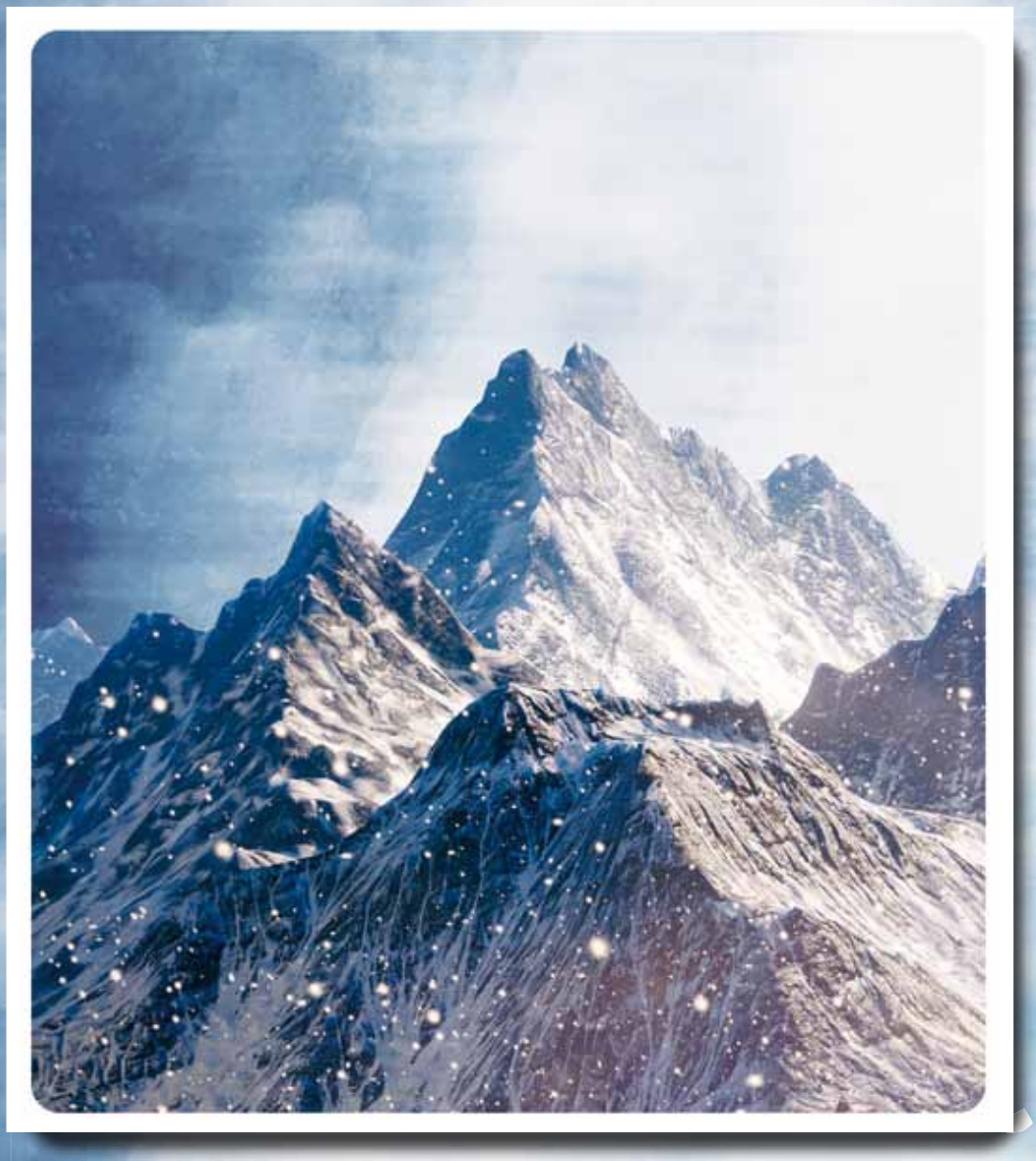
4th Conference on

Science & Geopolitics of HIMALAYA-ARCTIC-ANTARCTIC

November 30 & December 1, 2017, New Delhi



The SaGHAA IV Book

National Centre for Earth Science Studies

Ministry of Earth Sciences, Government of India

The National Centre for Earth Science Studies (NCESS) is an autonomous research institute under the Earth System Science Organization (ESSO) of the Ministry of Earth Sciences (MoES), Government of India. The vision of NCESS is to excel in understanding the deep internal and surface processes of solid earth, its interactive mechanism with the hydrosphere and atmosphere, and to address various scientific issues of concern to the society. The institute hosts a state-of-the-art laboratory infrastructure which enables multidisciplinary research in emerging areas with an integrated approach.

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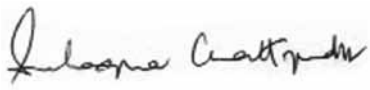
The Prelude

The Conference on Science and Geopolitics of Polar Regions-Himalaya- 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.

SaGHAA 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. The LIGHTS has been successful in bringing eminent scientists working in diverse subjects such as glacial, environmental, social and political fields togetherto addto better understanding of the issues involved and give relevant advice to policy makers.



(Sulagna Chattopadhyay)
Convener & President
LIGHTS Research Foundation

(Rasik Ravindra)
Chairman, Organising Committee
SaGHAA-IV

A

THE CONTEXT

The SaGAA VI

Arctic-Antarctic-Himalaya
(Compiled from Published Literature)

The Need

Concerns on the Climate change and its impact on land, environment and mankind have been growing. Nowhere else these changes are manifested more glaringly than in the cryosphere regions of our Earth, as the snow and ice exhibit the response to such changes in perceptible form to the naked eye. The scientists working in Arctic, Antarctic and Himalaya-the three repositories of snow and ice, have been working relentlessly in these inhospitable and harsh terrains enriching the world with new insight and data. The LIGHTS Research Foundation has been endeavoring to provide a platform to such scientists, experts in the fields of geopolitics, environment and social sciences, policy makers etc., to come together to deliberate and evolve a synergy for better understanding of the issues. The conference on Science and Geopolitics of Arctic and Antarctic (SaGAA) Initiated in 2011, 2012 was followed by SaGHAA- III in 2015, when the Himalaya was added to the discussions. The SaGHAA IV is thus a step towards adding emerging perspective to the existing data base.

The Himalaya

The Himalaya, supports largest accumulation of snow and ice after the Polar Regions of Arctic , Antarctic and the Greenland. The 2400 km long arcuate Himalaya-Hindu Kush mountain range and the Tibetan Plateau, sometimes referred to as the Third Pole, comprises world's highest mountain Range where several peaks attain heights more than 8000m above mean sea level. The mighty Himalaya is also the source of many major rivers that support about 1.3 billion people, in one of the most densely populated region of the world. Researchers have attempted to understand the feedback mechanism between climate forcing and the glacier response by mapping of glacier characteristics such as their distribution pattern, changes in their length and thickness, mass-balance, basement topography etc. Glaciers can display dissimilar behavior even in similar regional climatic settings due to varying geometry and bedrock topography, thus necessitating their long term monitoring to arrive at a conclusion regarding their behaviour. Recently, it has been established that presence of thick debris cover on a glacier may decrease its rate of recession as compared to an adjoining glacier devoid of the cover (Parmanand et. al, 2016).

The Controversy on the health of Himalayan glaciers, given rise to by IPCC 2007 Report, saw the publication of large number of scientific papers in national and international journals, outlining collective and independent behaviour of glaciers. The result of studies published by Space Application Centre of country's prestigious Space Research Organization (ISRO) on the long term monitoring of snout of glaciers in three main basins- Ganga, Indus and Brahmaputra- in the two periods of 1989-90 to 2001-

04 and 2001-02 to 2010-11 has presented a contrasting picture. During the period of 1989-90 to 2001-2004, 76 per cent of the glaciers have shown retreat, 7 per cent have advanced and 17 per cent have shown no change. As compared to this, during the next decade i.e. 2001-02 to 2010-11, only 12.3 per cent glaciers have shown retreat, 86.6 per cent of glaciers have shown stable front and 0.9 per cent have shown advancement (Ajai, 2017). Apart from SAC, multiple agencies in India, such as Universities, Geological Survey of India, Wadia Institute of Himalayan Geology, National Institute of Hydrology, National Centre for Antarctica and Ocean Research etc are monitoring some glaciers by field and remote sensing techniques showing a wide mismatch in the findings. This highlights the need for standardisation of tools and techniques of parameterisation as also necessity of ground checks of the interpreted results from satellite data. There is also a need for coordination among these institutions to ensure proper utilisation of scarce trained manpower in the field of glaciology as also cover more and more spread of glaciers, considering that India has more than 30,000 small and big glaciers as per SAC's glacier Inventory of Himalayan glaciers. The quantitative data on dating of moraines, though is gaining ground, yet much needs to be done to obtain TL/OSL and Cosmogenic dates to build a history of nature of glaciers in Holocene, Little Ice Age etc.

There is also no consensus among scientists on percentage contribution of glacial melt to the stream flow and general hydrological cycle in Himalayan region. However, there is no doubt that combined inputs from melting of glaciers and snow cover impacts the long-term lean season flow of rivers. Schaneret. al (2012) and others have cautioned that decreasing glacial input to stream flow will put large population in Asia at risk. For example, "The Indus stands out as a major river basin in which a large glacier contribution during part of the year combines with a high population density". Recession of Himalayan glaciers will not only reduce the glacial cover causing permanent loss in the size of glacier, it would also imply permanent change of land morphology, glacial lake outbursts, reduced water availability for hydropower generation and consequently impact life of thousands of people depending on agriculture as their means of livelihood.

The Himalaya has a profound impact on regional climate. It is warming much faster than rest of the globe. It affects wind circulation and storm tracks over large distances. Due to its unique geographic position and high altitude, it faces rapid changes in the weather patterns and ecosystem. The glaciers, snow-capped mountains, permafrost soils; cold deserts and wetlands hold large reserves of carbon.The climate change processes have caused changes in rainfall pattern, recession of glaciers, loss of snow cover, scarcity of water and forced changes in cultivation patterns, bringing the Himalayan Earth System to a critical stage that necessitate intervention for its

protection and preservation. Monitoring, studying and understanding various scientific and related social aspect of Himalaya pertaining to meteorological parameters and glaciers are of vital importance for weather forecasting, managing the river flows, irrigation, power generation, conserving the biodiversity and sustaining the life systems of the Himalayan terrain, the people and the plains below.

The Himalayan ecosystem is vital to the ecological security of the Indian landmass. It is highly vulnerable and susceptible to the impacts and consequences of excessive anthropogenic emissions and developmental paradigms of the modern society. It needs to be protected to conserve its biodiversity for providing a rich base for high value agriculture, and development of sustainable tourism. The issues pertaining to preservation and protection of this fragile Himalayan ecosystem, understanding the coupling between this ecosystem and the climate factors and provide inputs for Himalayan Sustainable development come under the preview of the National Action Plan on Climate Change (NAPCC). To achieve the assigned objectives, the Mission needs to develop a synergy among the climatologists, glaciologists and social scientists. It is heartening that realising the importance of Himalaya to nation's well- being, Ministry of Environment, Forest and Climate Change of Government of India has launched the "National Mission on Himalayan Studies (NMHS) in 2015 with a vision to support the sustenance and enhancement of ecological, natural, cultural and socio-economic aspects of Indian Himalayan Region (IHR). This mission has been revamped recently to focus on research on thematic areas such as water management, livelihood options, biodiversity conservation and capacity building. It is hoped that national institutions and research bodies will rise to the occasion and participate in the "Demand Driven Action Research" under this Mission.

During SaGHAA III held in 2015 , the Conference had highlighted the need for development of a concept of a "Himalayan Council" on the lines of the Arctic Council, wherein most of the Himalayan nations like: Afghanistan, Bhutan, China, India, Nepal and Pakistan could come together to address common scientific agenda as the magnitude of the problems and geographical spread is such that no single stakeholder can do justice to the subject that has a great relevance to the indigenous people inhabiting the inaccessible and inhospitable high altitudes area with rich biodiversity but hostile climate. It is therefore of prime importance that earth processes having pronounced effect on Himalayan eco system be identified, monitored and coordinated steps be taken to preserve the sensitive system by stakeholders.

The Arctic

Arctic Ocean and the surrounding regions not only govern the earth's climate but also faithfully records its past climatic history. The region is also an excellent harbinger of future change, because the signals that signify climate change are so much stronger in the Arctic than elsewhere on the planet. Any change in extreme Northern hemisphere (Arctic region) has profound impact on the global climate, sea level, biodiversity etc. The Arctic sea ice perennial and multiyear, is showing decrease in every successive decade since 1979. As per a report of the NSID, the Arctic lost 37,000 km^2 of ice, each day, in just first ten days of June last year. The sea ice coverage as on August 1st 2012 at 6.53 million km^2 was at its second lowest level since 1979 when the monitoring of sea ice through satellite was initiated nearly half the average for the 1960s

The figures from IPCC 2013 Report reveal that perennial sea ice extent in Arctic decreased between 1979 and 2012 at 11.5 ± 2.1% per decade and the multiyear ice decreased at a rate of 13.5 ± 2.5% per decade. The elastic response of the crustal deformation in terms of uplift rate, as measured in Greenland, has confirmed the Arctic ice loss. Measurements made during the period 2010–2012 with the help of submarine, EM probes, and satellite altimetry have revealed that the average decrease in winter sea ice thickness for this period was likely between 1.3 and 2.3 m and record a decrease in sea ice volume compared to the period 2003–2008. These changes also result in increase of sea ice drift, increase in the period of surface melt as well as increase in the period of ice free duration. An irreversible climate 'tipping point' could occur within next 20 years as per some estimates due to release of huge amount of organic carbon locked in permafrost. A record 30.6 Gt of CO_2 were emitted in 2010, a 5 per cent jump from 2008 (Steve Connor). With dwindling sea ice shield, fresh ocean surface is exposed that absorbs the solar heat (albedo effect), warming the sea in turn and melting fresh sea ice- a vicious cycle.

The consequences of ice free Arctic are grave. Firstly, it will open a rat race for the exploitation of natural resources in the Arctic Ocean, a known store house of the oil and gas resources, between the Arctic nations which may be joined by energy hungry nations like China and India. The ice free nature of the sea will also open a Trans-Arctic passage that will link the Pacific and Atlantic by a shortest route creating a profitable commercial option for the maritime operations. The Northern Sea Route (NSR), along the coast of Siberia has already started attracting traffic and it is reported that in 2011, 34 ships used the Northern Sea Route to ship bulk cargo weighing about 800,000 tonnes like iron ore, coal and gas condensate to customers in China. The NSR passes along Russia's northern coast in the Arctic Sea and connects Murmansk in the West to the Bering Strait in the east. This route is promising and is being regarded as an alternative to the present shipping route connecting Europe with Asia via the Suez Canal and the piracy infested Gulf of Aden. The second route, the North West passage, will pass along the coast of Canada. But, this

route is still underdeveloped unlike the NSR. To capitalise on Arctic shipping, the Russians have already set up a North Sea Route administration, which issues permits to ships wanting to transit through the route. Atomflot, a Russian organisation, provides nuclear powered ice breakers to ships transiting through the Northern Sea Route. The route, though challenging, is open for about 3 or 4 months in a year. But it saves the shipping companies about 4,000-5,000 km of distance and 10-20 days of time as compared to the traditional route through the Suez Canal. China, Japan, South Korea will be the main beneficiaries of the route.

On account of the decision in oil output in the North Sea, Norway is now shifting its attention to the 'high north' in a big way. Both Russia and Norway have major plans to develop their respective northern regions. For them global warming has been a boon. The Arctic Region is expected to provide the next big push in the economic revival of Russia. The opening of the sea routes and the exploration of hydrocarbons present economic opportunities which Indian companies can also exploit.

Arctic Region was highly militarised some years back and there were strong differences on territorial claims over the Exclusive Economic Zones (EEZ) and the more serious issues of limits of Extended Continental Shelf, that could be claimed based on the provisions contained in the Law of the Sea of United Nations. Most of the Arctic nations including Russia, Iceland, and Denmark etc have since deposited their claims on the Extended Continental Shelf beyond the EEZ with the UN Commission on Limits of Continental Shelf freezing the dispute clause to enable the Commission to consider their claims.

India and the Arctic Connection

India's interest in the high latitude regions of Arctic lies essentially in the tele-connection between Arctic sea-ice coupled system and the Indian Monsoon. Recent researches have shown that natural climatic variability in Polar Regions such as North Atlantic Oscillation and Arctic -surface-temperatures can impart control over Indian monsoon via coupled ocean-atmosphere pathways or tele-connections. The North Atlantic Sea Surface Temperature is strongly linked with the Indian monsoon on inter-decadal and longer time scales. For a tropical country like India, such processes assume greater significance as these affect the monsoon which is the backbone of the agriculture dominated Indian economy. Understanding the physical mechanisms behind these tele-connections may help us improve our predictive capability for the Indian monsoon.The Indian scientific endeavors in the Arctic realm commenced in 2007 with a five-member scientific team visiting Ny-Ålesund on the Svalbard archipelago of Norway. India also took on lease a building at Ny-Ålesund from Kings Bay AS which owns and manages the facilities at the International Research Base to establish its Research Base 'Himadari' there. India became

a Member of the International Arctic Science Committee in 2012 and an Observer at the Arctic Council on May 15, 2013. The Arctic Council has eight states as members, the five coastal states, Canada, Russia, the U.S., Norway and Denmark (through Greenland), and Sweden, Iceland and Finland. Other countries that joined India as Observers were China, Japan, South Korea, Singapore and Italy. The United Kingdom, France, Germany, Poland, Spain and the Netherlands are already Observers in the Council. Though Observer nations do not have the voting rights yet they can participate in developmental programmes and raise their concerns, if any.

The Arctic Sea area is unlikely to be governed by an Antarctica type international treaty which makes the region a "global common". India need to remain engaged with the leading organisations like the Arctic Council and International Arctic Science Committee where many important decisions on the science, environmental protection and preservation of pristine eco-system of the Arctic region will be taken. These can have direct or indirect impact on India. Indian universities and think tanks should pay greater attention to the study of analysis of the developments in the Arctic Region.

In accepting to abide by the criteria for joining the council, India has recognised the territorial jurisdiction and sovereign rights of the Arctic littoral states and hence their pre-eminent and even pre-emptive role over the Arctic zone. The acceptance of the Law of the Sea as the governing instrument for the Arctic also implies that the extension of jurisdiction over the continental shelf as well as over maritime passage and the resources of the ocean space will lie with the littoral states. With limits of the extended continental shelf of these States being drawn up to 350 nm from the base line of the country as per the provisions of the law of the Sea, Arctic Ocean has virtually been shared by five coastal states— Russia, Norway, Denmark, Canada and the United States. In the Antarctica Treaty of 1959, territorial claims have been kept in abeyance in favour of a global commons approach respecting the pristine nature of the ice covered continent. However, since US is not a claimant nation with no territorial claim over Antarctica and has kept its rights reserved on this issue and Antarctic Treaty has survived the most crucial cold war period, it is likely to sail through in future too. Or is it only a question of time before the northern Gold Rush is followed by its rampant Southern version, needs to be seen. The question remains that 'what could be done to restrain this headlong rush into a potential ecological catastrophe of global dimensions? There are some suggestions (Rick Steiner) for UN to set up its own Arctic Body on the lines of the Indian Ocean Commission, which may provide the international community the capacity to monitor what is happening in the region, draw up strict norms for activities, taking into account the "global commons" character of the Arctic. However, it must be borne in mind that very little area of Arctic Ocean will be free and available for 'global common', once the legal rights over extended continental

shelf, as per the law of the Sea, are granted to the Arctic States.

Having agreed to the provisions of Arctic Council and without violating its role of Observer at the Arctic Council, can India along with other developing states, put the Arctic on the agenda of the ongoing multilateral negotiations on Climate Change under the U.N. Framework Convention on Climate Change? A separate resolution or decision of the Conference of Parties to the Convention could draw attention to the Arctic as a global commons, its impact on global climate and the need to ensure that the activities undertaken there do not harm the well-being of the vast majority of people around the world (Abstracted from an article by Shyam Saran in Dec 2013, Hindu).

The Antarctic

Antarctica, the icy continent defined as 'all of the land and ice shelves south of 60°S latitude', is governed by a unique Antarctic treaty that has stood the test of the times. The Treaty that entered into force in 1961 with 53 parties as of 2016,sets aside Antarctica as a scientific preserve promising freedom of scientific investigation and prohibiting any military activity,has been hailed as one of the most successful Treaties of modern times forming the basis for treaties of oceans and space. The Antarctic regions, on and off the continent, are believed to be rich in resources and controversial in terms of geopolitical relations. Science and politics might seem opposite side of the coin but are intertwined they ned and more so in the frozen realms of Antarctic and Arctic where science is the currency. It has steadily acquired an extraordinary complexity due to the fact that scientific activities have played, and continue to play, an important role in supporting Antarctic Parties' political engagement with the continent. The seven states which maintain territorial claims to Antarctic—Argentina, Australia, Chile, France, New Zealand, Norway and the United Kingdom—all operate research stations within 'their zones' and, even today, fund more or less exclusive scientific research activities located therein. Thus science has been used a surrogate for occupation and, arguably, has facilitated the effective colonisation of Antarctic. Equally non-claimant states have used scientific activities and expeditions as a means to deny territorial claims, and this is perhaps illustrated best by the US construction of the Amundsen-Scott research station at the South Pole; a location which manages to both physically straddle, and allow the United States to philosophically set itself above, all other sovereign claims. Yet science also provides both the motive and the means to negotiate and adopt, at the height of the Cold War, the Antarctic Treaty, under the auspices of which, a successful, effective and enduring regime for Antarctic has been developed (Adapted from a paper by Sanjay Chaturvedi, published in Scientific and Geopolitical interests in Arctic and Antarctica, ISBN No. 978-93-5067-908-1).

