavior due to early water availability in the basin. Snowmelt is the predominant source of river discharge during the early ablation season, whereas ice melt reaches a maximum in the peak melt period in this basin. The runoff from the glacierised

parts of the catchments is sensitive to temperature changes and 1°C rise in air temperature leads to increase in the river discharge by 15 per cent of mean discharge. Rapid expansion of glacial lakes in term of number, area and volume has critically influence the glacier and downstream hydrology. The formation of glacial lakes trigger positive feedbacks, whereby lakes promote further ice loss through calving and subaqueous melting, causing additional melt and retreat and further lake expansion. Two major proglacial lakes (Samudra Tapu and Gepang Gath) in Chandra basin showed substantial expansion (20-25 times) in their volume during last five decades due to accelerated melting of feeder glaciers. These lakes expansion have a major threat for a substantial hazard in the form of GLOFs and can result in significant loss of life. Himalayan region are the most exposed region to get impacted from potential GLOFs where on average more than a million people live close (within 10 km) to the glacial lakes. Over the past few years, the HKH region has experienced multiple GLOF events that have resulted in considerable damage to communities, their livelihoods and infrastructure. Overall, we can say that the snow and glacier melt in the Himalayan water cycle stabilises the river runoff during dry summer months, buffering the basins against drought but are highly susceptible to climate-change impacts.

Understanding the Himalayan Debris Covered Glaciers: Characteristics and Evolution

Dr Aparna Shukla
Scientist, Hydrology and Cryosphere, Ministry of Earth Sciences

Inherent ability of mountain glaciers to respond rapidly (on decadal scale) to any variation in regional environment makes them a reliable indicator of climate change. The Himalaya stores the largest number of mountain glaciers with varying geometry that serve as the prime source of fresh water for habitations downstream. Considerable areas of the Himalayan glaciers are covered with supraglacial debris. Debris is added to the glacier system primarily through headwalls, sidewalls and glacial bed erosion. The properties (thickness, composition, size, porosity and moisture content) of debris cover induce sizable heterogeneity in surface ablation and geomorphic evolution of the DCGs. The presence of supraglacial debris complicates the interplay of processes linking climate change, topography and glacier dynamics. DCGs, thus, differ significantly from their clean counterparts, as they exhibit a complex system with many forcing factors, couplings and feedback mechanisms that are yet to be fully understood. Resolving the uncertain response and evolution of the DCGs is vital for devising sustainable management strategies for freshwater availability, glacier-related hazards, hydro-power generation, and also for more precise estimation of their contribution to the global eustatic changes.

Green Hydrogen Developments in Australia

Dr Dilawar Singh
CEO, Sun Brilliance Group, Australia

Australia's ambition is to become a renewable energy super power, decarbonise its economy, and increase clean energy exports to contribute to regional and global decarbonisation. Green hydrogen use in Australia would help the country to reduce emissions in the high-temperature industries as well as some transport sectors. Work is also underway to understand how hydrogen could be used to power our homes and kitchens. Australia has a potential to build a clean, innovative, safe and competitive hydrogen industry. Since the release of Australia's National Hydrogen Strategy in 2019, there is now a $127 billion of projects announced in Australia. This includes over 15 projects that have passed final investment decision and over 80 announced renewable hydrogen projects. The Australian Government, industry and researchers have undertaken a substantial amount of work to quantify the opportunities of renewable hydrogen in Australia and set the goal for hydrogen production at under $ 2 per kilogram. The country is setting the foundations for Australia to be a major hydrogen exporter by partnering with other countries to attract investment, build supply chains, and advance research and development.

Innovations in Cryospheric Research using Space based Technology

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The cryosphere, which includes areas of the Earth covered by ice and snow, plays a crucial role in regulating the planet's climate system and sustaining global water resources. It serves as a sensitive indicator of climate change. In recent years, space-based technology has revolutionised our ability to study the cryosphere, providing us with new insights and capabilities to advance our understanding of these remote and inaccessible regions. Both passive and active remote sensing is employed to address the cryosphere. Optical remote sensing is generally used for monitoring of seasonal snow and glacier dynamics. Knowledge on glacier extent, surface features, and meltwater runoff, provides a valuable information on glacier mass balance and ice dynamics. Optical remote sensing has also been used to study snow and ice albedo, which is the reflectivity of snow and ice surfaces and plays a crucial role in the energy balance of snowpack, glaciers and ice sheets. SAR is another powerful remote sensing technology used in cryospheric research.