Science and Geopolitics share bi-polar relation but geo security acts as magnifying

force to club them together to hold the sovereignty of all creatures and all abstract resources of the Polar Regions. It's a hard challenge for the researchers to pursue the research as well as interconnect those with another discipline in a feedback loop system. The countries undertaking research on the polar realms have developed specialized scientific skills that is today counted as a shared resource for mankind. The co-existence of distinctive scientific thoughts of different countries sharing the hostile environment has made the regions further geopolitically relevant.

The Antarctic Treaty of 1959, over the past five decades and more, has evolved into a fairly complex, multilayered governance regime (termed as the Antarctic Treaty System–ATS) with several compelling issues on its current agenda demanding serious attention, including the effective implementation of 1991 Madrid Protocol and its annexes, regulation of tourism, biological prospecting and climate change. The transformed geopolitical context of the ATS in terms of an increasingly diverse membership (with Malaysia and Pakistan having acceded to the Antarctic Treaty recently) as well the growing complexity of its governance agenda, demand an urgent focus on the changing nature and role of 'Antarctic Science', and a critical examination of existing knowledge-power equations underlying agenda setting, dialogic politics and consensus based diplomacy (Brady, 2012a). The Antarctic Treaty (1959) was adopted for the purpose of bringing peace and stability to Antarctica and to facilitate cooperation in scientific research conducted on and around the continent. It has now been over fifty years since the signing of the treaty, nevertheless security continues to drive and shape the laws and policy regime, which governs the region. Antarctic Security in the Twenty-First Century: Legal and Policy Perspectives assess Antarctic security from multiple legal and policy perspectives (Hemmings and Rothwell 2012).

Karen N. Scott (2012:284) has aptly argued that, ".. Antarctic has arguably been constructed through science as a geopolitical and legal space." In a geo-historical perspective, the so called 'discovery' voyages, cartographic practices, setting up of scientific bases and geopolitical rituals such as flag planting and naming practices ably contributed towards making Antarctic legible for colonial-imperial project of staking territorial claims on the continent. If on the one hand, science has performed the strategic role as "the glue of the Antarctic Treaty System" (Elzinga 1992: 75), then, on the other hand, remains the fact that "the external history of Antarctic science is … by and large a history of great power rivalry fired by imperialist ambitions which have been contained and sublimated in science" (ibid. 87).

As Tom Griffiths (2007:145-146) points out "the International Geophysical Year [IGY] had indeed achieved the unexpected. Science as an international social system had never before revealed itself to be so powerful". And the site where this achievement happened so graphically was Antarctic, which "was at the threshold of two ages: one

of competitive nationalism and the other of cooperative internationalism. Antarctic could be seen as the site of both the latest phase of imperial partition and the first expression of planetary awareness. Its treaty regime became the model for management of the sea and outer space" (ibid. 146).

Some scholars have argued that, "the dawn of the twenty-first century is often referred to as the advent of a global knowledge society. In this society, knowledge, having become the major factor of production in the new economy, is expected to flow more freely than ever before, no longer limited by national constraints" (Meyer, Kaplan and Charum 2002). It is precisely the labyrinth of Trans border, transnational, non-hierarchical knowledge flows, anchored in the notion of global public good, that constitutes one of the most important facets of the idealised state of mutual trust and sharing described as global knowledge commons.

Antarctic Resources Vs the protectionism

As a result of extensive resource survry, a rather impressive outline of Antarctic resources became available and was soon filled in by perceptions of the burgeoning population in terms of consumption and depletion of resources in the wake of the oil crisis. When early initiatives for a minerals regime surfaced during early 1970s, there were not many who would dare to think that commercial activity was likely, or feasible, let alone imminent, for decades to come. The prevailing economic, technological and geopolitical climate at the time ruled out any prospects of mining the Antarctic. Few would have the slightest idea about the sites and structures for the purpose, the costs involved, and the environmental-ecological consequences that might follow (Chaturvedi 1996).

The moment ATCPs turned to the question of Antarctic minerals in 1970, to be joined by India and Brazil as consultative members in 1983, the division between claimant and non-claimant states surfaced in all its intricacies. It was far from being certain whether the legal status quo under the Treaty could be reconciled with an equitable plan to develop mineral resources. India, Brazil, China and Uruguay, once admitted as consultative members, formed a lobby of countries in their condition to watch and promote third world interests in the minerals negotiations. No wonder that the ATCPs, faced with delicate negotiations, marked by such dilemmas, felt compelled to reiterate that under no circumstances their respective positions on the question of territorial claims in Antarctic could/should be compromised.

The Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) was opened for signature in Wellington, New Zealand, in November 1988. It prescribed tough procedures to be adopted before any patch of land or offshore area could be identified for exploration and development. Provisions having a direct or indirect

bearing on the environmental [protection] aspect of potential minerals activity were inserted in various sections of CRAMRA. Whereas some of these provisions qualified as purely environmental in nature, others were general but carried implications for the environment.

In January 1988, when CRAMRA seemed a virtual certainty, the knowledge-power interface in Antarctic governance acquired a new dimension with the dispatch of an expedition to service the Greenpeace's World Park base at Cape Evans. This marked the persistent and well articulated campaign of the Greenpeace movement, along with many other national and international environmental groups, against the very idea of mining the Antarctic (ibid). This also announced the arrival of a new non-state contributor and claimant to knowledge production, value addition and representational practices in the ATS; what would eventually become ASOC.

The prospects of CRAMRA dimmed and disappeared eventually, when, in May 1989, the Government of Australia refused on sign on the grounds of environmental conservation. Australia now felt strongly committed to the view that mining should be prohibited in and around Antarctic and instead the urgent negotiations of a comprehensive environmental protection convention within the framework of the ATS should commence. As Australia sought international support for this position, including the establishment of an 'Antarctic Wilderness Park', the French support promptly followed. CRAMRA, in order to enter into force, had to be ratified by all the countries having territorial claims in Antarctic. With the consensus within ATS under serious threat, the 'U' turns by Australia and France on CRAMRA brought into question the collective understanding of the ATCPs to abide by the norms of the system, seriously undermined the capability of the ATS to resolve intra-system conflicts, and exposed the soft underbelly of Antarctic governance in the form of dubious and disputed ownership of a continent larger than India and China put together and its resource endowment. From another perspective, the crisis of consensus was a powerful but painful reminder that the Antarctic Treaty, despite its overall legal-geopolitical innovation, had under Article IV made the first order value of pursuit of science and scientific knowledge a 'permanent' hostage to the colonial legacy of territorial claims and counter-claims.

The announcement on 4 July 1991, of the U.S. decision to sign the Protocol on Environmental Protection to the Antarctic Treaty restored not only the dialogic politics and consensual diplomacy to the ATS but also the state and status of Antarctic as global knowledge commons.

The environmental Protection of Antarctica

The Protocol on Environmental Protection to the Antarctic- 1991(the Protocol) designates Antarctic as a 'natural reserve devoted to peace and science' and binds

its present and future signatories to total protection of the Antarctic environment—its intrinsic and extrinsic worth, including its wilderness, aesthetic value, and its value as an area for scientific research. It categorically prohibits any activity relating to mineral resources, 'other than scientific research'. The Protocol sets out some basic environmental principles to govern all human activity in Antarctic be it scientific, tourism related, governmental, non-governmental or related to logistic support. The Protocol, vide its Article 11, has established a new institution of immense value and considerable competence: the Committee for Environmental Protection [CEP] comprising all signatories to the Protocol. The Protocol relies upon its State parties in addressing questions of monitoring and compliance, who must take 'appropriate measures within [their] competence' to ensure compliance with the provisions of the Protocol. Regular and effective monitoring is encouraged but centralised responsibility for this is lacking. Inspections are to be conducted under the terms of the Antarctic Treaty, on an individual and collective basis.

Linked to the Antarctic Treaty and other components of the ATS, the Protocol in no way changes the 'special legal and political status of Antarctic'. Still, it does break new ground in terms of geopolitics of knowledge production, while raising certain pertinent questions about the protection of the Antarctic environment. It is difficult to deny at the same time that in the wake of mounting global awareness and interest of all kinds, certain ATCPs have acquired a new scientific and technological capability to devise new uses or find new values and sub-values (including scientific, intrinsic, aesthetic) of the area. As Alan Hemmings puts it,

"A consequence of the process of abandonment of CRAMRA was the emergence and legitimisation of new sorts of Antarctic scientific focus (as well as the broadening of intellectual engagement by non-science disciplines, different parts of national bureaucracies and wider civil society), most obviously the appearance of both taxa-specific and systems-oriented ecological and environmental sciences. Particularly during the 1990s and early 2000, environmental and biological sciences moved into the vanguard of operationalising the new environmental standards resulting from the Madrid Protocol. The picture is now changing again with the increased prominence of new biological sciences, and something of a resurgence of earth sciences as mineral interests awaken" (Hemmings2012a: 145).

The changing nature of Antarctic science is likely to challenge the common good principle anchoring global knowledge commons in ways hitherto un-imagined and unanticipated. One major challenge is already on the horizon, namely biological prospecting. At the beginning of the 21st century, ably assisted by a new revolution in the filed of biotechnology, the industries of the future are increasingly targeting the materials and processes in plants, animals and microorganisms. Unique biodiversity of Antarctic and surrounding Southern Ocean has already started attracting bioprospectors but not

without raising complex questions with regard to access, ownership, legitimate use, equity, benefit sharing (Chaturvedi 2009, Joyner 2012).

The role of science and the scientists in the case of Antarctic bioprospecting is going to oscillate between the value of fundamental science and the lure of commercial-corporate interests. As Alan D. Hemmings (2010: 11) notes, "Here, for the first time, science wears two hats, its traditional Antarctic bonnet, and the hard-hat of commercial self-interest." In his view, in order to pre-empt 'conflict of interests' some 'formal mechanism' would be required along with "some deliberate mechanism to ensure that the interests of science as exploiter are not laundered through its standing as privileged participant in the ATS."The Antarctic regime, argues Hemmings, cannot afford to be complacent and will have to continuously reinvent itself at regular intervals to meet the new challenges.

As far as marine scientific research is concerned, it "may also raise other–more traditional–security concerns",(Scott 2008: 113). Whereas the ATCPs have been discussing recently whether to locate biological prospecting within the category of pure or applied scientific research, the activity remains regulated at all levels. Future disputes arising over complex issues such as access, equity and rights in connection with, the exploitation of these biological resources cannot be ruled out (ibid.). "Indeed, the most confrontational dispute to date over scientific research taking place within the region in fact relates to biological resources: the legitimacy of Japanese scientific whaling taking place within the Australian Antarctic Territory (AAT). Furthermore, the distinction between MSR and hydrographic surveying for military purposes is disputed and, in the Antarctic region, this engages yet another layer of complexity through them application of Article I of the 1959 Antarctic Treaty" (ibid.).

Rise of Asia and the Antarctica Treaty System

The rise of Asia as a new economicpower is shifting the international geopolitical scene towards Asia. A new geopolitics of fear is in the making, it seems. It is a truism that there are discernible shifts in the global geopolitical tectonic plates and the "centre of gravity' has shifted to Asia. Kishore Mahbubani (2008) has argued that, "the era of Western domination has run its course, bringing good as well as harm and destruction to human history. It is futile for the 12 per cent of the world's population who live in the West to imagine they can determine the destinies of the remaining 88 per cent, many of whom feel newly energised and empowered" (ibid. 336)Whereas according to a recent futuristic study on the rise of Asia,It is Asia where global savings take place and will continue to be the place, 'offering it the pleasant policy dilemma of how to use the money available, rather than pondering where to get the money from'. Not only will Asia be the world's creditor, but Asia will take over a large part of global economic activity....most of the new multinationals entering the list of the world's largest and most important enterprises will grow out of Asia (Møller 2011: 105-106).

The sheer pace and scale at which some of the fastest growing economies in Asia (especially China), are investing in Antarctic science and logistics are indeed noticeable. Anne Marie-Brady, for example, has argued that, "while the budgets of traditional players such as the United States [with the largest Antarctic budget] have remained static, Russia's has declined from its days when as the USSR it rivalled the USA; China, India, and Korea have made major increases in their investment and reach in Antarctic activities and Australia has also increased its spend" (Brady 2012b: 1). Having noted that, it needs to be acknowledged at the same time, in my view, that the return of Asia, especially in the context of international geopolitical economy, is yet to be fully reflected in various multilateral institutions and agencies including the ATS. May be it is not so much a question as to whether but when this would change. The following comment made by Anne-Marie Brady deserves attention in this context:

"Budgets are not the only way to measure power and influence in Antarctic. Research output is a key indicator of a nation's level of influence and engagement in Antarctic. This is for two reasons: (1) engaging in scientific research in Antarctic is the institutional fig leaf justifying a state's participation in Antarctic governance; and (2) knowledge, as always, is power, and states which can come up with scientific evidence to back up any policy changes they wish to promote are likely to be more influential" (Brady 2012b: 2).

What about Asian countries? Can we anticipate an Asian grouping that will coordinate not only scientific pursuits but also policy initiatives and interventions in the ATS? It is useful to take note of how 'Asian' presence in the ATSis being approached and interpreted by some of the claimant states. According to a note dated 24 September 2012 authored by Jason Mundy (Australian, Antarctic Division Department of Sustainability, Environment, Water, Population and Communities) and Tony Press (Antarctic Climate and Ecosystems Cooperative Research Centre), "As Asian interests in the Antarctic expand as the 'Asian Century' unfolds, Australia is well placed to take advantage of its geographic proximity to both Asia and Antarctic, strong bilateral links with prominent Asian players and multilateral opportunities through the Antarctic Treaty System to continue to build on our scientific, logistic and diplomatic collaboration with these key nations and remain a leading Antarctic nation throughout the years ahead" (Mundy and Press 2012: 2). It was also pointed out that, "The interests of Asian players in Antarctic are often divergent, and even though an Asian science and logistics group Asian Forum for Polar Sciences (AFoPS) meets regularly to discuss common interests, Asian countries do not operate as an homogenous bloc in Antarctic affairs" (ibid. 1).

In some contrast to the above mentioned note (conveying a subtle mix of hope and fear), a geopolitical analysis in the form of a narrative, raising questions marks in terms of

'motives' before the physical-scientific presence of Asian member states, especially China and India, is being presented by some analysts in following terms:

"The emerging Asian powers are increasing their presence in Antarctic…Both China and India have active Antarctic programmes and are seeking to increase the number of their Antarctic bases…India's bases are in the Norwegian and Australian claimed areas. One of them already has a monitoring role though this is claimed to be for scientific observation and experimentation purposes"(Bateman 2012: 121).

The extent to which such imaginative geographies of 'insecurities' are prompted and legitimised by the persisting mismatch between growing Asian physical-scientific presence on Antarctic and a rather minimal geopolitical-policy profile at the ATCMs may be difficult to ascertain but demands for sure, some critical reflection. One among several impressions that one gathers from such realist-alarmist accounts is that the interest of rising Asian powers in the Antarctic is going to be largely dictated and driven by strategic-military calculations and/or natural resource exploitation. Whereas the 'original signatories' to the Antarctic Treaty are seen as motivated by a different set of values and priorities. They are the ones who are being compelled by a vast majority of Antarctic Treaty member states to carry on their shoulders almost the entire burden of peacefully securing the 'values' of Antarctic regime, including agenda setting and science diplomacy.

It is further argued that the 'Great Game' between China and India in the Indian Ocean Region is going to spill over into the Southern Ocean and could destabilise the delicately maintained geopolitical equilibrium on which the ATS rests. The emerging strategic competition between China and India on the one hand, and India and Japan on the other, is one development that could impact on activities in Antarctic. China is looking more to the Indian Ocean while India is seeking a role in the Pacific. There is increased risk of geopolitical competition in and around Antarctic. All major Asian powers have problems of energy security and are seeking access to untapped sources of energy, wherever they might be (Bateman 2012: 120).

Whether and how through a dialogic politics and diplomacy the 'emerging Asian powers' will encounter and question such geopolitical narratives (Bateman 2012, Bateman and Bergin 2012) remains to be seen. What remains more or less certain however is that lack of mutual trust among the ATCPs, in both its intended and unintended effects could seriously undermine the spirit of international cooperation and exchange of information and knowledge in the ATS. In short the fear of being misconstrued on the part of some could not only perpetuate further silence on their part in the ATCMs but also contribute to the tragedy of global knowledge commons; governance not only in the absence of full knowledge but also mutual trust.

History of SaGAA

SaGAA I (2011)

The first National Conference on Science and Geopolitics or Arctic and Antarctic was held between January 14 and 15, 2011. A consortium of scientists, policy makers and activists gathered to put forward balanced and enabling views on global positions outlining the role of developing nations such as India. The Plenary Session/ Technical Session 1 titled " Changing Global Positions and Legal Framework of the Polar Realms" began with Dr. Sanjay Chaturvedi's presentation of his paper titled "Emerging Science-Geopolitics Interface in the Antarctic: The Indian Challenge". The sessions were graced with the presence of Dr Shailesh Nayak, Prof. P C Pandey, Dr Ajit Tyagi, Dr N. C. Mehrotra, Dr Anil K. Gupta, Dr Rasik Ravindra, Dr S. Shivaji, Dr S. L. Jain, Dr V. M. Tiwari, Dr T. Meloth, Dr Subba Rao, Dr S. K. Mehta, Prof. Dhruv Sen Singh, and Dr I.M.L. Das. The last session saw Prof. G.N. Nayak, Dr R. Ramesh, Dr R.P. Lal, Prof. A.K. Gwal, Dr V. D. Mishra, Prof. Mihir K. Dash and Dr B.C. Arya. Dr S.K. Das and Dr Ravindran and Dr M. Sudhakar.

Discussion on multiple issues of Global Climate change and its impact on India by several eminent researchers have made the event an extremely successful event. Dr P C Pandey laid emphasis on the fact that in this post-colonial, multipolar and peaceful era of independence, the twin concerns of governance was 'Science' and the 'Protection of the Antarctic Environment'. Science and related research was the order of the day. Dr Ajit Tyagi laid stress on were the linkages between the Southern Ocean and the Antarctic as regards the issue of the monsoons and the impact of the changing Arctic weather on the Southern Hemisphere. In the nutshell, the issue of Climate Change and the Southern Ocean. Dr Anil K Gupta said both science and geopolitics was equally important. Changes in the Arctic influenced the monsoons and the Himalayan glaciers. And hence, this region was important not only for its mineral and other natural resources but also for future climatic changes. He called Himalayas the third pole and added that atmospheric studies should include Himalayas within its purview. Dr Shailesh Nayak spoke of the factors affecting the glaciers which were affected not only by changes in temperatures but also by human intervention. Dr M. Sudhakar stated that the Southern Ocean needed to be studied more. The Antarctic was already being researched upon for the last 30 years and the geology of the region was more-or-less understood. Successful expeditions to the Southern Ocean had been undertaken since 2004 but just talking of those was not enough. Researchers needed to find the problem areas regarding the Southern Ocean and conduct studies on those.

Dr Rasik Ravindra, spoke about the paradigm shift of the Govt. of India (GOI) since 1983 towards its policy on Antarctica, when India acceded to the Antarctica Treaty stressing that one needed to be cautious in taking a very aggressive/assertive stand as it needed to be supported by facts. According to him Antarctic issues such as liability annex etc. need the support from legislature. Dr S K Das, MoES, in drawing the discussion to a close, said that the exchange of knowledge that had taken place in the workshop, had provided a platform for new ideas and programmes which the Ministry could take up at the 3rd station. He highlighted the need for long-term multi-dimensional programmes involving several institutional actors within its ambit. Dr P C Pandey, IIT, Kharagpur commented that though it would indeed be a hard task competing with the rest of the world, the sky was the limit. The 3rd station in the Antarctic was only the beginning. He too was of the opinion that the need of the hour was to focus on science and microbiology and not talk of Bioprospecting and highlighting controversial issues. In the words of the country's erstwhile President Dr A.P.J. Abdul Kalam 'science is empowering'.

SaGAA-II .2012

The International Conference on Science and Geopolitics of Arctic and Antarctic (II- SaGAA 2012) in New Delhi held between March 9 and 11, 2012 successfully bounded the session on Geopolitics: UNCLOS and the Global Commons; Geopolitics of the Global Realms; Biotechnology: Microbial resources in Polar Regions; Dynamics in Polar Marine Biodiversity (Prokaryotes, vertebrates and invertebrates) Information Exchange and Intellectual Property Rights, Resources of the Southern Ocean; Ice Core for Paleo Climate, Southern Ocean and Solar Impact: Sea ice melting, Ice core studies, Southern Ocean Experiments; Paleo climate studies; Polar Atmospheric Research: Ozone depletion Meteorological Studies. Theses identified themes helped for enhancing the holistic understanding of the Polar realms by synergising geopolitics and science.

Senior scientists such as Dr P S Goel, Dr Shailesh Nayak, Dr S.W.A. Naqvi, Prof. S. K. Tandon, Dr Rasik Ravindra, Prof. John Turner, Dr Timo Koivurova, Dr Victor Smetacek, Dr John P. Bowman, Prof. Nalan Koc, Prof. John M. Reynolds, Dr George John, Dr M. Sudhakar, Dr S. Shivaji, Dr Ajit Tyagi, Prof. Sanjay Chaturvedi, Dr Vijay Sakhuja, Dr Ajai Saxena, Dr P.A. Loka Bharathi, Dr Maria Judith, Dr Savita Kerkar, Dr B. Meenakumari, Dr C. N. Ravishankar, Dr Pravin Puthra, Prof R. Ramesh, Prof. A. K. Gwal, Dr T. Meloth, Abhinav Srivastava, Dr C. G. Deshpande, Dr Sandip Oza, Dr Nityanand Singh, Dr S Rajan, Dr R.P. Lal, Jai Prakash Chaubey, Prof. A. L. Ramanathan and Dr D.P. Dobhal etc, attended apart from representatives from the countries such as United Kingdom, Finland, Germany, Australia, Norway and Chile. The participation of about 100 scientists recorded in the Conference included many reputed and renowned scientists from all over the world along with students, and research scholars

from different parts of India. Dr. P. S. Goel discussed the global consequences of science and geopolitical issues of Arctic and Antarctic and the aspect of career opportunities for young researchers and scholars in this field of study which is yet unexplored in the country. He remarked that the Polar Regions contain 70 per cent of the world's water resources and future resources of untapped minerals and hydro resources. The region has huge environmental implications and requires an equitable floor of the benefits for all. This makes the geopolitics of the regions a major subject for consideration and needs an active deliberation by all the nations of Earth. Dr. P. S Goel further said that the space treaty is derived from the Antarctic treaty. We know that the geopolitical issues of the Antarctic are clearly drawn but there is no such clarity in the context of the Arctic region. As for Arctic it is very different in nature because it is surrounded by many developed countries. Dr Sailesh Nayak focused India's interest in Arctic and Antarctic purely stands on science because whatever happens in these areas largely effects India as well and since the earth behaves as a single system the effects are felt worldwide. Dr. B. Meenakumari said that there is no need of influencing politics with science. However, when there is a discussion on the Arctic and Antarctic one cannot do away with politics, as these regions come under no man's land or territory, thereby politics cannot be excluded in this area. Dr Ajit Tyagi said that the paramount for the scientists is the credibility and the confidence of the layman and the politicians around the world. The larger goal of the society should be emphasized in this field of research and study that can benefit the world as a whole. Dr. M. Sudhakar stated that the way to deal in the area of Antarctic and Arctic is with the complete hand in hand approach of science and politics towards the issues. To establish the relation between science and geopolitics in Polar Regions. Dr. Timo Koivurova said that, there exists a very widely accepted strong governance of Geopolitics in National and International level in both the Polar Regions. He said that the presence of Arctic Council and Convention for Biological Diversity (CBD) is not enough as there is much more International space and we require more ambitious government interventions. Dr. John P. Bowman opined that the area of Polar geopolitics and science is very vast and wide and that there are many commercial interests that also combine with various geopolitical aspects, thereby harnessing the actual resources of the Arctic and Antarctic in some form or the other. He spoke about the 'future crisis' to be brought by the ever increasing trend of world population, resulting to scarcity of resources and shortage of food supply, the consequences and effects of which will be detrimental and this situation will be the same everywhere around the world. Dr Rasik Ravindra felt that there was no dedicated desk to deal with the subjects on Arctic and Antarctica in the Ministry of External Affairs in India. He said that the global atmospheric processes are very intricately linked and that environmental changes in the Tropical or

Polar Regions will eventually affect the whole planet, and therefore it is important for India to recognize these regions and enhance the scientific work being undertaken by India here.

SaGAA –III. 2015

The subjects covered by the SaGAA-2015 has been divided into fiveinterlinked broad themes. Session I dealt with geopolitics of the Polar Region in global context and also how India is responding to it. It built a platform to explore the multi coloured personality of Arctic Region and the coexistence of different roles that Arctic plays in International relations. The geopolitical significances of the region is so vast and handled by multiple units that the protection of resources as well as the intervention should be carefully controlled and restricted to create a sustainable and ecological protected space. This session also talked about diplomacy related dilemma regarding resource use of Polar Regions in global context emphasizing the perspective of India on it. It focused on current debates of intermingling the two streams—science and geopolitics and how they are going to be implemented in the most efficient manner. The Indian strategy regarding Polar issues were unfolded and analysed to understand the key challenges and controversies. This session focused on the hurdles of adapting Article 16 of Madrid Protocol as well as Annex VI. It stressed on the environmental risk in Antarctic region and how the damages in those regions can be compensated. It emphasized the decision making process of Indian legislation regarding the International laws on Antarctic Region.

Session II broadly dealt with the impact of Global Climate Change in Polar Regions. The time series study of meteorological parameters of Polar Region is the key way to trace the little changes in climate and its impact on global climate change. It covered the climate change patterns in both the polar realmsconstructing different efficient models to predict the future. It also focused on the degree of melt of polar ices and its spatial variation. It interconnects higher latitudes phenomenon within a concrete shell to understand the mutual coherence of the climatic attributes.

The Session III connected the global circulation system with regional climatic phenomenon and analyzes the sensitivity of regional climatic phenomena in relation with the global one. The inter connectivity between Indian Summer Monsoon and Polar indices should be studied more focused way to provide valuable information to the policy makers. The role of Southern rim of Himalaya on Southern monsoon was reanalysed and how the climatic change is inducing random catastrophic events is being investigated. To give the platform a chronological tint the history of Himalaya of 10,000 years was discussed taking the glacier as the indicator of climate change.

Holding the concept of "The Present is the key to the Past" the history has been traced to predict the future of the glaciers of Himalaya. The speed of glacial advance or retreat and the time interval between two successive events is utmost important to study to understand the process of geomorphic change and its impact on climate and vise-e-versa. Moving to Antarctic Oceanthis session also focuses on the temperature distribution in the Southern Ocean and its impact on global climate. The physical attributes, chemical composition of this ocean need to be studied to get the idea of the impact of global warming and ice-melting.

Session IV covered the themes of Living and Non-living Resources Potential in marine protected areas and its relation with geopolitics. The extraction of those resources without destroying the ecosystem is a very sensitive task. The over exploitation of fish resources, herbs intervene the normal functioning of marine ecosystem. The Southern Ocean has experienced notable collapses of marine species following exploitation, including seals in the 19th century, the great whales in the middle of the 20th century, the marbled rockcod (Nototheniarossii) in the early 1970s and, most recently, some stocks of the Patagonian toothfish (Dissostichuseleginoides). Amidst this background of over-exploitation, regulation of harvesting activities in the Antarctic has been attempted through a series of international conventions: the 1946 International Convention for the Regulation of Whaling, administered by the International Whaling Commission (IWC), the 1972 Convention for the Conservation of Antarctic Seals (CCAS) and the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). Antarctic krill (Euphausiasuperba) is central in the Antarctic food chain. The different components of the Antarctic marine ecosystem are made up of predators that rely, directly or indirectly, upon the health of the krill populations. Antarctic krill has a circumpolar distribution and is very abundant in the Southern Ocean. This session also dealt with the positive impact of climate change. The melted ice is widening the gateway of sea routes which is going to open large resource pool of hydrocarbon to many countries. Hence efficient involvement in policy making process is needed to take a stand in the geo-political forum centered on this zone.

Session V focused on the issues of tourism industry in Polar Regions. The notion of "Antarctic Tourism" came into existence from 1960s with the ease of sea route transportation. The non-scientific expeditionsattract large number of tourists which is disturbing the natural environment. Waste disposals, water transport pollution are damaging the health of marine ecosystem. Due to arrival of flights, ships in the Polar Regions water, snow are getting contaminated. Hence proper management policies and restrictions should be taken into account to deal with such issues.

The contributions to SaGAA III by H.E. Thórir Ibsen, Dr Alan D Hemmings, Prof. Bimal Dr N. Patel, Dr Uttam K. Sinha, Dr Rasik Ravindra , Dr M N Rajeevan, Dr Shailesh Nayak, Dr S. Rajan, Dr Ajai, Dr M R Bhutiyani, Dr H S Negi, Prof. A P Dimri, Dr Abul Amir Khan, Prof. N C Pant, Dr Anil V Kulkarni and Dr Pratibha were published in a volume edited by Dr P S Goel, Dr Rasik Ravindra and Dr Sulagna Chattopadhyay and published by Springer.

B

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Dr M. N. Rajeevan has contributed significantly in developing several application tools and prediction models for societal applications like long-range prediction models, gridded climate data sets, and diagnostic studies on the Inter-annual variability of southwest and northeast monsoons (tele-connections) for regional climate services. These models and application tools are being utilized by the India Meteorological Department for operational use. Current Secretary of the Ministry of Earth Sciences, he is the recipient of 2001 START Young Scientist Award for his paper in Journal of Climate, Young Scientist Award in Atmospheric Sciences by the Ministry of Earth Sciences (MOES), in 2007, 20th Biennial Mausam Award (2001) by Department of Science and Technology and many others. He is a Fellow of the Indian Academy of Sciences (IASc), Fellow of the Indian National Science Academy (INSA), Fellow of the National Science Academy of India (NASI) and a member of several international and national bodies including International Academy of Astronautics (IIA) High-level Adviser on Climate Services for the Commission on Climatology, WMO; Chairman, Council of the Regional Integrated Multi-Hazard Early Warning System (RIMES) for Africa and Asia, Bangkok etc.

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Prof. Ashutosh Sharma's research contributions are highly interdisciplinary, spanning a wide range in nanotechnology. He is the current Secretary of Department of Science and Technology, Government of India. He received his Ph. D. from the State University of New York at Buffalo (SUNYAB; 1988). He was a professor (1997), an Institute Chair Professor (2007) and the Head (2003-05) of Chemical Engineering and the

founding Coordinator of Nanosciences Center and Advanced Imaging Center at IIT, Kanpur. He has a broad international experience as a research faculty at SUNY Buffalo School of Medicine (1988-90), visiting faculty at University of Texas at Austin, University of Western Ontario, University of Erlangen Nuremberg and the World Class University Programme of South Korea and as a Member of the European Research Commission. Dr Ashutoshis recipient of numerous honours and awards including Bhatnagar Prize, the inaugural Infosys Prize in Engineering and Computer Science, TWAS Science Prize, Award of the Humboldt Foundation, J. C. Bose Fellowship, Homi J. Bhabha Award UGC, Syed Husain Zaheer Medal of INSA and the Lifetime Achievement Award of the Indian Science Congress among several others. He is an elected Fellow of INSA, The Indian Academy of Sciences, The National Academy of Sciences, and Indian National Academy of Engineering etc. He has published over 300 peer reviewed papers, filed over 15 patents, given over 100 invited or key note conference presentations.

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Dr Trilochan Mohapatra has worked in molecular genetics and genomics. His research accomplishments include development of the first high yielding Basmati rice variety resistant to bacterial leaf blight through molecular marker assisted selection, physical mapping and genome sequencing of rice and tomato. He is the current Secretary, Department of Agricultural Research Education (DARE) and Director General, Indian Council for Agricultural research (ICAR). Dr Mohapatra was also holding the position of Director-cum-Vice Chancellor of the prestigious Indian Agricultural Research Institute, New Delhi. Prior to this, he worked as the Director of National Rice Research Institute (formerly CRRI), Cuttack and served at National Research Centre on Plant Biotechnology, IARI, New Delhi for about 20 years. He has over 145 research papers in national and international journals of repute and several book chapters. He is a Fellow of the Indian National Science Academy, National Academy of Sciences, Allahabad and the National Academy of Agricultural Sciences, New Delhi.

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Dr P. S. Goel former Secretary to Government of India, Ministry of Earth Sciences is currently Raja Ramanna Chair Professor at NIAS, Indian Space Research Organisation (ISRO) Bangalore. He has contributed significantly to the development of magnetic altitude control system, mission planning for remote sensing, communication and scientific missions and authored over 100 research papers in referred journals and conferences. Dr Goel developed the spin axis orientation system, Bhaskara I & II satellites, magnetic control for spinning satellites, momentum biased 3-axis control system for APPLE, zero momentum based 3¬axis control system for IRS. V, and, configuration momentum biased altitude control system for highly stabilised INSAT-2. Dr Goel developed a very agile control system with step and stare capability to spot imaging mission TES and guided the evolution of re-entry capability for SRE Mission. Dr. Goel was Chairman, Spacecraft System Advisory Board for IRS-1, Project engineer AOCS for APPLE and Associate Project Director INSAT-I. He was Head, Control System Division, Group Director AOCS, Deputy Director Mission and Control Area, Associate Director of ISAC and was Director ISRO Satellite Centre from 1997 to 2005. He was DRDO Chair at RCI/ DRDO Hyderabad pursuing space for National Security. Dr Goel was awarded Padma Shri in 2001. He has received several awards including Life Time Achievement Award of the Aeronautical Society of India and Distinguished Scientist Award of ISRO. He is fellow of Indian Academy of Sciences, Bangalore, National Academy of Sciences, Allahabad; Indian National Science Academy (INSA), New Delhi; Institution of Electronic & Telecommunication Engineers, New Delhi; Aeronautical Society of India, Bangalore and Third World Academy of Sciences. He has recently been honoured with Fellowship of Indian Society of Systems for Science and Engineering.

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Dr Shailesh Nayak was the Chair, Earth System Science Organisation (ESSO) and Secretary to the Government of India for Ministry of Earth Sciences (MoES), between August 2008-2015. He has made outstanding contributions in improving advisory services related to potential fishing zones, ocean state forecast, and Indian Argo project. Dr Nayak was the Chairman of the Research Advisory Committee of the National Institute of Oceanography, Goa (2008-2015), Centre for Earth Science Studies (2007-2013) and Defence Terrain Research Laboratory, Delhi. He joined the Space Applications Centre, Indian Space Research Organisation (ISRO) in 1978 as a scientist, and was subsequently elevated as the Director of Marine and Water Resources. Dr Nayak took over as the Director, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, in May 2006, where he set up early warning system for Tsunami and Storm Surges in the Indian Ocean. Dr Nayak is Fellow of the Indian Academy of Sciences, Bengaluru, the International Society of Photogrammetry and Remote Sensing (ISPRS), and elected Member of the International Academy of Astronautics. Dr. Nayak is recipient of IGU, Hari Narain Lifetime Achievement Award in Geosciences-2013, the ISCA Vikram Sarabhai Memorial Award 2012, the Bhaskara Award for 2009, the Indian National Remote Sensing Award for 1994, and the National Mineral Award for the year 2005. Dr Nayak is the President, Federation of Indian Geoscientists Associations and the President, Indian Geophysical Union, Hyderabad apart from several other national scientific bodies. Dr Nayak has published about 150 papers in reputed international and national journals.

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Dr Ashok K. Chauhan is a visionary and founder Director of Amity Education Group that runs five universities, 150+ institutions and several educational establishments including some campuses in foreign countries. After obtaining his Master's degree in Chemistry, he undertook research in chemical engineering and plastic technology in Germany and then became Head of Development at Daetwyler Europe. In 1973, he started his own business in Frankfurt and expanded it into AKC Group of Companies dealing with petrochemicals, manufacturing, high-technology and healthcare, among others; with a turnover of over US $1.6 Billion. Proving himself a successful entrepreneur in Europe for over three decades, Dr Chauhan returned to India, established Ritnand Balved Education Foundation in 1986 to impart quality education to youngsters. Grounded to his dreams, he has always believed in the policy of lending one eye on vision and one eye on implementation. It is therefore no surprise that Dr Chauhan's innovative leadership strategies have transformed the AKC Group and the Ritnand Balved Education Foundation into a well known educational hub.

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Dr Swati Basu held the position of Scientific Secretary in the office of Principal Scientific Adviser to Government of India till 31st July 2017 where she was engaged in science advice for policies of the government. Prior to this she was an Advisor in the Ministry of Earth Sciences and Director of National Centre for Medium Range Weather Forecasting (NCMRWF) and played pivotal role for successful implementation of various international agreements with USA, UK, Korea, Germany, France, Indonesia, BIMSTEC and RIM countries on cooperation in Climate science and modernization of India Meteorological Department. A representative of India in Belmont Forum, she was responsible for developing high resolution state-of-Art models and establishing BIMSTEC Centre for Weather & Climate in India. She holds a PhD in air pollution modelling from IIT, Delhi and has the distinction of being one of the few Indian women to go up to 80-degree North.

B

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Dr B. Meenakumari has contributed immensely to the development of deep sea demersal trawls and towards improved material for lobster making traps—helping the traditional fishermen gain better economic returns. She has popularised new and cheaper materials like polypropylene and nylon monofilament for gill net fisheries in both inland and marine sector. Dr Meenakumari is the current Chairperson of Marine Biodiversity Authority and is responsible for research and development / policy support and decisions in the inland and marine fisheries sector, fish production from aquaculture and fishing industry in India. She commercialised combination of wire ropes for deep sea demersal trawls thus substituting import of the ropes. Dr Meenakumari is actively working to conserve resources for the sustainable development of Indian fisheries and is interested in impact assessment and environmental monitoring. She has worked on Ecobiology of Fouling and received a gold medal. She is the recipient of prestigious awards like the Young Scientist Award by Kerala State in 1989, Panjab Rao Desmukh Women Scientist Award 2002 instituted by ICAR, the Marie Curie Mahila Vijnana Puraskar, 2010, the Bhoominirman Award-2011, and Dr R. S. Paroda Gold Medal for outstanding contributions in Fisheries, 2012. She has published more than 180 articles in reputed national and international journals.

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Nils Ragnar Kamsvåg was appointed Norwegian ambassador to India in 2015. He has served as Ambassador to Serbia, Macedonia and Montenegro (2010-15), as Representative to the Palestinian Authority and as Ambassador, Middle East and North Africa, in the Ministry of Foreign Affairs. Ambassador Kamsvåg joined the MFA in 1981. In addition to various positions in the MFA, he has been posted to Beirut, Rome, Brussels, Beijing, Jerusalem and Belgrade. From 1990 to 1993, he was Director of Public Affairs in Norsk Hydro. Mr. Kamsvåg has an MA in History from the University of Oslo.

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Dr K. J. Ramesh is the current Director General of Meteorology in India Meteorological Department. He obtained his Ph D from IIT Delhi on Monsoon Dynamics and M.Sc. (Meteorology) from Andhra University. He specialized sin 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 10 years followed by Group Head position in NCMRWF and Head Disaster management Unit of Government of Andhra Pradesh. In 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, elected Member of National Academy of Sciences, Allahabad and has more than 50 papers in peer reviewed journals to his credit.

Dr Akhilesh Gupta
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Dr Akhilesh Gupta is currently heading the Climate Change Programme (CCP) of DST coordinating two National Missions on Climate Change under National Action Plan on Climate Change. He obtained his PhD degree in Atmospheric Sciences from IIT, Delhi and has worked in the India Meteorological Department; National Centre for Medium Range Weather Forecasting and Disaster Management Cell of DST during 1985-2007 in various capacities. During 2007-09, Dr Gupta was Adviser to the Union Minister for Science and Technology and Earth Sciences. Dr Gupta was Secretary, University Grants Commission (UGC) during 2012-13. He was a

member of National Coordination Team, which drafted India's National Action Plan on Climate Change in 2008. Dr Gupta is a member of over 70 national level committees in various capacities and is also a Fellow of Indian National Academy of Engineering (INAE) and Indian Meteorological Society. He was awarded D.Lit (Honoris Causa) by JRH University in 2013 and Honorary Professorship by Amity University Rajasthan. He has published over 110 research papers in various national and international journals. He is co-editor of 3 books, author of over 200 articles and nearly 300 reports.

Dr S. C. Shenoi,
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Dr S. C. Shenoi's professional interests include observational oceanography, ocean currents, impact of oceans on monsoons and satellite oceanography. He played a lead role in DST-Arabian Sea Monsoon Experiment (ARMEX), which changed our traditional view from a passive role for the ocean in monsoonal processes to an active role in the monsoonal air-sea coupling. After the tsunami struck the Indian coast in 2004, he coordinated the research that described quantitatively the tsunami off the Indian coast and enabled an improved estimate of the extent of the tsunami source region. He obtained his M.Sc. (Physical Oceanography) and Ph.D. from Cochin University of Science & Technology, Kochi. Dr Shenoi has more than 30 years of research experience in Physical Oceanography. He was a senior member of the group that carried out hydrographic observations during 1987-1994 to map the seasonal cycle of circulation off the Indian coast. He also made limited current-meter observations to provide a quantitative description of coastal currents. Prior to joining INCOIS, he was leading a major programme making direct current measurements off the Indian coast to enable a quantitative description of the variability within a season and across years, marking a paradigm shift in our knowledge of the seas around India. He is a Fellow of Indian Academy of Sciences and has authored/ co-authored more than 70 research papers in journals of international repute.

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Dr M. Sudhakar has served two premier research institutions of the country -- National Institute of Oceanography (NIO) & National Centre for Antarctic and Ocean Research (NCAOR) in Goa, before taking charge of Director, CMLRE, Kochi. A veteran Oceanographer, he has occupied various positions such as project leader and scientist and has spent more than 1500 days at sea on-board research vessels, as leader of expeditions to 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 (LTC) of the International Seabed Authority (ISBA) for the term 2007-2011 and (2012-16). Dr Sudhakar was also a member of Scientific Committee on Ocean Research (SCOR), ICSU, serving for 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 to be held in India). He was the 'Commissioner General' of Govt. of India for the Yeosu (World) Expo 2012 held in Republic of Korea.