SAR uses active microwave radar to measure the properties of the Earth's surface and has the ability to penetrate clouds, dry snow, ice and operate day and night, providing all-weather imaging capabilities. SAR data can be used to monitor changes in sea ice extent and thickness, measure glacier flow velocity, measure snowpack properties, and detect changes in snow cover and permafrost. Passive microwave radiometers and active microwave scatterometers has also been used to monitor the polar ice sheets and sea ice, providing a valuable information about sea ice dynamics. One of the key innovations in cryospheric research using space-based technology is the use of LiDAR. It is a remote sensing technique that uses laser pulses to measure the distance to the Earth's surface. It has become a valuable tool in cryospheric research due to its ability to provide high-resolution elevation measurements with centimeter-level accuracy allowing scientists to track changes in ice surface elevation over time, estimate ice volume changes, and monitor glacier and ice sheet dynamics, such as ice elevation changes, flow velocity and glacier mass balance. LiDAR data can also be used to study snow cover properties, such as snow depth and density, and investigate permafrost characteristics, such as active layer thickness and ground subsidence. Advanced Thermal remote sensing techniques are used to measure the temperature of the Earth's surface and are particularly useful in studying permafrost dynamics. GPR is another innovative space-based technology that has been used in cryospheric research, particularly for studying ice thickness, snow properties, and permafrost characteristics. The gravity-based satellites such as GRACE and GRACE FO missions have provided very important regional estimates of polar ice sheet changes over Greenland and Antarctica along with Himalayan glaciers in the last 20 years. It is clear from past observations that Earth's ice is changing but accurate estimation of this change is also important. Converting the knowledge of changes in the 'area' of sea ice, glacier, snow, ice sheet and permafrost into 'volume' of these cryosphere components is one the main challenge of future. We need improved information about snow/ice/permafrost active layer thickness using combined use of LiDAR as well as multi-frequency microwave SAR and altimeters. Constellation of satellites with observations in optical, thermal and microwave regions aimed to quantification of cryospheric parameters and processes would be needed to resolve various uncertainty in estimates and predict the trends in future using long term datasets.

An idea for Early Warning System for Flash Floods in Himalaya

Dr Vimal Singh
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Globally on an average 45,000 lives are lost each year due to natural hazards, out of which most lives are lost due to flood and drought but it has also been noticed that the loss of lives due to these two factors has reduced in recent years. An increase in deadly flash floods have been recorded in the Himalaya in the recent years. Since 2000, around 13 such incidents have been recorded. This increase has been ascribed to the climate change and it is also expected that the frequency of such events will increase in future with melting of the glaciers.

Events like Kedarnath (2013) and Rishiganga (2021) are examples of such flash floods. Hundreds of lives were lost in these events. So now, the question arises that can we develop an early warning system for the same. It appears that we already have all the elements required to develop an early warning system for the flash floods. We have a robust weather forecasting system (which is improving with time) that can predict rainfall and a high resolution landslides inventory. There are ongoing efforts to map the glacial lakes-an important cause for the flashfloods in higher Himalaya. Recent studies have shown, how geophysical methods can help in identifying the debris flow which are generally driven by lake outburst or cloud burst events. Apart from these elements, significant advancements have been made in the field of Artificial Intelligence and Machine learning. All these elements along with additional surface processes understanding can be brought together to develop an early warning system that can help us to warn the people in advance and also issue alerts to the most vulnerable zones in real time. This can help save precious lives that are lost in such events.