Dr M. Ravichandran
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Dr M. Ravichandran is the current Director of National Centre for Antarctic and Ocean Research Goa. He has worked as a Scientist in Indian Institute of Tropical Meteorology (IITM) in the field of Atmospheric Science, National Institute of Ocean Technology (NIOT) in the field of Ocean Observing System (Marine Meteorology) and Indian National Centre for Ocean Information Services (INCOIS) in the field of ocean observing

System and ocean modelling. His research interests include Atmospheric Physics & Ocean Dynamics, Marine Meteorology & Air-sea interaction, Ocean Observing Systems and Ocean Modelling among others. He is Co-Chair, CLIVAR/IOC-GOOS, Indian Ocean Region Panel; Member, International Argo Steering Team, Member, SIBER (Sustained Indian Ocean Biogeochemical and Ecological Research) Scientific Steering Committee.

Dr N. Purnachandra Rao
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Dr Purnachandra Rao's area of expertise relate to seismic ambient noise correlation tomography, reservoir triggered seismicity and earthquake forecast, deep drilling for earthquake studies, seismic hazard assessment and microzonation studies, moment tensor inversion studies for earthquake source mechanism and seismic waveform modelling to study earth's internal structure , Stress field and seismotectonics. Prior to taking over new position at NCESS, he has worked at National Geophysical Research Institute (NGRI) from 1989 to 2017 at various scientific positions. He is the proud recipient of National Geoscience Award (2016) from Ministry of mines, Government of India; Alexander von Humboldt (Avah) fellow, Germany; Visiting Professor, Univ. of Tokyo, Japan; Professor, Academy of Scientific Innovative; Raman Research Fellow at University of California, USA and many more. Dr Rao is Fellow of Geological Society of India, Andhra Pradesh and Telangana Akademi of Sciences, Member of Editorial Board, Journal of Asian Earth Sciences, Advisory member of Editorial Board, Indian Journal of Earth Sciences Studies etc.

Dr C. N. Ravishankar
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Dr C. N. Ravishankar is presently working as Director, Central Institute of Fisheries Technology (CIFT), Cochin. His areas of specialisation include fish processing and packaging technologies and has developed, popularised and transferred many technologies to the seafood industry. He was instrumental in establishing a Business Incubation Centre with office and pilot plant facility for the entrepreneurship development in fish and other food products. In addition to his many other activities, he has delivered numerous invited talks on fish preservation techniques, food packaging, business incubation and other related areas. Dr Ravishankar earned his Bachelor Degree in Fisheries Sciences from College of Fisheries, Mangalore under the University of Agricultural Sciences, Bangalore in 1984 followed by post-graduation and Ph.D. from the same University in 1986 and 1990 respectively. He joined CIFT, Cochin as Scientist in 1991 and has been working ever since in various capacities in the fish processing division. He has participated in the First Indian Antarctic Expedition and has travelled abroad widely for training and consultancy programmes. Dr. Ravishankar received the Outstanding Team Research award in the field of Fish Products Technology from the Indian Council of Agricultural Research, and K. Chidambaram Memorial Award from Fisheries Technocrats Forum, Gold Medal for his Ph.D. and Merit Certificate from Royal Institute of Public Health & Hygiene, London. He is a Fellow of National Academy of Agricultural Sciences, New Delhi and Society of Fisheries Technologists (India). He has more than 200 International and National publications to his credit and has filed 17 patents.

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Dr V. M. Tiwari's research interest includes measurement and modeling of gravity and magnetic data for the investigation of Earth's structure and resources. He is currently engaged in lithospheric configuration and deformation of converging plate margins and water mass variability estimation from new generation of satellite data. Prior to taking over as the Director of CSIR-NGRI, Hyderabad, he headed the Centre for Earth Science Studies (presently NCESS). He was post-doctoral fellow at IPGP, Paris, LEGOS, CNES Toulouse France, Research Scientist at GEOMAR&CAU Kiel Germany and Research Associate at University of Colorado, Boulder USA. He has received several awards and honours including Krishnan Gold Medal (IGU) -2008, National Mineral Award- 2007, CSIR Young Scientist Award, 2003, UP-CST Young Scientist Award, 2001, INSA MEDAL for Young Scientist, 2000 and ONGC-AEG Best Ph.D. Award, 1999. He is Fellow of Indian National Science Academy and Indian Geophysical Union. He is a member of INSA-IUGG/CODATA, Research Advisory Council of Wadia Institute of Himalayan Geology, Dehradun and the Editorial boards of the Journals such as Himalayan Geology and J E.S.I.

Dr Sunil Kumar Singh
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Dr Sunil Kumar Singh is a geochemist and the director of the CSIR - National Institute of Oceanography. He is known for his studies on low temperature elemental and isotope geochemistry and biogeochemistry of trace elements and isotopes in the Indian Ocean. His researches are reported to have assisted in widening the understanding on the impact of origin and evolution of the Himalaya on the ocean biogeochemistry and the climate change. Dr Singh's studies have been documented in several peer-reviewed articles. He completed his bachelor

and master studies in BHU, Varanasi and pursued PhD from Physical Research Laboratory, Ahmedabad. He spent about three years in France as post doctoral fellow. He worked at PRL as scientist for about 15 years. Dr Singh, is a former Scientific Steering committee member and the incumbent member of the Data Management Committee of GEOTRACES, an international forum for research on the marine biogeochemical cycles of trace elements and isotopes. He is the coordinator of the GEOTRACES-India programme. He is a recipient of the National Geoscience Award and an elected fellow of the Indian Academy of Sciences. He has been awarded the Shanti Swarup Bhatnagar Prize for Science and Technology, one of the highest Indian science awards for his contributions to Earth, Atmosphere, Ocean and Planetary Sciences in 2016 by the Council of Scientific and Industrial Research, the apex agency of the Government of India for scientific research. He is serving as associate editor for several international journals.

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Dr Vijay Kumar's area of research includes groundwater modelling, analysis of hydro-meteorological variables, climate change, spatial modelling, lake hydrology etc. At MoES he is responsible for monitoring and coordination of programmes related to Polar Science & Cryosphere (comprising Arctic, Antarctic and Himalaya) as also the programmes on Southern Ocean, Water Cycle, Ocean Survey & Mineral Resources (Geo-scientific studies of the Exclusive Economic Zone, Delineation of India's Continental shelf, Gas Hydrates Exploration, Poly-Metallic Nodules (PMN), and Studies on Hydrothermal Sulphides) etc. He obtained his Ph.D. in Water Resources Engineering from the Indian Institute of Technology, Delhi. Prior to joining MoES, he has worked in National Institute of Hydrology (NIH) where he contributed significantly in many consultancy and sponsored projects. He has conducted many specialized training courses hydrological aspects for field engineers. He has more than 100 papers in various International and National journals, conferences etc. to his credit.

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Dr R. Krishnan specializes in climate modelling on scientific issues relating to the 'Dynamics and variability of the Asian monsoon'. His interests include: monsoon dynamics and variability; phenomenon of monsoon-breaks and droughts; large-scale organization of monsoon convection; global climate change and impacts on the Asian monsoon; and, regional climate extremes. Currently Dr. Krishnan is leading the Centre for Climate Change Research (CCCR) at the Indian Institute of Tropical Meteorology, Pune and is deeply involved in developing in-house capability in Earth System Modelling to address climate change and related scientific issues. He carried out his research for PhD in Atmospheric Sciences at the Physical Research Laboratory, Ahmedabad and was awarded the degree from University of Pune in 1994. He was an eminent Senior Scientific Officer, National Centre for Medium Range Weather Forecasting, and Delhi for five years. Dr. Krishnan is Senior Scientist in Indian Institute of Tropical Meteorology, Pune from 1995 till present. He was honoured with Frontier Outstanding Research Award, FRSGC, Japan (Twice: 1999 and 2000), IITM Golden Jubilee Biennial Award, 2014 for Outstanding Research Contributions, IITM Silver Jubilee Award for best research paper, IITM, Pune (thrice: 1998, 2005, 2009), Prof. Anandu Vernekar Award, India Meteorological Society (IMS). Dr Krishnan was a member of the prestigious Asia Australia Monsoon Panel (AAMP), CLIVAR, and World Climate Research Programme. He occupied the chair of CORDEX Science Advisory Team, World Climate Research Programme. He was part of Scientific Steering Committee, Monsoon Asia Integrated Regional Study (MAIRS). He was an editor, Earth System Dynamics, Open Access Journal, and European Geophysical Union. Dr Krishnan has published over 80 scientific articles (63 in peer-reviewed Journals & book chapters; 17 Research Reports).

Dr Ashwagosha Ganju
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Dr Ashwagosha Ganju has conducted hydrological and sediment transport studies, prepared geomorphologic map and established a chain of observatory network in Siachen Area along with preparing an Avalanche Atlas of Siachen Glacier. He pioneered the technique of translucent snow profile for studying weak layers in snow pack and developed statistical and AI based models for prediction of avalanches in different snow climatic zones. He formalized avalanche forecast process at SASE using contributory factors approach and adopted a multi model approach of prediction of avalanches using statistical avalanche forecast Model (nearest neighbour), snow pack build-up approach of avalanche prediction (SPBU) and AI techniques. Dr Ganjujoined SASE, (DRDO) in 1985 and took up Cold Regions Science and Engineering related work. He has nearly thirty years of research experience in Cold Regions Sciences.He has been instrumental in initiating the research work on spatial and temporal variability of snow cover in Western Himalayas and study of Micro Tremor Activity in Karakoram ranges. He is the recipient of SASE Best Performance Award (1990), Siachen Medal (1992), Science Day Medal (2004), Best Science Article in Hindi (2004), HR Leadership Award (2012), Defence Technology Spin off Award (2013) and Best Citizenship Award (2014). He has more than 50 publications in national/international journals of repute and conferences.

Dr M R Bhutiyani
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Dr M R Bhutiyani's works on natural hazards such as avalanches, rock falls, ice avalanches, crevasses and glacier-melt water floods afflicting the troops deployed in the glaciated terrain of the eastern Karakoram Himalaya resulted in preparation of route maps of all glaciers of that region and ensured the safety of pedestrian routes and camp sites for the troops. His work on glaciological studies on the Siachen Glacier, has culminated in development of methodology of estimation of mass balance of very long glaciers by an innovative hydrological method and suspended sediment transport studies in the Nubra River. He obtained his M.Sc. in Geology with specialisation in Engineering Geology and Groundwater Hydrology in 1981 and Ph D in Environmental Science on the 'Response of Glaciers to the Climate Change and its Implications on NW Himalaya' from the University of Pune in 2005. He started his career as a lecturer in Geology in Science College, Karad, and later worked as a geo-scientist in Government of Maharashtra and in Geological Survey of India. He joined Snow and Avalanche Study Establishment (SASE), DRDO as a Scientist in 1984 and carried out research on the Himalayan Glaciers. He organised a special training programme on Precision Manufacturing Techniques and GD&T Principles in 2014. His research papers published in International Journal of Glaciology and Journal of Hydrology are now the most widely cited papers on this subject. His path breaking work on the Siachen Glacier has paved the way for exploring many other large glaciers in other parts of the Himalaya.

Dr Bimal N Patel,
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Professor Bimal Patel, Director of Gujarat National law University since 2008, holds a Ph D (International Law) from Leiden University, the Netherlands, Ph D (International Law and Governance) from Jaipur National University and LLM (International Law, University of Leiden, the Netherlands). He obtained his MA and Post Master Diploma (International Relations) from University of Amsterdam, the Netherlands); Post-Graduate Diploma from International Institute of Social Studies, the Hague, the Netherlands); Summer School Certificate (Foreign Policy & Government, Oslo University, Norway. He is a Member, Law Commission of India, Government of India, Member, National Security Advisory Board, Government of India,Adviser, Insolvency and Bankruptcy Board of India Regulation Committee, Member, Gujarat Council on Research interests in International Courts and Tribunals, Law of the Sea and Maritime Laws, International Law & International Organisations, State practice on international law, Foreign Policy and International Law and Public-Private Partnership in Legal Education, Research and Training. He is Editor-in-Chief, Developing World Review on Trade and Competition, Chief Editor, Journal of Law, Development and Politics, Chief Editor, GNLU Law Review and Editor -in-Chief, Gujarat Law Journal. He has authored several books on Law of the Sea and maritime laws among others.

B

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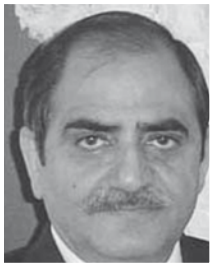

Dr Rasik Ravindra held the position of the Director of NCAOR between January 2006 and August 2012 after relinquishing the post of Deputy Director General in Geological Survey of India, an organization that he served from 1971 to 2005.

A veteran Antarctican, he participated in Indian Expedition to Antarctica in 1987-88 for the first time and subsequently led Ninth Antarctic Expedition in 1989-91, visiting the icy continent again in 1996-97, 2003-04, 2007 and 2009 in various capacities for specific assignments, contributing to different facets of Antarctic science, logistics and policy of this mission. He has led the first Indian Expedition to South Pole and the first Indian Arctic Expedition. He was Chairman of the DST constituted Program Monitoring Committee on "Dynamics of Himalayan Glaciers from 2007 to 2012 and was appointed Chair, Panikkar Professor in October 2012 by Ministry of Earth Sciences. He has served as an elected Member of the U N Commission on Limits of Continental Shelf for 2014-2017 Term. He has received National Award for Polar Sciences and Cryosphere, 2013, National Mineral Award- 1990, Antarctic Award- 2002, H. N. Siddiqui Gold Medal from IGU in 2011, Prof Prem Bahadur Verma Memorial Lecture and R C Mishra Memorial Gold Medal 2017.

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Dr Gopal Raman Iyengar, is involved in Planning and Coordination of atmospheric science programmes in MoES. His area of expertise includes weather and climate modelling. Prior to joining MoES, he has worked in National Centre for Medium Range Weather Forecasting (NCMRWF) from 1990 to 2015 in various scientific positions.

Dr Ajit Tyagi
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Air Vice Marshal (Retd.) Dr AjitTyagi, has served as Director General of Meteorology, India Meteorological Department, Assistant Chief of Air Staff (Meteorology) and Principal Director (Information Technology) in Indian Air Force. Dr Tyagi has successfully executed first phase of modernisation programme of India Meteorological Department and has formulated Himalayan Meteorology Programme. He is on the Monsoon Panel of World Weather Research Programme of World Meteorological Organisation (WMO). He has served as Permanent Representative of India with WMO on Monsoon Meteorology. He is member of several scientific committees of Department of Science and Technology. Dr Tyagi is currently the President of India Meteorological Society, also. He has been commended by Chief of Air Staff and awarded Vishistha Sewa Medal by President of India for his distinguished services to the nation.

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Prof. Sachidananda Sinha is Chairperson of Centre for the Study of Regional Development (CSRD) in Jawaharlal Nehru University, New Delhi. He has over 40 years of experience in teaching and research on issues related to Education, Geography, and Livelihood. He has published papers in national and international journals on these issues. He is member in several committees of Government of India and has held several positions at various level in the past.

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Prof. A L Ramanathan's areas of specialization/ research interests include Environmental Geology, Hydrogeochemistry, Biogeochemistry, Glaciology, Water Resource Management and Coastal Zone Management. He is teaching in JNU since 2000. Prior to this he was a Senior Lecturer, Dept. of Geology, Annamalai University, Tamilnadu. He is the recipient of 13 awards and several honours, including the Young Scientist Award (project) Sweden (2009-11). He is currently a professor in School of Environmental Studies, Jawaharlal Nehru University, New Delhi. He has guided 15 Ph D scholars. He has peer-reviewed 3 journals/ books and five publications. He has also worked on various projects in collaboration with international organisations especially from France and Norway.

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Dr Bikramaditya K. Choudhary is Assistant Professor at Centre for the Study of Regional Development, School of Social Sciences, Jawaharlal Nehru University. He has been teaching courses on Urban and Regional Development. His core area of research is Health Geography the sub-field in which he completed PhD from Jawaharlal Nehru University in 2006 on the topic of the Political Ecology of Disease, which was later on published as a book. He has written extensively on health and disease, waste-pickers and urban dynamics. Currently, he is working on two projects in the city of Varanasi, India on the themes of 'urban segregation' and 'space and performance'.

Sulagna Chattopadhyay
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Sulagna Chattopadhyay, is known for internationally reputed journo-magazine on environment and development titled 'Geography and You', (G'nY) that she founded an in 2001. An M.Phil. from Jawaharlal Nehru University, New Delhi, she has published 105 issues of the magazine so far. She is also a founding President of an NGO, Learning in Geography, Humanities, Technology and Science (LIGHTS) and has been organising national and international conferences/seminars, notable among these are: Round table conclave on seas and oceans around India, National Conference on Science & Geopolitics on Arctic and Antarctic (SaGAA) in 2011, SaGAA in 2012 and SaGHAA in 2015. The LIGHTS has organised a multi-city GIS training programme for school teachers in seven locations under her leadership. She was nominated as the Member of the Working Group for Disaster Management in Planning Commission in 2011. She also won an Environmental Documentary Short Film Contest, STL- 2 : 2015 for her short film titled 'O Bhai Saab'. Sulagna has edited 12 books, prominent among them are 'the Scientific and Geopolitical Interests in Arctic and Antarctic' co-edited with Dr R Ramesh and Dr M Sudhakar in 2103 and the' Science and Geopolitics of White World co-authored with Dr P S Goel and Dr Rasik Ravindra' published by Springer in 2017.

Dr N. Prasad
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Dr N. Prasad is currently Director, Parliamentary & Administrative Research Institute, constituted under LIGHTS Research Foundation. The Institute is engaged in research and training in parliamentary processes and holding capacity building programmes for Central and State government officials. Formerly Additional Director at Rajya Sabha, Parliament of India, Dr Prasad has obtained his Ph.D. from the Centre for International Politics, Organisation and Disarmament, Jawaharlal Nehru University, New Delhi in 2001. He has two books to his credit and has been the honorary editor of Bhugol aur Aap, an environment and development magazine in Hindi, from its inception in 2002.

B

THE PEOPLE

SPEAKERS*

**arranged alphabetically*

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Sarfaraz Alam has a PhD in Political Geography from School of International Studies, Jawaharlal Nehru University, New Delhi. Presently, Dr Alam is working as Associate Professor in the Department of Geography, Institute of Science, Banaras Hindu University, Varanasi. He has briefly served in IGNOU as a Reader in Geography (School of Sciences). Dr Alam has also worked in the Institute for Defence Studies and Analysis (IDSA), New Delhi and J P University, Chapra (Bihar). His research interests include geopolitics, environmental conflict and security in South Asia and geography education. Presently, he is writing a book on the theme of Geography, Environment and National Security of Bangladesh to be published by Cambridge Scholars Publishing, UK.

Dr Ayyanadar Arunachalam
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Dr Ayyanadar Arunachalam's areas on interest are natural resource management, agroforestry and restoration ecology. He holds a Ph D in environmental management and has held various positions such as: faculty in Indian Agricultural Research Institute, New Delhi, Adjunct Professor in Navsari Agricultural University, Gujarat, Honorary Professor, Amity University, Noida and Florida Agricultural and Mechanical University, USA among others. He has been awarded several awards some of which are : DST-BOYSCAST Fellowship in Restoration Ecology, University of Massachusetts, Boston (USA), Pran Vohra Award in Agriculture and Forestry Sciences by Indian Science Congress, (2003-04), Indian Science Congress Association; Environmentalist of the Year award (2008), National Environmental Science Academy; Eminent Scientist of the Year award (2012) by National Environmental Science Academy. He is also editorial board member of many Journals viz: Agriculture, Ecosystems and Environment (2006-15); Journal of Food, Agriculture and Environment, Finland; Asian Journal of Microbiology, Biotechnology and Environmental Science as also the Chief Editor of Indian Journal of Hill Farming.

Dr M A Atmanand
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Dr M A Atmanand, has done pioneering work in the area of deep sea technologies in India. An instrumentation and control engineer by profession, he took Master's and Doctorate degrees from Indian Institute of Technology, Madras. He led a team of engineers for the design and development of underwater crawler for deep sea operation. The team developed the in-situ soil tester, which was tested at a depth of 5200 m in the Central Indian Ocean Basin. It was under his supervision that the design of Electrical, Instrumentation and Control system of the India's first Remotely Operable Vehicle was completed. This was later tested at a depth of 5289 m under water. He has also guided various indigenisation programmes for ocean observation and under water systems. His areas of interest include development of underwater vehicles with specific reference to their control; development of components for deep sea applications; and development of test protocols for testing of deep sea devices. He received the IEEE-Oceanic Engineering presidential Award in 2016, National Geoscience award 2010 from Ministry of Mines and the International Society for Offshore and Polar Engineers (ISOPE) Ocean Mining Symposium Award - 2009. He is Associate Editor of IEEE Journal of Oceanic Engineering. He has widely travelled in capacities like technology transfer, as part of delegations etc. to various countries. He received United Nations Fellowship in 1985 – 86 and is the founder Chair of IEEE Oceanic Engineering Society in India. He has served IEEE Madras section in various capacities and he is the current Chair. Dr Atmanand has presented and published more than 100 papers in international journals, international conferences, book chapters, national conference and others.

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Professor C. R. Babu is working in the field of taxonomy and ecology, systematics genetics, conservation and sustainable utilization of biodiversity, ecosystem dynamics and function, ecological restoration of mined areas and degraded ecosystems. He has been ex -chairman of several Commissions/ Committees that include, the Indian Subcontinent Plant Specialist Group of the IUCN Species for ten years between 1995 and 2005, IUCN Committee on threatened plants of Indian subcontinent, Member of the IUCN Commission on ecosystem management. Prof Babu is an elected Fellow of the Indian Academy of Sciences, Fellow of the New York Academy of Sciences, Fellow of the Indian Society of Genetics and Plant Breeding etc. He has been honoured with Indira Gandhi Paryavaran Puraskar, VASVIK Award 2005 for Environmental Science and Technology and Narain Dutt Award 2008 for Conservation of Nature.

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Dr M Javed Beg has contributed significantly to Indian Antarctic Program by organizing logistics, development of infrastructure facilities at Indian Research Stations and facilitating research output of scientists. He was the project manager for construction of third Indian Research Station-Bharati in Antarctica. He is a geologist by profession and holds MBA degree from Maastricht School of Management, The Netherlands. Prior to joining NCAOR, he served in Geological Survey of India where he conducted geological investigations in J&K Himalayas and Antarctica. He has participated in several Indian Expeditions to Antarctica including the First Indian Expedition to South Pole and has undertaken geological and glaciological studies including those on melt water lakes of Schirrmacher and Larsemann Hills areas. Recipient of National Mineral Award (National Geoscience Awards) 2004. He is the current Vice Chair of Council of Managers of National Antarctic Programs (COMNAP) and has several research publications in peer reviewed journals.

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Dr Sujata Dash, is instrumental in process optimization of large area trans-border mapping with the exploitation of multi- sensor high resolution satellite images. During her 21 years of scientific career in DTRL, she has been actively involved in various multidisciplinary mission-mode projects on geospatial technological applications for military planning and operations. She has developed expertise in the field of coastal environments including coastal ocean circulation studies; microwave and thermal remote sensing based terrain modelling and soil moisture retrieval system and Geospatial Intelligence for Defence preparedness. Dr Sujata Dash is a Gold Medalist in MSc (Tech) in Geophysics from BHU in 1994. Subsequently, she has completed her Doctorate in Oceanography (2005) from IIT-Delhi and MBA in Disaster Management (2012) from Guru Gobind Singh Indraprastha University, Delhi. She has thirty five research papers published in international journals. Dr Sujata has received the 'Best paper award' - ICMARS (2006), ISRS (2009) Hindi Conference (2011) and International women's day workshop (2015). She had also received 'Scientist of the year award (2006)' and Technology Group Awards (2005 and 2009) of DTRL.

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Dr Prabir Dastidar has more than two decades of experience in science administration, science policies and modelling and managing of the growth of science and technology of earth system science research in India. His research interest is intellectual structure and statistical approach to results of researches in earth system science, including polar sciences. He has designed internationally recognized research analysis framework for Antarctic Sciences. He obtained his

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Dr A. P. Dimri currently professor in School of Environmental Sciences in Jawaharlal Nehru University (JNU), completed his M. Phil from JNU and pursued his Ph D from the Indian Institute of Tropical Meteorology (IITM). His research area focuses on regional climate dynamics, change and variability, climate and numerical modelling, statistical and dynamical downscaling of numerical model outputs, climate change,

extreme events and their physical understanding and Indian winter monsoon and western disturbances. Dr Dimri is involved in the ongoing projects on the study of extreme precipitating events (cloudburst) leading to natural hazards and disasters; measurements and modelling of evapo-transpiration and other hydrological processes in the lesser Himalayas; and development of Dynamical Mass Balance Model for Gangotri Glacier.

Dr. Dimri was the recipient of the Commonwealth Academic Fellowship 2014-2015. He was elected as Council Member, Indian Geophysical Union (IGU) and Indian Meteorological Society (IMS) during 2014-2016. He has been awarded a fellowship in Japan Society for the Promotion of Science and Indian Geophysical Union (IGU) and has received the Technology Award 2006 from Defence Research and Development Organization (DRDO). Dr Dimri has more than 60 publications in peer reviewed research journals.

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Dr D. P. Dobhal is associated with research programme on glaciological studies of the Himalaya glaciers since 1986. The programme comprises long term monitoring of selected Himalayan glaciers to understand the glacier dynamics and the recession processes in context to climate change. He uses eco-friendly bamboo stakes for the measurement of the snow/ice glacier melting (mass balance) and flow-dynamics studies which has been appreciated worldwide. Dr Dobhal is coordinating a DST sponsored project "Establishment of Centre for Glaciology". He has participated in a number of Glacier Expeditions, few of them are XX Indian Antarctic Expedition, 2000-2001 and Glacier Mass balance study tourto Norwegian glaciers, August, 2013. Dr Dobhal has authored more than 70 research articles in peer reviewed journals and supervised three Ph Ds so far.

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Dr Malti Goel has contributed immensely to emerging environment concerns. She has worked in energy and climate change field as an expert. She headed the Inter-sectoral Science and Technology Advisory Committee Division in Department of Science and Technology of the Government of India and is known for her new initiatives in Joint Technology Projects in current topics of science and technology. She was Programme Coordinator for Atmospheric Sciences in Earth System Science Division and steered successfully the Monsoon Trough Boundary Layer Experiment and Indian component of Tropical Oceans Global Atmosphere, conducted at all India level. She was associated with the thrust area programmes in physical sciences and led researches in lasers science and technology, superconductivity and greenhouse gas monitoring, mitigation among others. Her original research work has been cited in handbooks and patents. Recipient of many awards and honours, she has recently been awarded 'Life Time Achievement Award 2016' for Educational Excellence in Climate Change Research.' She has authored over 250 research papers and edited a book in 2017 jointly with Sudhakar M on 'Carbon Utilization: Applications to the Energy Industry', published by Springer.

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Prof Tanu Jindal Director of Amity Institute of Environmental Sciences, Amity Institute for Environmental Toxicology, Safety and Management and Amity Centre for Antarctic Research and Studies, is an environment scientist, working on the project of Environmental Toxicological Studies in Schirrmacher area in Antarctic Region in collaboration with National Centre of Antarctic and Ocean Research. She obtained her Ph D from Department of Zoology, Delhi University as

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Dr Rajeev Kumar Mehajan, Group Captain (Retired) 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 Indian Air Force (IAF). Dr Mehajan has been the Director - Forecasting and Communication at Ministry of Defence (MoD) and Program Director - Atmospheric and Ocean Divisions at Ministry of Earth Sciences (MoES). He has also served the U N as Chief Meteorological Officer in Democratic Republic of Congo (DRC). He holds Master's Degree in Mathematics and Strategic Science and a Ph D in Meteorology. He has organized many national level seminars and conferences and has been Ex 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 Melothhas made pioneering contributions to the polar ice and snow studies in the country. He was instrumental in establishing South Asia's first and the only state-of-the-art Ice Core Laboratory with world class facilities for ice research at NCAOR. He is currently a senior Scientist and Group Director at NCAOR. Thamban obtained his M Sc in Marine Geology from Cochin University of Science and Technology (CUSAT) and Ph D from the National Institute of Oceanography (Goa) in 1999. Since then he served at various positions in academic and research institutions that include: Lecturer in Geology at the Government College Kasargod (2000-2002), scientist at the National Institute of Oceanography, before taking up a position at NCAOR in 2002. Dr Thamban has led several major glaciological expeditions to Antarctic, Arctic, and Himalayas. He was one among the few chosen scientists for the first Indian Scientific Expedition to South Pole in 2010 that endured a month-long over-snow traverse of nearly 2300 km over the frozen continent. Dr. Thamban was also the leader of the Indo-Norwegian MADICE project in Antarctica during 2016 –2017 field seasons, which included researchers from India and Norway. He has been awarded several national and international awards that include: DAAD Fellowship (1997), Young Sedimentologist Award (1997), JSPS Post Doctoral Fellowship in Japan (2001), Young Scientist Award by the Indian Science Congress (2001), START Young Scientist Award (2001) by the International Geosphere Biosphere Programme (IGBP), Prof. Naganna Gold Medal (2003) by the Mineralogical Society of India, as well as the prestigious National Geoscience Award (2013) by the Government of India. Dr Thamban is also an invited member of various international and national scientific committees and technical bodies. Thamban has published more than 60 research papers in prestigious peer-reviewed international and national journals, and as invited chapters in international books.

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Prof. N C Pant has made significant contributions in establishing extension of East African Orogen in east Antarctica, described high pressure (HP) metamorphism from Indian Archean craton (Bundelkhand), applied innovative and uncommon application of Electro Probe Micro Analysis (EPMA) 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 has contributed immensely in establishing, developing and nurturing micro-domain characterization laboratories in India and propagating the chemical geochronology in the country. He has previously served in Geological Survey of India and Indian Institute of Technology (Kharagpur) and been decorated with National Mineral Award (1996), Antarctic Silver Jubilee Award and British Council Innovation Award in form of ICECAP-2 project (2015-2017). Dr Pant has been actively associated with Antarctic science since 1985, including last 6 years as an Officer of SCAR (Secretary and Deputy Chief of the Geosciences Group).He has about eighty international and national research publications to his credit.

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Dr H. S. Negi specialized in the field of multi-spectral and hyper-spectral remote sensing for snow characteristics, snow cover monitoring, snow avalanche and other cryosphere hazards, glacier and climate change study. He obtained his M.Tech. in Cold Region Science & Engineering from G B Pant University of Agriculture and Technology, Pantnagar and holds a Ph D in remote sensing of snow from H N B Garhwal University, Srinagar. He has nearly two decades of experience in remote sensing of snow and glaciers. He is the recipient of BOYSCAST fellowship of DST and worked at University of Bremen, Germany. He is the recipient of DRDO Young Scientist Award (2006) and Technology Group Award as a team leader, SASE (2015). He also participated in Indian Science Expedition to Antarctica. He has around 40 research papers in peer reviewed journals and symposiums.

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Dr Susheela Negi is a Principal Scientific Officer at the Ministry of Science and Technology, Government of India. She holds a Doctorate Degree in Agriculture from the Himachal Pradesh Krishi Vishwavidyalay, Palampur. She was a recipient of a Junior Research Fellowship from the Indian Council of Agricultural Research for doing her Masters in Agriculture. She has been with the Department of Science and Technology for more than a decade, working on promotion of Science and Technology in the country.

Dr Negi is associated with the initiation and implementation of the 'National Program on CO_2 Research in India'. Presently Dr Negi is associated with the implementation of coordination of two National Missions on Climate Change of the Government of India. These missions are: (a) National Mission for Sustaining the Himalayan Ecosystem (NMSHE) and (b) National Mission on Strategic Knowledge for Climate Change (NMSKCC).

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Dr Rajiv Nigam has worked extensively in the fields of marine geology, paleoclimate, foraminifera and its laboratory culture, otoliths, sea level changes, paleo-monsoon, paleo-storm, sediment transport, marine pollution, coastal zone and industrial surveys and has headed the Geological Oceanography Division of NIO. He was convener of the 16th Indian Colloquium on Micropaleontology and Stratigraphy (ICMS) held in 1996 and President ICMS, 2002. D. Sc. from Aligarh Muslim University, he has been decorated with several national awards, including Outstanding Young Person Award 1989, CSIR Young Scientist Award 1989, Certificate of appreciation (NIO) 1997, Krishnan Medal by IGU in 1994 and the prestigious Bhatnagar Award. He has been a council

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Dr Rajagopal the present head of NCMRWF has over 30 years of experience in numerical modelling of weather and climate. He has played a pivotal role in the model implementations at NCMRWF. Currently actively involved in Unified Model (UM) upgradations, he also manages the UM based Analysis-Forecast Suite at NCMRWF. His research interests include modelling of atmospheric convection, land surface processes and planetary boundary layer for weather prediction. He has been awarded the Certificate of Merit for outstanding contributions in Atmospheric Science for the year 2007 by Ministry of Earth Science, Govt. of India and has about 100 publications in peer reviewed national and international journals.

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Dr G. A. Ramadass is a senior scientist at National Institute of Technology (NIOT), Chennai. His research areas include Deep Sea Technology, Underwater Acoustics and Marine Instruments. At NIOT he is the head of Deep Sea Technology Group. In 2010 he won the National Geoscience award under the Exploration of Oil and Natural Gas category. He led NIOT team of the Indian Scientific Expedition to Antarctica in February- March 2015. Polar Remotely Operated Vehicle (PROVe), developed indigenously at NIOT, was used for exploration in the lake and shelf area of Antarctica during this expedition. A doctorate from Indian Institute of Technology, Madras, he has handled technology development programmes leading to products and patents. He has been the Chief Scientist of 15 cruises and scientific explorations on-board various research vessels. His work includes publications in the international journals, contributions to international conferences and four international patents.

Dr Rengaswamy Ramesh
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Prof. Rengaswamy Ramesh is an eminent geochemist currently working as senior professor at School of Earth and Planetary Sciences at National Institute of Science Education and Research, Bhubaneswar. He has worked as a Ph D guide at the Department of Geology, Maharaja Sayajirao University of Baroda, Vadodara and was an Outstanding Scientist at Geosciences Division, Stable Isotope Geochemistry, Physical Research Laboratory, Ahmedabad. His research interests are climate change and oceanography. He is a recipient of INSA Young Scientist award, TWAS award, the K R Ramanathan Memorial Gold medal and the prestigious S S Bhatnagar Award. He is a fellow of all the three Academies of Science and also the Third World Academy of Science Italy. He was a lead author for IPCC AR 4&5 and got special citation for Nobel Peace Prize 2007. He has more than 200 publications in reputed national and international peer reviewed journals.

Dr Luther Rangreji
Director, L&T Division
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Dr Luther Rangreji is currently Director in Legal and Treaties Division, Ministry of External Affairs of Government of India. His areas of specialisation include – law of the sea, international organisation and international environmental law. He has dealt with diverse matters relating to extradition, International Criminal Court, work of the International Law Commission, United Nations, collective security, narcotics and international terrorism, international environmental issues such as climate change, biodiversity, biosafety, atomic energy, water disputes, Antarctic matters, disarmament etc. He obtained his L.L.M from Pune University and M. Phil and Ph D in International Law from Jawaharlal Nehru University (JNU), New Delhi. He has worked

as Legal Adviser at the Secretariat of the Asian-African Legal Consultative Organization (AALCO) New Delhi, an intergovernmental organisation devoted to study of international legal issues of concern to the Asian-African countries. He was on deputation to the Faculty of Legal Studies, South Asian University as a faculty member. He is a Visiting Faculty at the Indian Society of International Law, Indian Law Institute, New Delhi, WWF -Centre for Environmental Law, National Law School, Bangalore, University of Pune and Symbiosis International University. He has presented and published papers on various problems of international law issues in national and international journals.

Dr Soban Singh Rawat
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Dr Soban Singh Rawat is currently posted at Western Himalayan Regional Centre of NIH, Jammu Cantt. His research interest include hydrology of Himalayan Springs and strategy for their development, hill slope soil erosion and sediment process. After obtaining his Ph D on"Rainfall-Runoff-Sediment Yield Modeling of Mountainous Watersheds" from IIT, Roorkee, he worked as Assistant Professor at G B Pant University of Agriculture and Technology, Pantnagar. He is the Life member of Indian Water Resource Society,Indian Association of Soil and Water Conservationists and Indian Association of Hydrologist. Dr Rawat has published about 16 research papers in reputed journals.

Dr Walter R. Roest
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Walter R Roest has a PhD in marine geophysics from the Vening Meinesz Laboratory of the University of Utrecht, the Netherlands. After a three year post-doc at the Atlantic Geoscience Centre of the Bedford Institute of Oceanography in Nova Scotia, Canada, he joined the Geological Survey of Canada in Ottawa as a research scientist. He headed the Crustal Geophysics Subdivision, was acting Chief Geoscientist, and acting director of the Continental Geosciences Division of the GSC, before joining the French marine research institute Ifremer in Brest in 2003, as director of the Marine Geosciences Department (until 2009). From 2004 to 2012, he headed the French UNCLOS programme for the delineation of the continental shelf beyond 200 nautical miles, and headed many research cruises offshore the French overseas territories. He is (co-)author of over 80 peer reviewed papers, dealing with topics ranging from global geodynamics, tectonics and regional magnetics to continental margin studies. Walter Roest was nominated by France to be a member of the UN Commission on the limits of the continental shelf and was elected for the period 2012-2017.

Dr Shakil A Romshoo
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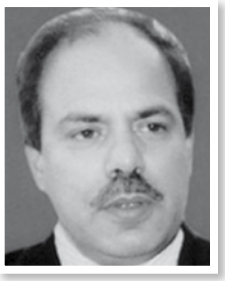

Prof. Romshoo, in addition to his academic duties is engaged in collaborative and sponsored research on hydrology, glaciology and climate change impact studies in the Himalayan region. He has a multidisciplinary academic and research background having obtained his Ph D in Civil Engineering (water resources) from the University of Tokyo, Japan and Master's Degree in Remote Sensing and GIS from the Asian Institute of Technology, Bangkok Thailand. He has worked, in the past, as a scientist at the Japan Aerospace Exploration Agency (JAXA), Tokyo and Fellow at the Energy and Research

Institute (TERI), New Delhi. Professor Romshoo has published more than 165 publications in peer reviewed national and international journals and book chapters. Professor Romshoo is a member of more than a score of policy and decision-making committees and Working Groups related to environment, water, climate change and disaster management at the national and international level. He has won several national and international awards for his academic achievements. Notable among them are the Kasumigaura International Prize from Government of Japan in 2009, the National Geoscience Award from Government of India conferred by the President of India in 2013 and the ISG President Appreciation Medal for the promotion of Geomatics in India in 2015.

Dr Sandip Kumar Roy
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Dr Sandip Kumar Roy is an active field geologist who has participated in four national expeditions to the Antarctica and three expeditions to the Arctic. He obtained his masters from ISM, Dhanbad in 1997 and Doctorate in Structural Geology from Jadavpur University in 2013. He has worked as a mining geologist in Hutti Gold Mines, before joining GSI in 2002. From 2006 onwards, he has been associated with the scientific programmes of Polar Regions. His main research interests lie in understanding the Neo Proterozoic granulitic terrane of cDML as well as Prydz bay and dynamics of the Polar Ice sheet around Schirmacher Oasis. During the expeditions to Antarctica, he worked mainly on the Schirmacher Oasis, Nunataks in between Wohlthat and Schirmacher Oasis as well as in the Larsemann Hills area of East Antarctic. In the Arctic regions, his work was related to ongoing glaciological project and late Quaternary climate changes.

Dr K. Satheesan
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Dr K. Satheesan's research interests include atmospheric sciences. Earlier he had worked as a Scientist at National Centre for Antarctic and Ocean Research, Goa and at Space Applications Centre, ISRO, Ahmedabad. He did M.Tech and Ph D in Atmospheric Sciences from Cochin University of Science and Technology and M.Sc. in Mathematics from Calicut University.

Dr S. Sathyakumar
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Wildlife Institute of India (WII)
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Dr S. Sathyakumar is M.Sc. and Ph.D in Wildlife Sciences and has been specialising in biodiversity research and conservation for over 30 years in the Himalayan Region. His research interests include: biodiversity inventory, assessment, and monitoring, planning and executing ecological research particularly on species-habitat relationships in relation to human use, climate change, human-wildlife interactions or conflicts, and environmental impact assessments of developmental projects. He developed and implemented the WII's Long-term Wildlife Monitoring Programme in the Southern Indian Ocean and Antarctica in 1995 and has participated in two InSEA expeditions. He has worked in multidisciplinary and multi- national teams for biodiversity assessment and planning, capacity building, and management of natural resources through stakeholder partnerships, preparation of nomination dossiers of natural sites nominated for UNESCO World Heritage status, and evaluation of the effectiveness of protected area management. Currently, he is a member of the World Commission on Protected Areas and IUCN/SSC Bear, Caprinae, and Galliformes Specialist Groups. He has

published several research papers in peer reviewed national and international journals, and technical reports. Currently, he is Nodal Scientist for the DST National Mission on Sustaining the Himalayan Ecosystem (NMSHE) Task Force on Fauna and Microflora and MoEFCC's National Mission on Himalayan Studies (NMHS) Project on Human – Wildlife Conflict Reduction in the Himalaya through Research, Management and Community Participation.

Dr Satya Prakash Shukla
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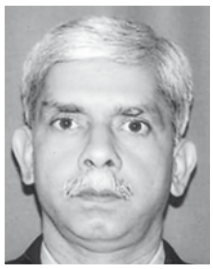

Dr Satya Prakash Shukla has vast experience in the field of snow, ice and glaciers of Himalaya. He obtained his M.Sc. and Ph.D. in Geology from University of Lucknow and joined Geological Survey of India in 1987. During his illustrious career he has visited more than thirty glaciers in the Indian Himalaya and Arctic Region and has participated in fifteen expeditions (including nine expeditions as leader) for glaciological studies. He also participated as member of Indian Scientific Expedition to Arctic - 2008, 2010 and carried out glaciological and geomorphology studies of Arctic region in connection with project on 'Parameterisation of glaciers in Northern hemisphere to variation of climate - inter annual and intra annual'. He has co-authored four GSI publications on glaciers. Dr Shukla has been a regular faculty for Department of Science & Technology/ Science & Engineering Board, sponsored Training Courses in Glaciology and was technical course coordinator of the last four courses organized in 2012, 2014, 2016 and 2017. He is member of several committees including 'Working Group to study the risk of Glacial Lake Outburst Flood (GLOF) at South Lhonal Lake, Sikkim', 'Programme Advisory Committee on Earth & Atmospheric Sciences' (Science and Engineering Research Board), for review of Glaciology related projects and 'Glacial Lake Monitoring and Hazard Assessment' of Central Water Commission.