Accounting for Climate Change

Dr Monica Singhania
Professor, Faculty of Management Studies, University of Delhi, New Delhi

Sustainability accounting is interwoven with the complex challenge of climate change which mandates it to aggressively expand and entwine with other disciplines. This necessitates the need to map its literature in a manner hereto not undertaken. This study will review past three decades of sustainability accounting literature at the company and country levels, culminating in stimulating ideas for future research. This study uses a systematic and comprehensive methodology to map the literature on sustainability accounting. Previous reviews have been discussed to present the need and motivation of our work. We utilised a corpus of 1,702 articles from 1991-2021 retrieved from the WoS database to conduct the scientometric analysis using statistical tool- CiteSpace. Co-authorship network analysis, affiliation analysis, cluster analysis (keywords and co-cited documents), citation burst analysis are used to provide research fronts and future directions. The literature on country-level sustainability accounting is more extensive than that on company-level and more collaboration on company level research is needed. The scarcity of detailed studies on citizen/individual level participation in sustainable accounting is observed. The major future research themes were depicted as Sustainability Management Accounting, Sustainable National Accounts, Zero Emission Economy, Strong Sustainability, Ecosystem Accounting, Innovation and Technology, Sustainable Finance, Governance and People. This study provides a rudimentary framework for the people/individual/citizen level sustainability accounting which adds to a new perspective of sustainability accounting literature by connecting country and company level accounting.

Transitioning World Energy Routes

Prof R Srikanth
Dean, School of Natural Sciences and Engineering, National Institute of Advanced Studies, Bangalore

The Strait of Malacca connects the Indian Ocean with the Pacific Ocean through the South China Sea. It is the shortest sea route between the major oil and gas suppliers in the Persian Gulf and key Asian markets like China, Japan, and South Korea and about 84,000 ships transit it every year. While the Straits of Malacca also provides the shortest trade route between the Far East and the West, it is of primary importance to all countries in Southeast Asia and East Asia who depend on this route for their energy security. Therefore, irrespective of the opening of the NSR, the Malacca Straits will continue to retain its strategic place in global seaborne trade.

Assessing Hydrological Resources through Innovative Technologies

Dr V M Tiwari
Outstanding Scientist & JC Bose National Fellow; CSIR & Former Director, NGRI, Hyderabad

Sustainable management of limited fresh water resources is crucial to achieve a water secure future in the changing climatic scenarios and fulfill the increasing water demand. Assessment of hydrological/water resources, both surface and groundwater, is central for scheming an effective water-resource management and policy. Space and airborne geophysical observations provide new possibilities of mapping and monitoring of water resources, which can allow to develop coupled surface water and groundwater models. It is planned to deliberate novel techniques for aquifer mapping, and quantification of hydrological fluxes at watershed and river basin scales essential for forecasting and management of resources.

Dr Sarat C Tripathy
Scientist F, National Centre for Polar and Ocean Research, Goa

Summer variability in bio-optical properties and phytoplankton pigment signatures in two adjacent high Arctic fjords, Svalbard

Arctic fjords are sensitive to the enhanced climate warming-induced glacial meltwater discharge that influences its hydrography and biology. The study showcased in this presentation explains the impacts of the underwater light environment and nutrient limitation on the phytoplankton biomass, composition, and light absorption in the sunlit zone of the Kongsfjorden (KG)-Krossfjorden (KR) twin fjord ecosystem during summer when the meltwater discharge is at maximum. Observations in two phases in each fjord revealed pronounced spatial hydrographic variations between the phases and among the fjords. The intrusion of warm Atlantic water into fjords and subsurface chlorophyll maxima was observed. Meltwater-induced higher concentrations of optically active constituents in KG resulted in a shallower euphotic zone than KR. Nitrate and silicate limitation was evident in both fjords. Higher phytoplankton light absorption coefficient (a_{pH}, m^{-1}) and chlorophyll-a in KR implied its higher productivity potential. However, the light-absorption efficiency of surface microplankton was affected by pigment- package effect. Phytoplankton pigments analyses revealed an inter-fjord difference in surface phytoplankton composition predominated by microphytoplankton followed by nano and picoplankton. The average diversity index for the phytoplankton group (H') was higher in KR (0.71) than KG (0.55), which was possibly controlled by microzooplankton grazing. This study reveals that environmental settings in both fjords were quite different, which drives their productivity potential and species diversity. Thus, increased warming climate can have different impacts on fjord ecosystems despite their close geographical proximity.