Dr A. K. Singh,
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Dr A. K. Singh, has an active research interest in fishery resource management and sustainable development; responsible fishery and biodiversity conservation; impact assessment of Introduced Fish Species (IAIFS), sex control of important aquaculture fish species using biotechnological tools for reproductive containment and production of monosex population for aquaculture and ecological security etc. He has served in Department of Fisheries, Government of Uttar Pradesh, Indian Veterinary Research Institute, National Bureau of Fish Genetic Resources and Directorate of Coldwater Fisheries Research. Dr Singh has been conferred with several prestigious awards such as Vigyan Ratanby Government of Uttar Pradesh, Dutta Munshi Gold Medal Award of Zoological Society of India, SZ Quasim Gold Medal Award and several Fellowships from prestigious national and international Societies. He is serving on Editorial Boards of some of the reputed journals. Dr Singh has published over 247 research papers in peer reviewed journals, book chapters, popular articles and also over ten books.

Dr Parmanand Sharma
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Dr Parmanand Sharma, currently scientist at NCAOR, Goa, has pioneered in the mass balance studies in Indian Himalaya to understand glacier–climate inter-relationship. He has taken parts in several scientific expeditions to Himalaya and Arctic. He has used steam drill and Ground Penetrating Radars (GPR) to fix stakes at high altitude glaciers and for understanding the basement topography in the glaciers of Chandra Basin in Lahaul and Spiti district of Himachal Pradesh. Sharma obtained his Masters and M.Phil. in Environmental Sciences from Jawaharlal Nehru University New Delhi in 2000, 2002 respectively, followed by Ph.D. in Glaciology from the

same University in 2008. He joined NCAOR in 2012 as Research Scientist and took over charge of Scientist D in same year. He was awarded CSIR NET (Earth Sciences) in 2011, MCM Scholarship, Jawaharlal Nehru University in 1998 and National Merit Scholarship in 1983. He has published results of his studies on cryosphere in several reputed national and international journals.

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Jawaharlal Nehru University ***sreekesh@mail.jnu.ac.in***

Dr S. Sreekesh is an Associate Professor at the Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi. Prior to this he was Head, Department of Natural Resources, TERI University and Fellow at The Energy and Resources Institute, New Delhi. He has obtained his M Phil and Ph D degrees from the Jawaharlal Nehru University, New Delhi and PG Diploma in Remote Sensing Applications from Indian Institute of Remote Sensing, Dehradun. He is actively engaged in teaching and research in the field of climate change and water resources management. He has expertise in application of geospatial techniques in resource and environment management. He also has vast experience in multi- institutional collaborative research with the support from the national and international funding agencies. He has 23 years of research and teaching experience. He has published 5 books, 14 research papers in national and international journals, 21 chapters in edited books and 17 research reports to his credit.

Dr Uttam Kumar Sinha
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Dr Uttam Kumar Sinha, is a fellow at IDSA and holds an adjunct position at the Malaviya Centre for Peace Research, Banaras Hindu University and an honorary position of a Senior Fellow at the Institute for National Security Studies Sri Lanka, Colombo. At IDSA, he is the Managing Editor of *Strategic Analysis* published by Routledge. A doctorate in International Politics from Jawaharlal Nehru University, his research areas include strategic and security issues, climate change, transboundary water issues and the Arctic region. He is actively engaged in Track-1.5 dialogue process and was India's representative to the CSCAP Working Group on Water Resources Security. Currently on the technical advisory board of the South Asia Water Governance Programme and in a policy advisory role to the International Centre for Integrated Mountain Development (ICIMOD) in Kathmandu, Dr Sinha was a visiting fellow at the Peace Research Institute Oslo (PRIO) in 2006, a Chevening 'Gurukul' Scholar at the London School of Economics in 2008; and a visitor at the Harvard Kennedy School on a Executive Leaders Programme in 2015. His work on the Arctic includes a co-edited volume *Arctic: Commerce, Governance and Policy* (Routledge, 2015) and a monograph *Climate Change narratives: Reading the Arctic* (IDSA, 2014). His publications also include the book *Riverine Neighbourhood: Hydro-politics in South Asia* (Pentagon Press, 2016) among other edited volumes.

Dr Vijay Kumar Soni
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and Polar Meteorological Research Division
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Dr Vijay Kumar Soni has contributed significantly in establishing aerosol monitoring network in India for measurement of aerosol optical properties and estimation of aerosol radiative forcing, which includes Black Carbon Monitoring Network, and Multi- wavelength Integrating Nephelometer Network. He has contributed immensely in setting up a modern Meteorological Observatory that has GPS based Ozonesonde system apart from other modern meteorological instruments at Bharati Station in Antarctica and has been awarded Certificate of Merit by Ministry of Earth Sciences for his outstanding scientific contributions in the field of Atmospheric Sciences. He holds Ph D in Atmospheric Sciences from University of Pune and has worked in various research divisions of IMD since 1998. He is serving as a committee member/reviewer for various national and international agencies/journals. Dr Soni has published about 35 research papers in peer-reviewed journals, 4 Meteorological Monographs and chapters in several books.

Dr Arild Sundfjord
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Dr Arild Sundfjord's work includes studies on long-term moorings linking vertical processes with their driving forces and the resulting impact on biology and chemistry. He has also worked with regional- and local-scale numerical ocean modeling, with the goal of achieving better understanding of fundamental exchange processes in Arctic regions. He is the Principal Investigator of the projects: "Study on the quantification and relevance of interactions and fluxes between sea ice, atmosphere and ocean in the Arctic" and "Sea Ice in the Arctic Ocean, Technology and Systems of Agreements - a Fram Centre flagship project". He is also associated with studies on Arctic climate and environments of the Nordic Seas and the Svalbard - Greenland Area (AWAKE-II), Long-term variability and trends in the Atlantic Water inflow region (A-TWAIN) and Mesoscale modeling of Ice, Ocean and Ecology of the Arctic Ocean (ModOIE) among others.

Dr Ashit Kumar Swain
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Dr Ashit Kumar Swain has contributed to studies on Hamtah glacier of the Himalayan region and imparted training to the trainees of field glaciology course under Department of Science and Technology programme. Apart from his regular field assignments, he also worked in collaboration with Delhi Police and Archaeological Survey of India for specific investigations after Kedarnath tragedy. Dr Ashit obtained his M.Sc. (Applied Geology) from University of Allahabad and Ph D (Geology) from Ravenshaw University. He was engaged in research at Indian Statistical Institute, Kolkata on structural and petrological studies of rocks of Eastern Ghats and continued his research on Granulite Terrain in South India (SGT) after joining Geological Survey of India (GSI) in 2001. He worked at Indian Institute of Technology (IIT), Kharagpur as a young scientist under DST scheme to carry out AMS studies on the rocks of SGT. He joined Antarctic Division of GSI in 2006 from where he conducted geological, geomorphological and glaciological investigations in and around Schirrmacher Oasis, East Antarctic. Dr Ashit participated in 27th, 29th, 30th, 32nd and 34th Indian Scientific Expedition to Antarctic which included a wintering expedition. He was a member of the 1st Indian Scientific Expedition to South Pole in 2010. Dr Swain also participated in the Indian Arctic Expeditions of 2011 and 2014 and is a recipient of Youth Inspiration Award.

Dr Renoj J. Thayyen
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Dr Renoj J. Thayyen is a scientist at National Institute of Hydrology, Roorkee and has 25 years of research experience in Himalayan cryosphere and hydrology. He has worked on various aspects of Himalayan environment including glacial runoff and downstream impact, glacier mass balance, glacial chemistry, sediment transfer, mountain meteorology, extreme events and floods. Dr Thayyen's work focuses on

generating field data on snow, glacier, permafrsot and weather from data sparse regions of the higher Himalaya, especially Ladakh, following a glacier catchment research strategy proposed by him. He has established a couple of long-term research stations in the Indus and Ganga basins.

Dr Manish Tiwari
Scientist
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Dr Manish Tiwari is working in National Centre for Antarctic & Ocean Research, Goa as a Scientist since 2006 with a research interest in the application of stable isotopes of light elements and geochemical proxies to understand the dynamics of the past climatic changes including the Arctic region. He did his Ph D at *Physical Research Laboratory*, Ahmedabad where he worked on marine sediment cores from the Arabian Sea to document the past variations in the intensity of Indian monsoon using isotopic variations in planktic foraminifera. Based on his Ph D work, he was awarded the "Young Scientist Medal" of the *Indian National Science Academy* in the year 2009. He has also received the "Young Scientist Award" of the "Indian Science Congress Association", at the 94th Indian Science Congress at Annamalai University in 2007 and 'Certificate of Merit' in the field of Ocean Science and Technology by Ministry of Earth Sciences in 2012. He has participated in several expeditions to Arctic and various research cruises including international programmes like IODP (International Ocean Discovery Programme). He has published around 45 peer-reviewed research papers in highly rated international and national journals.

Dr Sarat Chandra Tripathy
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Dr S C Tripathy's major research interests includes phytoplankton productivity, bio-optics and bio-physical interaction studies to understand the ocean biogeochemistry. Since 2011 he is working as a senior scientist with the Ocean Sciences Group of NCAOR. He obtained his Ph D in Marine Biology from Berhampur University/NIO, India in the year 2005; and subsequently obtained D.Sc. in Earth and Environmental Sciences from Nagoya University, Japan during 2011. Before joining NCAOR, he was carrying out post doctoral research in Nagoya University, Japan. He has over 18 years post-M.Sc. research experience and has published his research findings in several peer-reviewed journals and scientific/technical reports. Presently he is working towards understanding the productivity potential and biogeochemistry of the Indian sector of Southern Ocean and Arctic waters by actively involving in the scientific expeditions to the polar waters. His previous research interests include study of harmful algal blooms, phytoplankton biomass/productivity, ocean color remote sensing, nutrient dynamics in estuarine and coastal environment. Dr Tripathy is the national representative of the Scientific Standing Group-Life Sciences for the Scientific Committee on Antarctic Research (SCAR).

Prof. (Dr) Narendra Tuteja
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Visiting Scientist
International Centre for Genetic Engineering and Biotechnology (ICGEB)
New Delhi

Prof. Narendra Tuteja is known internationally for reporting the first DNA helicase from plant and human systems. He discovered novel roles of Helicases, G-proteins, Ca2+ -binding proteins & Lec RLK in abiotic stress tolerance in plants; developed salinity/drought stress tolerant rice, groundnut, sugarcane etc. His group isolated number of genes for high salinity stress tolerance from plant and fungus P. indica. He also

developed marker-free transgenics ready for field trial. His results indicate the potential for improving crop production at suboptimal conditions. Prior to joining ICGEB, he held the position of Professor & Director, Amity Institute of Microbial Technology, Amity University, Noida (UP) and Senior Scientist at ICGEB, New Delhi and ICGEB, Italy. He is elected fellow of FNA; FNASc. FASc.; FNESA; FNAAS; FTWAS and has been decorated with several awards, some of which are: Excellence Award 2016 by International Multidisciplinary Research Foundation, Vigyan Gavrav Samman by U.P. Government, Best Scientist Award by the International Board of Awards of National Environmental Science Academy, and Genomic Pioneer Award. He has authored more than 334 research papers in reputed journals including those in Nature Genetic.

Dr Einar Vegsund
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Dr Einar Vegsund is a Naval Architect educated from the Aalesund University College (now NTNU). Einar served two years in the Royal Norwegian Airforce as maintenance officer for the F-16 Fighting Falcon in the period 1989-1991. Einar Joined Rolls-Royce in 1993 (former Nordvestconsult and later Vickers-Ulstein Marine) and worked as a project engineer and naval Architect in the company. In the period from 1993-2000 he was mainly involved in ship stability calculations, hull design, R&T projects and general Naval Architecture for a wide range of vessel types. In 2001, Einar was appointed Design Manager for the Fish and Special Purpose Vessel segments leading a team of naval Architects and Hydrodynamics in developing the next generation Rolls-Royce ship designs including the extensive design process for the oceanographic polar research vessels 'Kronprins Haakon' and RRS 'Sir Davis Attenborough'.

Rapid Shots Session Speakers

Amir Khan
Research Scholar, Delhi University

Shri Ankit Pramanik
Research Scholar,
NPI

Shri Deepak K Chaudhary
Research Scholar,
School of Environmental Sciences, JNU

Ms. Neelu Singh
Research Scholar,
NCAOR

Shri Nikhil Pareek
Research Scholar,
Department of Defence and National Security Studies, Panjab University

Shri Prashant Pandit
Research Scholar,
The Energy and Resources Institute

Shri Rupendra Singh
Research Scholar,
Sharda University

Shri Sathiyaseelan R
Research Scholar,
Indian Institute of Technology, Delhi

Ms Seema Rani
School of Environmental Sciences, JNU

Dr Shridhar Jawak
Co-ordinator Session
National Centre for Antarctic and Ocean Research

Shri Sourav Chatterjee
Scientist,
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Shri Virendra Bahadur Singh
Research Scholar,
School of Environmental Sciences, JNU

Participants

Shri A K Bhandari
Former Director, GSI and Adviser, FIMI, New Delhi

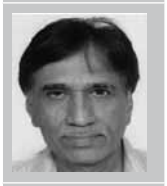
Shri C P Goyal
Joint Secretary, Department of Bio-Technology

Dr B R Arora
Former Director, Wadia Institute of Himalayan Geology

Shri Gautam Dasgupta
Former Deputy Director General, Geological Survey of India

Dr Hari Singh Saini
Former Director, GSI, Dean, Lingayas University, Faridabad.

Shri J K Bhalla
Former Director, Geological Survey of India



Shri K P Verma
GSI
Former Director, Geological Survey of India

Shri K. D. Jos
Sr. Tech Officer, Central Institute of Fisheries Technology

Dr. Praveen K. Thakur
Sc./Eng., SF,
WRD, IIRS (ISRO)
Dehradun

Dr M P Wakdikar
Scientist G, Ministry of Earth Sciences

Dr. Garima Gupta
Scientist,
Department of Bio-Technology

Shri Kuldeep Kachroo
Former Director,
Geological Survey of India

Dr M K Rao
Legal Consultant (ED),
Ministry of External Affairs

Shri R K Khorana
Former DG,
Geological Survey of India

Shri R K Sharma
Fmr Advisor, Ministry of Earth Sciences

Dr S C Garkoti
Professor SES,
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Shri Kamal Kazim
Former Director,
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Dr S K Roy Bhowmik
Scientist 'F', Indian
Meteorological
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Shri Rahul Saxena
Scientist 'E', Indian
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Dr D R Pattanaik
Scientist 'E',
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Shri Gajendra Kumar
Scientist 'E',
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Dr S D Kotal
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Dr P S Biju
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Fmr Director, Adhunik
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C

THE DISCOURSE

The SaGHAA IV 2017

Chairs: Dr Shailesh Nayak, Distinguished Scientist & Fmr Secretary, MoES; Dr K J Ramesh, DGM, IMD

	M. Ravichandran, Director, NCAOR, Goa	**Present and Future directions of Polar research by India**	**Climate change is a topic of worldwide concern and the impacts of global warming are felt first and most severely at the Polar Regions. To understand the role and response of the cryosphere in climate change, Ministry of Earth Sciences established the National Centre for Antarctic and Ocean Research (NCAOR) at Goa. The prime objective of NCAOR is to plan, promote, co-ordinate and execute scientific research in all three poles (Antarctic, Arctic and Himalaya) and its surrounding oceans. The present status of India's polar research activities on various themes such as atmospheric, cryospheric, oceanic, biological and solid earth sciences, in all three poles, including future directions will be presented. Also, the key scientific questions to be addressed by India from India's Polar research will be presented. Augmenting Polar research vessel, Renew/Build new Maitri station, strengthening observations in all three poles, Implementing southern ocean sea-ice modeling and Arctic regional ocean model, reconstruction of high resolution past climate from Antarctic/Arctic/ Himalaya sediments and Ice core, Understanding the variability and physical processes of the ocean and sea ice, tele-connection between poles and tropics, are some of the key areas where India will focus in the future.**

Ishmohan Bahuguna
Scientist
G, Space Applications Centre, ISRO

Observing Himalayan and Polar cryosphere through Indian satellites

Constituted of global snow and ice, Cryosphere, is one of the most important components of Earth system. Globally, it governs the terrestrial and oceanic radiation balance that regulates the eustatic level. Regionally, mountain snow and glaciers are of paramount significance to human life as they hold large reserves of fresh water which sustain the civilizations world over. Perennial Himalayan snow and glacier melt is the source of freshwater for South Asian countries supporting irrigation, hydropower and drinking water demands. Due to their sensitivity to variations in the temperature, all cryospheric elements are treated as sensitive indicators of climatic variations. Therefore, monitoring the cryosphere is of essence to understand the ever changing global climatic patterns. Owing to the areal expansivity, rugged terrain, remoteness in terms of accessibility and largely hostile weather conditions, only sparse in *situ* measurements are available for such regions. Monitoring from ground is evidently arduous, thus, in such a scenario, remote sensing becomes the *ipso facto* choice for monitoring and understanding the variability in various cryospheric phenomena and it is to this end that data from suitable sensors on-board various satellites are utilized.

Space Applications Centre (SAC), ISRO, Ahmedabad has been contributing to the development of techniques for the extraction of relevant information and its dissemination in the form of maps and products of snow, glaciers, ice sheets and sea ice derived from earth observation data acquired by sensors onboard Indian satellites for more than past two decades. The Centre has been instrumental in generating a colossal amount of digital database and maps that highly aid in comprehending the state of Himalayan and Polar cryosphere.

Chief contributions made towards investigating Himalayan cryosphere are:

			Chief contributions made towards investigating Himalayan cryosphere are: **• Creation of Himalayan glacial inventory using AWiFS data,** **• Development of Himalayan glacier information system (HGIS),** **• Monitoring and analysis of Himalayan snow cover utilizing AWiFS data,** **• Monitoring the variations in glaciated area based on LISS III and LISS IV sensors,** **• Extraction of variations in glacier zones from Indian Radar RISAT SAR data** **• Monitoring of glacial lakes, and** **• Extraction and analysis of glacier ice velocity using LISS III, LISS IV and SAR data.** **In Polar cryosphere, the major contributions are:** **• Monitoring of polar sea ice using Scaterrometer data,** **• Monitoring of ice shelves using multisensor data and** **• Monitoring the surface elevation of continental ice using SARAL /AltiKa data.** **The studies are planned to be continued using data from sensors onboard forthcoming missions so that long term database is utilized by large scientific community.**

	E.N. Rajagopal, ESSO-NCMRWF, MoES	**Polar Sea-Ice Simulation with a Coupled Model at NCMRWF**	**Numerical simulation of weather and climate has advanced significantly in the last two decades. With the advent of satellite data and high performance computers, now it has become possible to include the large-scale processes of the atmosphere, oceans, land-surfaces and the cryosphere including the polar sea-ice of Arctic and Antarctic regions into high resolution numerical global simulation models. These high resolution coupled earth-system models are able to capture the short-term climate variability including the polar sea-ice in a reasonable way. However, for south-Asian summer mean monsoon rainfall (variability) simulation and its tele-connection with many other remote atmosphere/oceanic parameters is still a challenge to the modelling community. Recent studies suggest a strong link of monsoon rainfall variability to polar sea-ice processes. Reduction of Arctic sea-ice in recent years is another cause of concern to the climatic community. Its possible link to the south-Asian monsoon has to be studied for a realistic prediction of monsoon rainfall in extended and seasonal time-scales.** **At NCMRWF a state-of-art coupled HadGEM3AO model has been implemented and is being run in real-time for polar prediction. A version of the model is used to study the quality of sea-ice simulations for Polar Regions at seasonal time-scales. The global coupled model has UM, NEMO, CICE and JULES as the respective sub-models for the atmosphere, oceans, sea-ice and land surfaces respectively. Using several years of hindcast data from this coupled model the sea-ice simulation for Arctic and Antarctic regions are evaluated against observed estimates from satellites. The model simulates the mean sea-ice concentration, extent and thickness in both the poles in a realistic way. The simulation of inter-annual variability of sea-ice is also seen to be realistic. The model has the potential to be used as a prediction model for sea-ice related parameters for both Arctic and Antarctic regions in real-time for short-term climate forecast. Results from real-time runs will also be presented in the workshop.**

	R. Ramesh, National Institute of Science Education and Research, Bhubaneswar	**Identifying meltwater signatures in Polar Regions using oxygen isotopes**	**Global warming and the consequent melting of the Arctic ice at an alarming rate is well documented. Though satellite pictures are available from which the ice loss, both seasonal and annual, are estimated in the Arctic, independent confirmation of these estimates would be useful. Stable oxygen isotopic ratio δ18O, measured as deviations in part per thousand (or per mil, ‰) from that of a standard such as Standard Mean Ocean Water (SMOW) is a well known useful tracer in snow hydrology. It can be used to quantify the extent of snow/ice melt in the Polar Regions, to corroborate the ice loss measurements made from satellites.** **In this talk I explain how this is done and present some examples from the Arctic and the Himalaya. Basically, ice/snow melt reaches the surrounding oceans and reduces the surface salinity and also the δ18O, as the freshwater in the Polar Regions is extremely depleted in 18O. Therefore the linear relationship between the salinity and the δ18O of the surface ocean changes. We have developed a theoretical model through which we can quantify the changes in the slope and intercept of the salinity-δ18O relationship of the surface ocean. We explain this model and also use it to calculate the meltwater flow into the Bay of Bengal from the Himalaya and also the Arctic. We believe that this is a useful method to complement satellite data.**

	Nalan Koc, Norwegian Polar Institute Tromso, Norway	**Changing Arctic sea-ice regime: regional and global consequences**	**The Arctic Ocean is changing profoundly and shifting to a new regime, where younger and thinner ice packs are replacing older, thicker sea ice. These changes will have regional and global consequences. In order to gain knowledge to understand the system in its current condition and to improve our capacity to predict its future, the Norwegian Young Sea Ice Cruise (N-ICE2015)* was launched for 5 months starting in January 2015. One hundred scientists from institutions in more than ten countries studied air-snow-ice-ocean interactions in a region with thin sea ice. The scientists also investigated how the marine ecosystem responds to these new conditions. Temperatures in the Arctic are increasing twice as fast as the global average, and the most rapid warming is recorded during the winter months. Arctic sea ice grows and thickens during fall and winter and therefore warmer winter air temperatures may further impede ice growth and expansion, accelerating the effects of global warming in the Arctic. Results from new studies elucidating the frequency and duration of Arctic winter warming events will be presented. Regional patterns of the trend in extreme cyclones will be related to sea-ice conditions of the recent years, as well as to large-scale atmospheric circulation changes.** ***http://www.npolar.no/en/projects/n-ice2015.html**

	Parma Nand Sharma, Lavkush Kumar Patel, Ajit Tapendra Singh, Thamban Meloth and Rasik Ravindra, ESSO-National Centre for Antarctic and Ocean Research, Goa	**Glacier response to climate in Arctic and Himalaya during twenty first century: a case study from Svalbard, Arctic and Chandra basin, Himalaya**	**Glaciers are widely known as one of the best indicators of climate change. Arctic and Himalaya both are abode of densely distributed snow and ice cover other than Antarctic and Greenland. The Arctic covers an area of 14.5 million km^2. Out of this, Svalbard glaciers and ice caps cover about 34600 km^2 with a total ice volume of roughly 7000 km^3. The Himalaya which covers 38000 km^2 area, includes Chandra basin glaciers that are spread over 706 km^2 area with ice volume of around 28.3 km^3. Himalayan glaciers are unique in many respects and in view of their socio economic importance and complex environmental settings. For the past one and half decades, the process of glacier retreat has enhanced in the Himalayas.** **Arctic glaciers and ice caps play an important role in the global climate system. In spite of the Arctic and the Himalayas having contrasting climate set ups i.e. high latitude and low latitude glaciated regions of Northern Hemisphere respectively, the glaciers here have been experiencing enhanced melting during recent years. The climate response of a large fraction of glaciers of Arctic and Himalayan regions is linked with atmospheric changes and oceanic circulation. While atmospheric changes are one of the main influencing factors for Himalayan glaciers, the ocean-atmosphere coupled system significantly influence Arctic glaciers. Snow and glaciers melting in Arctic has enhanced essentially due to large temperature changes, changes in sea ice cover, atmospheric flow patterns and precipitation. Ocean circulation close to fjord modulate melt rates of marine-terminating glaciers all over the Arctic.** **The mass balance data from both the region are used to address how rapidly these glaciers are adjusting to changing climate. The mean annual mass balance of Chandra basin and Svalbard Arctic are -0.67±0.14m w.e. and -0.36±0.02 m w.e. during last one and half decades, respectively. Artic glaciers and ice caps have been losing more glacier mass than Himalaya in total but melting rate of Himalayan glaciers is significantly higher than Arctic.**

			There has been a gradual warming with an apparent stronger trend observed in both the regions during the last one and half decades. The temperature trends are more pronounced for the winter seasons than for the summer seasons. This seasonality in climate change has been observed over most of the Himalayan and Arctic Region. Data revealed that the majority of the glaciers and ice caps of Arctic and glaciers of Himalaya are in a state of instability and their volume may significantly reduce if the climate stabilizes at its present state.

	Rasik Ravindra, Former Director, National Centre for Antarctic and Ocean Research, Goa	**Polar Regions and the Climate Change scenario**	**The snow, ice and glaciers act as sensitive thermometers recording the fluctuations in the climate. The Polar Regions -Antarctic, Arctic and the Himalaya- are all showing signs of increasing ice mass loss on a decadal scale as a consequence of the average rise of 0.8°C in global temperatures since 1880.** **The temperature warming of 2.5°C observed in the Antarctic Peninsula over the last 40 years has been the largest surface warming on the planet. In response, nearly 90 per cent of the glaciers in this region are in retreat with a succession of ice shelf disintegrations. The increase in surface run off, as a consequence of melting, has damaged the structural integrity of the ice shelves, leaving these vulnerable to collapse. The disintegration of these ice shelves has a cascading effect on the ice sheet dynamics. Recent breaking away of parts of Larsen 'C' Ice shelf in the Antarctic Peninsula in 2017 was preceded by collapse of loss of parts of Wilkins Ice shelf in 2008 and Larsen "B" Ice Shelf in 2002. The ice sheets in the west Antarctic too are also getting eroded (Rignot, 2008) due to ocean warming. Though east Antarctica does not show alarming ice mass loss as compared to Antarctic Peninsula and west Antarctica, but on a regional scale in Antarctica, average change in mass for the period 1992-2011 have been estimated to be -71±53 Gt yr^{-1} (Sheherd, 2012). There has been an increase in the rate of ice loss at 21±2 Gt yr^{-1}, (Rignot, 2011).** **The scene in the Arctic is more alarming with Arctic sea ice extent, both perennial and multi-year sea ice, showing decrease in every successive decade since 1979. As per a report of the NSID, the Arctic lost 37,000 Sq km of ice, each day, in just first ten days of June last year. The elastic response of the crustal deformation in terms of uplift rate, as measured in Greenland also confirms the Arctic ice loss (Khan, 2010).** **In the Himalaya, though the terminal snouts of some big glaciers are reported to have stabilized in last decade, but the picture for smaller glaciers is different. The loss of ice mass in glaciers throughout the 2,400 km long Himalayan Belt extending from Hindukush to Myanmar in the east, is continuing unabated.**

Chairs: Group Capt (Rtd.) Rajiv Mehajan, Dr Gopal Iyengar, Advisor, MoES

	R. Krishnan, T.P.Sabin, H.K. Madhura, R.Vellore, M. Mujumdar, J.Sanjay, S. Nayak and M. Rajeevan, Indian Institute of Tropical Meteorology, Pune	**Understanding non-monsoonal precipitation response in the Karakoram and Hindu Kush Himalayas to climate change**	**Winter-to-early spring precipitation in the western Himalayas (WH) primarily comes from eastward propagating weather systems from the Mediterranean region commonly known as western disturbances (WDs). Observations indicate that the frequency of precipitation extremes in the WH has been on a rise during the recent decades. Further, it is also reported that non-monsoonal winter precipitation is crucial for protecting the Karakoram-centered WH from significant snowmelt under warming climate. Yet, the large-scale dynamical controls on the non-monsoonal wintertime precipitation response to climate change are largely unclear. This issue is examined in this study using long-term high-resolution climate change simulations with and without anthropogenic forcing elements (i.e., GHG, aerosols, land-use / land-cover change). The present results indicate that the rising trends in surface temperature over the Himalayan region during the 20th century are largely attributable to anthropogenic effects. It is also seen that the rising trend of simulated precipitation extremes over the WH region concur with enhanced amplitude variations in the WD activity in response to changes in the background upper-level subtropical winds and mid-tropospheric temperature gradients over the Tibetan highlands. It is interesting to note that the high-resolution simulation which includes anthropogenic forcing showsenhancement of WD activity and associated snowfall amounts in the high elevations of the Hindu Kush and Karakoram rangesin the WH, although a declining tendency of snowfall is noted in the central and eastern Himalayas associated with increased surface warming.**

	A P Dimri, Prof. School of Environmental Sciences. JNU	**Indus: Climate and Water Budget**	**The Indus river basin (IRB) in the western Himalayas is an important basin for its inhabitants. It has many ramifications for the local socio-economic sector, stakeholders, cattle, fodder, water security, etc. There are studies from paleo- to present climate scales over this region. In the present work, discussion is provided on the changing climate and its impact on the water budget. For this, model outputs from regional climate models (REMOs) coupled with the MPI-ESM-LR global model are used for the present (1970 - 2005) and future (till 2099) under 2.6W/m^2 and 8.5 W/m^2 representative concentration pathways (RCPs). It is distinctly seen that there is likely increased precipitation over upper (and decreased for lower) IRB. Heterogeneous warming is depicted over the region. These changes in basic climate variables will have a huge impact on the corresponding water budget. Higher (lower) evapotranspiration over the lower (central) IRB raise serious concerns about water issues. Linkages with corresponding snowmelt, runoff and total water budget indicate depleting water over the southern IRB. Such a situation will put this region in a very precarious situation in the coming future.** **Key Words: Indus River Basin, Climate, Western Himalayas, Water Budget**

	S C Kar, National Centre for Medium Range Weather Forecasting, Noida	**Dynamic Downscaling of Climate over the Himalayas**	**Snowfall and snowmelt over the Himalayas exhibit considerable interannual variability. Observed climate data are few over the inaccessible regions of the Himalayas (especially western Himalayas). Consistency of satellite derived snow data with that of atmospheric re-analysis data has been studied and mechanism of snowfall and snowmelt variability has been studied over the western Himalayas.** **Characteristic similarity and differences of the climate variability over Karakoram region with that of adjoining Jammu and Kashmir and Himachal Pradesh has been studied. Dynamic downscaling simulations have been carried out using a regional climate model (RegCM) and the high-resolution WRF model. Sensitivity of cloud microphysics schemes in the WRF model indicates that a proper choice of microphysics scheme allows simulation of snowfall over the high mountain top or on the slopes. This study has been extended to examine the climate of the Himalayas in the climate change era.** **The surface hydrology model (SWAT) has been used to simulate streamflow due to snowmelt and rainfall in Sutlej River and the need for observed data in the basin has been highlighted.**

	V. K. Soni, M. Sateesh and Sanjay Bist, India Meteorological Department, New Delhi	**Meteorological and Ozone studies at Indian Stations in Antarctica**	**The study of the climate of Antarctica and its role in the Earth system is critically important as the region experiences change that can have global implications. The climate of the continent and the surrounding ocean are closely coupled to other parts of the global environment by the oceans and the atmosphere. Subjects of immediate interest are forecasting of weather and climate and understanding the effects and likely impacts of climate change. India Meteorological Department is taking part in Indian Scientific Expeditions to Antarctica since the very first expedition i.e. 1981-82. The meteorological data collected at Maitri station for the period 1990-2015 have been analyzed. The long term analysis of temperature records showed a slight cooling trend at Maitri station. The trend analysis of pressure, wind and blizzards during the period 1990-2015 is also analyzed. Recently, the India Meteorological Department has established manned permanent meteorological observatory at Bharati station with the objective to collect data on meteorological parameters, solar radiation and ozone so as to understand the Antarctic atmospheric processes and dynamics. WMO has enlisted Meteorological Observatory at Bharati, and assigned WMO Index number 89776. A GPS-based ozonesonde system has also been installed at Bharati for measurement of vertical profile of ozone. The recent results of vertical distribution of ozone and ozone hole have been analyzed.**

	K Satheesan, Department of Atmospheric Sciences, Cochin University of Science and Technology, Cochin	**Variability of the vertical and horizontal winds in the Troposphere observed by the Movable Atmospheric Radar for Antarctica at Maitri**	**Continuous sounding of the troposphere by the wind profiling radar, Movable Atmospheric Radar for Antarctica (MARA), at Maitri, Antarctica, since the beginning of 2014 provides a unique dataset to study the mesoscale wind field of the mid-troposphere over Maitri. Since the radar measures a time series of vertical profiles the term 'mesoscale' is used here to refer to the duration of the events which are of at least 1 h.** **Even though the data is available from 2014 onwards, there are gaps in the observations due to many reasons. However, wind observations are available for every month. A statistical analysis of vertical and horizontal air motion has been performed for data taken in the 1-10 km altitude range during the period. The variability of velocities is analyzed as a function of month, time of the day and synoptic weather conditions. The wind speed data generated from this data set is used to identify the strong wind events in the troposphere. The location of the peak winds of these features show these to be mainly warm sector and cold frontal in nature, with a number of tropopause folds. Wind roses are used to identify the prevailing wind direction.** **We present here the results of these analysis.**

H S Negi, Ritesh Kumar, Neha Kanda and N K Thakur,
Snow & Avalanche Study Establishment, Him Parisar

Spatio-temporal variations in land surface temperature (LST) using MODIS data in East Karakoram Himalaya

Surface temperature on glaciated terrain which controls the melting rate of snow and glacier ice is directly governed by the heat budget at the glaciated surface. An understanding of surface temperature is therefore crucial for studying the impact of climate change on glaciers which are considered sensitive indicators of climatic variability. The Karakoram Himalayan region, often termed as the 'Water tower of Asia' is source of many perennial rivers since large glacial masses exist in this region other than those present in the Arctic and Antarctic. Our study area viz. Shyok Basin, East Karakoram region lies in Indian territory, and interestingly Siachen Glacier, which is the longest in the Karakoram range and the second longest glacier in the non-polar regions of the world lies in this part only.

Thermal remote sensing data has the potential to provide spatial and temporal land surface temperature (LST). In this study, spatio-temporal variations of LST over Shyok Basin during 15 years (2001-2015) were analyzed using MOD11A1 LST product data of MODIS. The data was analyzed at different temporal resolutions viz. monthly, seasonal and annual basis for complete Shyok basin as well as for glaciated and non-glaciated terrain to study the prevailing temperature trends in the respective regions. The study shows that the estimated mean annual, winter and summer LST is approx. 2.2 ^{O}C, -7.8 ^{O}C and 12.1 ^{O}C respectively for entire Shyok Basin. Further, for glaciated regions, estimated annual, winter and summer mean temperature is -7.5 ^{O}C, -16.3 ^{O}C and 1.1 ^{O}C respectively. Whereas, for non-glaciated regions, the estimated annual, winter and summer LST were found to be 4.3 ^{O}C, -6.0 ^{O}C and 14.5 ^{O}C respectively. The inter-annual variability of LST over different parts of Shyok basin was studied and anomaly maps of LST were also generated. Short term trends (2001-2015) of LST over glaciated and non-glaciated regions in Shyok Basin depict warming. To ascertain the reliability of MODIS derived LST in representing the temperature trends over Shyok basin, the retrieved LST trends were also compared with field observed air-temperature data.

			Since glaciers are very sensitive to temperature fluctuations, the observed warming trends in LST have also been linked to rising number of glacier lakes during 2002-2014. In addition, maximum number of lake formation was observed in the altitude range of 5000-5500 m, which could be due to the fact that since maximum ablation zones of glaciated areas lie in this altitude range, and rising LST especially during the months of July and August months manifests itself in form of enhanced glacial melt. This study has further scope to assess various glaciers' hazards in the region like earth flow, snow & ice avalanches and variations in glaciers. **Keywords: Land surface temperature, MODIS, MOD 11A1, Karakoram Himalaya**

Dr Akhilesh Gupta, Head, SPLICE, DST and Dr Malti Goel, CEO, CCRS

	Akhilesh Gupta and Nisha Mendiratta, Climate Change Programme, SPLICE Division	**Addressing S&T Capacity Building in Climate Change for the Indian Himalayan Region: DST's Initiatives**	**The Himalayas is the largest and tallest mountain range in the world, bordering 8 countries and is the origin for 9 major perennial rivers. Nearly 1.5 billion people depend on the Himalayas for water, food and energy. The Indian Himalayan Region (IHR) consists of 10 Hilly States viz., Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and two partial hill states - Assam and West Bengal. Nearly 50 million people reside in the IHR alone.** **The Department of Science & Technology is implementing the National Mission for Sustaining the Himalaya Ecosystem (NMSHE) as part of National Action Plan on Climate Change to develop an understanding of the complex processes affecting the Himalayan Ecosystem and evolve suitable management and policy measures for sustaining and safeguarding the Himalayan eco-system, creating and building S&T capacities in different domains, networking of knowledge institutions engaged in research and development of a coherent data base on Himalayan ecosystems, detecting and decoupling natural and anthropogenic induced signals of global environmental changes in mountain ecosystems, etc.** **A number of programmes have been launched as part of the mission initiative. These include; the establishment of a Centre of Himalayan Glaciology; Thematic Task Forces anchored around 6 lead institutions, State climate change (CC) Cells in 11 out of 12 Himalayan States; Human capacity building programmes in glaciology under Indo-Swiss collaboration, etc. The paper presents outlines of programmes initiated so far, outcomes from these programmes and the new initiatives planned and the vision for the future.**

	Susheela Negi & Rabindra K Panigrahy, SPLICE, Department of Science & Technology	**Assessing Vulnerability and Risks due to Climate Change for the Indian Himalayan Region (IHR)**	**The Indian Himalayan Region (IHR) like other ecological regions of the world is facing significant challenges while dealing with the adverse impacts of climate change.The Indian Himalayan Region is impacted by climate change in terms of its socio-economic, biological and geophysical systems that include agriculture, hydro-geological resources, forests, biodiversity, food, energy, health, tourism and livelihoods. The vulnerability and risk associated with these sectors and communities vary across the region depending upon the degree of susceptibility and the ability to cope with the adverse impacts. In order to address adaptation needs and to reduce the vulnerability of the communities living in potentially affected regions, the National Mission on Sustaining Himalayan Ecosystem (NMSHE) being implemented by the Department of Science and Technology (DST) is targeting integrated vulnerability and risk assessment covering the Indian Himalayan Region (IHR). The assessment will serve as an important basis for prioritizing, planning and implementing adaptation measures at the district or sub-district level.** **DST has established State Climate Change Cells (SCCCs) in 11 out of the 12 States of the Indian Himalayan Region for implementing NMSHE related State CC Action Plans. One of the major objectives of these SCCCs is to assess vulnerability and risk at the sub-district level and develop seamless pan Himalayan vulnerability maps.** **The paper presents DST's efforts to develop a framework of vulnerability assessment for the IHR and initiatives to build capacity and create public awarness at the State level.**

	S.K. Nandi and R.S. Rawal, G.B. Pant National Institute of Himalayan Environment and Sustainable Development	**Need for reorienting climate change debate in the himalaya-balancing the approach**	**The Himalayas, the youngest but highest mountain system, that acts as (i) Store house of snow and ice more than anywhere else in the world, outside the two poles, (ii) Provider of large volumes of freshwater to the people in Indian subcontinent, is popularly described as 'The Third Pole' of the world. It is characterized by a complex geological structure, snow capped peaks, large valley glaciers, deep river gorges and rich biological diversity. Broadly the Himalayan region, encompassing the Hindu Kush mountains and Tibet region of China, spans over an area of more than 4.2 million km^2. Ten major rivers of the world originate from the Himalayan region, and drain a large part of Asia thereby making it a crucial ecological entity in the region.** **Climate change (CC) is a major global environmental challenge with implications on food production and security, fresh water supply, health, forests and biodiversity, and the overall environment. Projected studies indicate that Himalayan forests, and alpine grasslands including that of Indian Himalayan Region (IHR), can be very sensitive to CC. The region is likely to warm more rapidly, thus affecting the life and livelihoods of the people and stability of the region. Studies exhibit consistent trends in overall warming in the region over the past few decades, with indications that temperatures are rising at higher rates in higher altitude areas. Model-based projections also suggest that warming will continue for the foreseeable future. Under such a scenario of changing climate, it is expected that the diverse ecosystem components in the region will get affected. This phenomenon has wider implications for human survival both in uplands and lowlands where large populations are dependent on services emanating from the Himalayan ecosystem. In other words there is a need to develop effective strategies and plans for adaptation and mitigation. This requires attention and a balanced thinking at the local to the global level. While at local and national levels, following the projections on change, efforts are being made w.r.t. understanding the impacts, although the intensity and direction of investigations across regions is not uniform.**

			Therefore, the global understanding on CC implications in the Himalaya is heavily influenced by studies/trends emerging from bigger nations in the region. Further, it is most often based on data sets of a particular biome or land form (e.g. Tibetan grasslands) thereby making the other biomes/land forms and dependent communities less represented. As a result the global projections/ scenarios w.r.t. Himalaya remain less applicable for the entire region. This calls for uniform distribution of studies across diverse landforms/biomes so that scenarios become more agreeable. Under the National Mission for Sustaining the Himalayan Ecosystem (NMSHE), as one of the core constituents of India's National Action Plan on Climate Change (NAPCC), studies have been initiated to understand the long term effect on diverse ecosystem components. The G.B. Pant National Institute of Himalayan Environment & Development has been assigned coordination of the task force on 'Forest resources and plant biodiversity' of the IHR. Little information is available on climate data of this region. While some studies have been reported from Hindu Kush Himalayan region, which largely include the Tibetan plateau encompassing grasslands, such information may not reflect IHR scenarios as the latter is vastly forested landscape. Although data sets are being generated under NMSHE, there is a need for a more serious thought process and R&D by Indian Scientists on CC aspects on IHR. Other Institutes may join hands to generate a Pan-Himalayan picture, which should form the basis for adaptation and mitigation strategies in the region.