Dr Nisha Mendiratta
Adviser and Head, Women in Science and Engineering (WISE-KIRAN) and Climate Change Programs

Initiatives for IHR under National Mission on Sustaining Himalayan Ecosystem (NMSHE)

The NMSHE is one of the eight missions under National Action Plan on Climate Change which is being implemented, coordinated and monitored by DST. The main objective of NMSHE is to develop a capacity to scientifically assess the vulnerability of the Indian Himalayan region to climate change and continuously assess the health status of the Himalayan ecosystem. The broad objectives of NMSHE include understanding the Himalayan ecosystem and evolve suitable management and policy measures for sustaining and safeguarding the Himalayan ecosystem, creating and building capacities in different domains, and networking of knowledge institutions engaged in research and development of knowledge for Himalayan ecosystem. The major programmes launched under NMSHE include the establishment of a Centre of Glaciology at WIHG, Dehradun; creation of six Thematic Task Forces; climate change centres; Inter-Universities Consortium; Human and Institutional Capacity Building Programme and Indo-Swiss Capacity Building Programme in glaciology, and related areas. The task forces have successfully created database pertaining the hydro-meteorology for Upper Ganga Basin, floral and faunal diversity and indigenous traditional knowledge related to farming and use of wild bio-resources. A methodology for assessment of vulnerable glacial lakes has been developed and inventory of such lakes has been prepared. Also, the vulnerability of the IHR forests was assessed in relation to climate change and climate reconstruction through dendrochronology was also completed. To assure food security in hills, climate resilient varieties and improved breeds of livestock, poultry and fishes have been introduced at various pilot sites in IHR which has resulted in significant increase in net returns. In addition, the capacity building programmes conducted by the task forces have trained thousands of the farmers and research personals and foster the efforts of the Government of India to fulfil the global climate commitments. The established State Climate Change Cells have been successful in developing the first ever vulnerability profile of the 12 Himalayan states and a report Climate Vulnerability Assessment for IHR. Results from the vulnerability assessment are being incorporated in the SAPCC where the adaptation actions are oriented towards priority areas and sectors. The major activities under Indo-Swiss Development programme include the Pan India Climate vulnerability Assessment, training for adaptation planning and sensitising and training media. DST has built a strong partnership with Swiss Agency for development and cooperation which will strengthen in the future. The priority areas for the next five years under NMSHE are glaciology, climate modelling, urban climate and aerosol studies, extreme weather events, and Himalayan ecosystem. Overall, the NMSHE has made considerable progress and its objectives have been updated to align with India's NDC to fulfil the global climate commitments.

Space Applications in the Study of Antarctic Ice-Sheet

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Antarctic ice sheet is the Earths' largest fresh water reservoir in the form of frozen ice. It accounts for more than 90 per cent of the terrestrial fresh water and has potential to rise the sea level for more than 60m; thus, caters the attraction from polar scientific community to know what is happening over the surface of Antarctic ice sheet. Prevailing vast, remote and harsh environment along with prolong day night period emphasises that the only viable solution for the continuous monitoring of Antarctica is to utilise the remote sensing data, especially microwave remote sensing data. We have altimeters to understand the surface elevation changes, microwave scatterometer and radiometer to understand the surface melting, SAR, and optical remote sensing data to understand the morphological and ice margin changes. This presentation is to discuss the remote sensing derived outcomes that highlights the changes being observed over the Antarctic ice sheet with special emphasis on utilisation of Indian Earth Observation sensor data. Investigation of changes observed in surface elevation, using SARAL/AltiKa altimeter, indicates that ice loss is higher over West Antarctica (WIS) compared to East Antarctica (EIS). However, it is evident that loss is higher around margin as compared to inner ice sheet parts. As inner ice sheet portion is much lower over WIS compared to EIS, loss from WIS could be higher in comparison to that observed from EIS. Analysis of SAR and optical data confirms that throughout the peripheral ice margin, Antarctica is losing the mass through the calving process, particularly from ice shelves and glacier tongues. Such observations supports the ice loss around margin, which was observed using altimeter data. Summer surface melting is also contributing to the loss of ice. Moreover, melt water features (melt stream, melt ponds etc.) play a crucial role in weakening of the ice shelves fringing the Antarctica. Analysis carried out using Scatterometer and radiometer data highlights the spatio-temporal variations of surface melting observed over the Antarctic hot spot regions. The derived information and further analysis carried out using data from Indian EO missions (SARAL/AltiKa altimeter, RISAT-1A SAR, EOS-06 OCM-3 and SCAT-3 etc.) and missions from other nations (MODIS, Senstinel-1A SAR etc.) explains the status of noteworthy changes observed over the Antarctic ice sheet in the present day scenario of global warming and climate change.

Section C

The Glossary

The acronyms opened out for a quick capture of information

Acronym	Expanded Form
AI	Artificial Intelligence
AMOC	Atlantic Meridional Overturning Circulation
ASL	Amundsen Sea Low
ASMA	Antarctica Specially Managed Areas
ASOC	Antarctic and Southern Ocean Coalition
ASOI	Amity Southern Ocean Isolate
ASPA	Antarctic Specially Protected Area
ATCM	Antarctic Treaty Consultative Meeting
ATS	Antarctic Treaty Secretariat
BBNJ	Marine Biodiversity of Areas Beyond National Jurisdiction
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CEP	Committee for Environmental Protection
CMIP	Coupled Model Intercomparison Project
COMNAP	Council of Managers of National Antarctic Programs
COP	Conference of the Parties
DCG	Debris-Covered Glacier
DST	Department of Science and Technology
EEZ	Exclusive Economic Zone
EEZ	Exclusive economic zone
EOS	Earth Observing System
GRACE	Gravity Recovery and Climate Experiment
GRACE FO	Gravity Recovery and Climate Experiment- Follow-on
GDP	Gross Domestic Product
GHR	Greater Himalaya Range
GLOF	Glacial Lake Outburst Floods
GPR	Ground Penetrating Radar
HKH	Hindu Kush-Himalayan Region
IAATO	International Association of Antarctica Tour Operators
IHR	Indian Himalayan Range
IITM	Indian Institute of Tropical Meteorology
INSTC	International North-South Transport Corridor
IOR	Indian Ocean Region
IPCC	Intergovernmental Panel on Climate Change
IPR	Indo Pacific Region
IWRM	Integrated Water Resources Management

KKR	Karakoram range
LC	Long Chain
ML	Machine Learning
MODIS	Moderate Resolution Imaging Spectroradiometer
MOES	Ministry of Earth Sciences
MSP	Marine Spatial Planning
NATO	North Atlantic Treaty Organisation
NCAOR	National Centre for Antarctic and Ocean Research
NCPOR	National Centre for Polar and Ocean Research
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organisation
NIOT	National Institute of Ocean Technology
NMSHE	National Mission on Sustaining Himalayan Ecosystem
NSR	Northern Sea Route
OCM	Ocean Colour Monitor
POP	Persistent Organic Pollutants
PPR	Pir Panjal Range
RISAT	Radar Imaging Satellite
SAM	Southern Annular Mode
SAPCC	State Action Plan for Climate Change
SAR	Synthetic Aperture Radar
SARAL	Satellite with ARGOS and ALTIKA
SCAR	Scientific Committee on Antarctic Research
SCAT	Scatterometer satellite
SIE	Sea Ice Extent
SIOS	Svalbard Integrated Arctic Earth Observing System
SSP	Shared socioeconomic pathway
SST	Sea surface temperature
TWS	Terrestrial Water Storage
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
WAIS	West Antarctic Ice Sheet
WIHG	Wadia Institute of Himalayan Geology
WMO	World Meteorological Organisation
WoS	Web of Science

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