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Responses of Indian Summer Monsoon (ISM) dynamics and Late Quaternary fluvial development : Records from Yamuna River valley, NW-Himalaya

In the NW Himalaya, Late Quaternary sedimentary deposits along glacial fed Yamuna River offers an opportunity to understand thefeedback mechanism of Glacial-Interglacial cycles to ISM dynamics and resultant fluvial developmentsince MIS-5a (Interglacial). Fluvial terraces and alluvial fans contributes to major landforms along River valley from Higher Himalaya (source area) to Sub-Himalayan and comprises of ~10m upto ~180m thick gravel deposit carved into distinct terrace levels (T-1 to T-7; order of increasing height from modern Yamuna R.). In the present work, the geomorphological and sedimentological studiesand OSL based absolute chronology of these deposits constraintsmultiple phases (Phase-I to IV) of sediment dispersal and accretion in the pre-existing valleypunctuated by shorter incision periods.In the narrow upper reaches of the valley (near present glacier) and in the middle reach (Lakhamandal area), oldest fluvial aggradation (Phase-I) recorded during >83ka to ~80ka (MIS-5a) represented by distinct patches of fluvial deposits (T-7). This older aggradation indicative of limited glacial advance and fluvial (meltwater) sediment transport and deposition of gravel facies followed by incision. Phase-II aggradation continued around ~50ka to ~41ka coincides withMIS-3 (Inter-glacial stage) warm and humid climatic condition and preserved as remnant patch of fluvial deposits (T-6) followed by rapid incision owing to lower sediment: water ratio. During~37ka upto ~23ka,major sediment accretion phase (Phase-III) is recorded in the wider parts of valley (between MBT and MCT) in the form of ~120m thick clast supported fluvial gravel. This phase coincides with transitional MIS-3 & MIS-2 (Interglacial-Glacial transition). The sedimentary facies, accretion geometry suggests deposition under braided river environment. Glacier retreat and release of sediment might have responsible for such extensive aggradation under more sediment water ratio and less sediment transporting capacity of Yamuna River.

			The aggradation phase is carved into distinct degradational terrace levels (T-3 to T-5). Another younger aggradation phase (Phase-IV) represented by discontinuous terrace deposits (T-1 and T-2) is recorded across MCT. The Late Quaternary sedimentary archives in the valley across MCT and correlation of aggradation and incision phases are well correlates with Indian Summer Monsoon (ISM) dynamics (δ18O record), and profound control of glacial-interglacial cycles since MIS-5a.

Dr B Meenakumari, Chairperson, NBA,
Prof C R Babu, CEMDE, DES, DU

	Dr A. K. Singh, Director, DCFR	**Climate Smart Scientific approaches to Manage Himalayan Fishery and Aquaculture, India**	**In the past 20 years, humanity added 1.6 billion people to the planet, while losing 20 per cent of the world's wilderness, and exploiting 90 per cent of the world's fisheries. The Sustainable Development Goals (SDGs) have helped shape a national policy agenda that strives to conserve the country's ecosystems while meeting development priorities. In Indian Himalayan ecosystems, cold water Fisheries occupy an important place amongst the freshwater fishes of India. There are 16 big and small rivers in Himalayan and peninsular regions having an area of over 8,853 km. Apart from these rivers / streams, there are over 20,500 hectares of natural lakes and 50,000 hectares of man made reservoirs. The natural fish populations consisting of over 258 species of several Indian Himalayan rivers including hill streams are declining both quantitatively and qualitatively due to various environmental and anthropogenic reasons. Therefore, to enable sustainable management and utilization of the distinct class of fishes inhabiting the extremely diverse coldwater ecosystems (streams, rivers and lakes) is imperative. ICAR-DCFR has made steadfast progress in its research and development efforts to sustainably manage coldwater fisheries resources and enhance farmed fish production in the Indian Himalayas through scientific innovations, technological refinements/ developments and knowledge sharing in varying agro-ecologies, using available natural resources and farmers-centric approaches. Pursuing these endeavours, the ICAR-DCFR has been working for resource assessment and development of GIS based aquaculture site suitability maps; fish biodiversity maps for major river drainages; assessment of habitat status and fish diversity in selected**

river drainages and lakes. Contributions towards aquaculture development includes captive breeding and larval rearing of food fishes such as *Tor putitora, Neolissochilus hexagonolepis, Scizothorax richardsonii, Labeo dyocheilus, Bengana dero, B. devdevi, Labeo pangusia, and fish species of aquarium interest? such as Naziritor cheilinoides Barilius bendelisis, Chagunius chagunio, Puntius ticto* in controlled conditions; prototype of zero water exchange hatchery for coldwater fishes, especially minor carp and rainbow trout elucidated climate smart approaches on captive gonadal maturation.

To understand mechanisms involved in maturation and breeding, we have characterised aromatase encoding genes; expression profiling of *kisspeptin1* on the BPG axis; while for rearing and developing artificial diets we have detected appetite biomarkers and optimum protein requirement. Looking at the nutritional significance of various coldwater fish species, nutrient profiling of indigenous fishes were carried out. Further, a comprehensive database of pathogenic bacteria was also developed through systematic surveillance of coldwater fish diseases and pathogens. Significant research output in genetics and biotechnology includes the development and validation of fish viral peptide based nano delivery system; development of an inexpensive and robust RACE methodology; characterization of 26 growth and maturation related gene markers in snow trout; hi-throughput profiling of intestinal bacterial community in snow trout; genetic characterization of chocolate mahseer populations; identification of potential gene markers for thermal tolerance in snow trout; transcriptome database of immune response in golden mahseer to counter bacterial infection; and expression of recombinant Mx protein and transfection studies using its promoter for potential reporter gene assays. The paper presents details on the working of ICAR-DCFR to sustainably manage coldwater fishery resources in Indian uplands and to substantially augment hill aquaculture production through comprehensive research initiatives, technological interventions and knowledge transfer mechanisms.

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Enabling Climate Resilient Agriculture in the Indian Himalayan Region

The mighty Hindu-Kush Himalayan (HKH) region extending over 3500 km with an area of 43 lakh km^2 is the source of many perennial rivers like Brahmaputra, Ganga, Yamuna and the Indus; harbours biodiversity hotspots rich in endemic flora and fauna, many of which are listed in IUCN red list; is inhabited by several ethnic communities that have strategic traditional knowledge systems (TKS) and is rich in mineral deposits (i.e. limestone, dolomite, lead, iron, copper, etc.). The Indian Himalayan region (IHR) cover 5 lakh km^2 (11.6 per cent of total HKH region) which is around 16.2 per cent of the country's total geographic area with its rich natural resources providing livelihoods to around 210.53 million people. Reportedly, 80 per cent of the HKH population is dependent on farming for its livelihood, and the traditional societies do observe festivals that mostly are related to agriculture (for example, Hornbill festival of Nagaland, ChapcharKut of Mizoram, Nongkrem Dance festival of Meghalaya, Harela festival of Uttarakhand, etc) which show the bondage of socio-cultural principles with agriculture and agro-ecosystems.

The IHR covers twelve Indian states, namely Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, Manipur, Nagaland, Mizoram, Tripura, Sikkim and Meghalaya) along with the hilly parts of Assam and West Bengal. According to Census of India (2011), 13.73 per cent of India's population lives in the IHR. Further it is reported that 14.58 per cent of India's total rural population lives in the IHR states, which contribute to 8.7 per cent of the country's total agricultural land and 15.68 per cent of total number of estimated agricultural households. The major crops of IHR states are rice, wheat, potato, maize, onion, coarse cereals, bajra, *etc.*, and the average food grain yield of the IHR states is 1680.58 kg/ha, which is lower than the country's average yield i.e. 2984 kg/ha. Nonetheless, IHR states cover 17.16 per cent of total country's horticultural area and 18.56 per cent of the country's total horticultural production that includes fruits, vegetables, flowers, aromatics, spices, plantations and honey.

As far as milk, egg, wool and meat is concerned, the IHR states contribute 6.49 per cent, 9.14 per cent, 24.11 per cent and 15.75 per cent of the country's total milk, egg, wool and meat production, respectively. Further, it is interesting to note that 20.38 per cent of India's total fish production is from the IHR states. According to FIBL & IFOAM Year Book 2015, India ranks 15th in terms of World's Organic Agricultural land as per 2013 data. For instance, Sikkim and Mizoram are declared to be fully organic along with many districts of Uttarakhand.

While the IHR has biological species richness, cultural diversity and topographical variations that manifest an array of climatic variabilities, it still provides ample opportunities for agricultural heritage. Nevertheless, the changing climate scenario impacts the Himalayan ecosystems with a rising trend with extreme warm events, falling trends in extreme cold events, increasing incidences of floods and cloudbursts, irregularity in rainfall patterns, changing flowering and fruiting season of different crops, etc. Eventually, agriculture becomes a vulnerable profession and faces a lot of challenges like small and fragmented land holdings, low productivity, greater human migration from hills, lack of irrigation facilities, off-farm employment opportunities vis-à-vis increased agriculture labour shortage and costs, lack of proper transport and market availability, extreme climatic events (i.e. Kedarnath disaster, 2013, Malpa landslide, 1998, etc.), shifting cultivation in the north-eastern states and most importantly utmost monsoon dependency.

For proper agricultural development in the IHR states, an inclusive approach of integrated mountain development is required that warrants *jhum* re-development, micro-watershed based farming systems, amelioration of acidic soils, micro rainwater harvesting structure, strengthening irrigation facilities, promoting organic agriculture, conservation agriculture, access to climate resilient crop varieties, profitable integrated farming system (IFS) models and also documentation and validation of the traditional knowledge system (TKS) of the local communities to enable and ensure climate resilient agriculture in the IHR.

	Narendra Tuteja, Narendra Tuteja, Visiting Scientist & Former Group Leader, International Center for Genetic Engineering and Biotechnology	**Improvement of crops productivity under climate change**	**Food security could be in danger due to the negative impact of climate change/global warming which may leads to low production; therefore, there is an urgent need to develop climate-resilient crops with no yield loss for future food security. Use of beneficial fungus (root endophyte *Piriformospora indica*) through non-transgenic and transgenic approaches could be one of the best innovative approaches for improvement crop productivity. Through non-transgenic approach P. indica has been found to provide strong growth-promoting activity during its symbiosis with a broad spectrum of plants including mustard, pea, tobacco, tomato, onions, rice, lepidium and medicinal plant Coleus *forskohlii*. Despite its positive impact on the host, little is known about the *P. indica* genes that may be involved in stress tolerance. However, for transgenic approach to improve the crop under stress condition, first high salinity-tolerant genes from P. indica need to be cloned. Recently we have cloned several salinity-tolerant genes from *P. indica* fungus by functional screening, based on random over-expression of a *P. indica* cDNA library in *Escherichia coli* grown on medium supplemented with 0.6 M NaCl. Out of these one of the salinity tolerant genes from *P. indica (cyclophilin; PiCypA)* has been functionally validated for its role in salinity tolerance in bacteria and plant. This gene product catalyzes the inter-conversion of peptidyl prolyl imide bonds in peptide and protein substrates and functions as molecular chaperones. This is also known to be involved in pre-mRNA splicing. Other approaches for crop improvement will be discussed.**

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Assessing impacts of climate change on wild fauna and micro-flora of the Indian Himalayan Region

Climate change impacts on micro-flora,wild fauna, and their habitats in the Indian Himalayan Region (IHR) is less studied. Under the National Mission for Sustaining the Himalayan Ecosystems (NMSHE), field and lab investigations are underway to assess taxa specific species diversity, distribution and abundance,climate change impacts onwild fauna, micro-flora and ecosystem services. This paper presents the details of the recent initiatives and discusses some of the preliminary findings. Bhagirathi Basin (~7000 km^2, Uttarakhand), Beas Basin (~ 3,000 km^2, Himachal Pradesh), and Teesta Basin (~ 5,000 km^2, Sikkim) are the study sites.

Preliminary analysis of climate variables and projections have been carried out for six Himalayan States. A 17 model ensemble was used to project changes in mean annual temperature and annual precipitation for future periods (2050s and 2080s) with respect to the baseline (1960-1990) and for two scenarios RCP45 and RCP85. An increasing warming trend and rising precipitation levels are observed. Geo-spatial analyses and regression modeling were employed to identify the drivers of landscape productivity change in Uttarakhand in three different scales (16km, 4km and 1km grids). At the 16 km scale (n=251) the changes in landscape productivity were driven primarily by precipitation while seasonal extremes of temperature and precipitation were dominant at the 4 km (n=3478) and 1 km scales (n = 53148). Human footprint was found to be one of the primary drivers behind the decline in landscape productivity at all scales.

Research trend and knowledge gap analysis for micro-flora and wild fauna helped to compile>4500 articles into a database for IHR. To obtain the fine scale temperature and humidity records, data loggers (n= 111) have been deployed in the different Basins in every 16 x 16 km grids covering an elevation gradient from 357m to 5000m.

			In Bhagirathi basin, primary information collections were carried out covering an elevation extent from 500m to 5000m. In order to simulate the warming effects on microflora (lichens and soil bacteria) and microfauna (soil nematodes), six Open Top Chambers (OTC) have been deployed inside Gangotri National Park. Inventory and elevation ranges of mammals and Galliformes (camera trapping, n=290), herpetofauna (visual search, n= 108) and odonates (point sampling, n= 220) were updated for Bhagirathi Basin. Household level questionnaire surveys (n= 701, 32 villages) were carried out to document the impact of climate change on ecosystem services. Baseline information on soil bacterial community and Soil Organic Carbon degrading activity were generated. Considerable differences in plant species growth inside the OTCs were observed in the first growing season. Presence of ~100 lichen, eight nematode genera, 85 Odonata, 15 fish, 18 reptiles and 17 amphibians, 9 Galliformes and 40 mammal species were confirmed from Bhagirathi Basin. Changes in rainfall pattern and frequency of human-animal interaction were the major reasons for change in agricultural pattern as perceived by the villagers. The research outputs would provide information for future management strategies in the IHR.

	Renoj J. Thayyen and S.K. Jain, National Institute of Hydrology Roorkee	**Need for a Paradigm shift in the cryospheric research priorities in the Himalayas**	**Snow and glacier melt form a considerable contribution to three major Himalayan rivers: Indus, Ganga, and Brahmaputra in different proportions, and a large population depend on the water of these rivers. The transboundary nature of all the major Himalayan Rivers, which sustain the world's most populous region, ensure constant focus on their waters. The Indian Himalayan Region (IHR) of Ganga and Brahmaputra basins have around 3700 km^2 of glacier cover, whereas upper Indus basin alone has around 7100 km^2 covered by glaciers with large number of big glaciers. Thus the major part of glacier resources of India lies in the upper Indus basin in Ladakh where glacier melt contribution is critical to the downstream flow. Shyok basin alone has the largest glacier ice reserve in the country, which is more than that of the Ganga- Brahmaputra basins put together and is critical for the geopolitical dynamics of the region. However, Indian research efforts in the upper Indus basin is inadequate compared to the efforts in Uttarakhand or Himachal Pradesh.** **Traditionally, cryospheric research is glacier centric in India and the research methodologies we practice are entrenched in borrowed "Alpine" concepts and methodologies. This has led to the undermining of specific characteristics of precipitation dominant "Himalayan catchments" and its unique stream discharge response at its downstream reaches. Observed asynchronous fluctuation of the cryosphere across the region further complicate the Himalayan conundrum. Inadequate level of research and knowledge creation in the Indian Himalayan Region (IHR), which constitutes a major part of the Himalaya, therefore, remains as a major gray area.For most parts of the Himalayas, changes occurring to the precipitation regime may lead to reduced downstream flow and enhanced glacier melt concurrently. This suggests that research on snow cover, permafrost and elevation control on precipitation is critically important for many basins in the Himalayas. The lack of studies are resulting in our inability to fathom a true and clear picture of the climate change response of the Himalayan Rivers.**

			As climate change exacerbates the current challenges in understanding the variability and interplay between snow- glacier-monsoon dynamics in the region, informed decision making is a formidable challenge at present and for the future.It is important to significantly enhance field-based research in these areas for evolving a science-based policy framework for managing the water resources of the region. Data restrictions existing in the Indian Himalayan region due to geo-political reasons is another key roadblock restraining the free flow of knowledge generation. This paper calls for a paradigm shift in research priorities to fill knowledge gaps in the present understanding of the Himalayan cryosphere to facilitate a robust and transparent science based policy framework by the stakeholders in the region.

Chairs: Dr M N Rajeevan, Secretary, MoES;
Dr Ashwagosha Ganju, Director, SASE, DRDO.

	Virendra M. Tiwari & Harika Munagapati, CSIR- National Geophysical Research Institute, Hyderabad.	**Mass variability over Himalayan glaciated region**	**The nature of hydrological seasonality over the Himalayan Glaciated Region (HGR) is complex due to varied climatic and precipitation patterns. We attempt to exemplify the spatio-temporal variation of hydrological mass over the HGR using a time variable gravity field from the GRACE satellite for the period 2002-2014 on seasonal and inter-annual time scales. The mass signal derived from GRACE data is decomposed using Empirical orthogonal Functions (EOF), which allows to identify causes of mass change within HGR and delineate the three broad divisions viz Western, Central, and Eastern, divisions of HGR based on the seasonal mass gain or loss that corroborate with prevailing climatic models. We also find that the Western region registers a different pattern compared to the rest i.e. mass gain of the Hindukush and Karakorum Glaciers. It appears that this mass gain was initiated due to the excessive snowfall in 2005-2008. However, as our results indicate, in spite of dampening of snowfall rates after 2008, mass has been steadily increasing. This is attributed to the lowering and to stabilizing of temperature increases in this region after 2008.**

	AL. Ramanthan[1], Parmanand Sharma[2], Arindan Mandal[1], Thupstan Angchuk[1], Lavkush Patel[2], Naveen Kumar[1], Mohd. Soheb[1], Shyam Ranjan[1], Som Dutta Mishra[1], Sarvagya Vatsal[1], [1]School of Environmental Science, JNU. [2]ESSO-National Centre for Antarctic and Ocean Research, Goa	**Present health and dynamics of glaciers in the Arctic and the Himalayas**	**Glaciers are loosing mass and are in an imbalanced state almost everywhere in the world except for a few regions like Karakoram, Pamir etc. In spite of having less temperature fluctuations annually, the glaciers in the high Arctic are also melting rapidly. In one of the most populated areas of the world, these glaciers are important contributors to streamflow. Around 60 per cent of Svalbard's land area is covered by glaciers. Direct glaciological method has been used for calculating the glacial mass balance and surface ice velocity estimation of the Vestre Broggerbreen (VB) and Feiringbreen glaciers. Surface ice velocity is almost between 2 and 3 m/annum at most of the points. However, there are few points in VB where velocity is much higher than expectations (10-20 m/annum). Ground Penetrating Radar (GPR) survey has been performed to measure ice thickness. The average snow water equivalent (SWE) for the years 2014, 2015, and 2016 was 697.9±185 kg m^{-2}, 603.4±162 kg m^{-2}, and 376.8±172 kg m^{-2} over the VB respectively, while for the Feiringbreen it was 381.9±187 kg m^{-2} in the year 2016.** **Recent studies in the Hindu-Kush Karakorum Himalaya (HKH) region suggest that, the glaciers have lost a significant amount of mass and presently are in an imbalanced state. Here we present the long term annual and seasonal mass balances (MB) and meteorological conditions of Chhota Shigri glacier ("tier-2" type, representative glacier of the region) located in Lahaul and Spiti region, northern India. The glacier has lost mass between 2002 and 2016 (over last 14 years) with a cumulative glaciological MB of -7.72 m w.e. corresponding to a mean annual glacier-wide MB of -0.55 m w.e. a^{-1}. The lower ablation part close to 4425 m a.s.l. (excluding debris-covered area) experienced the highest melting throughout the entire measurement period (since 2002) with cumulative value of ~50 m w.e. Melting at lowest part of the ablation zone is reduced by -1 to -2 m w.e. a^{-1} regardless of its altitude due to the "*debris effect*", which protects the ice beneath the debris-cover from direct solar radiation and the atmosphere at the surface.**

	Dr. M R Bhutiyani, Director, Defence Terrain Research laboratory	**An overview of high altitude warming in the Himalayas: A study based on instrumental records and Land Surface Temperatures (LST) derived from Landsat-5 TM and OLI data**	**The specter of climate change is leading to drastic alterations in the Earth's cryosphere. With reference to the Himalayan Mountains, the analyses of the temperature data collected manually at different observatories during the period from 1866 to 2012 show significant rates of warming during the winter season (1.4^{o}C/100 years) than the monsoon temperature (0.6^{o}C/100 years) due to rapid increase in both, the maximum as well as minimum temperatures, with the maximum increasing much more rapidly. Annual rate of warming (1.1^{o}C/100 years) is abnormally higher than the global rate (about 0.7^{o}C/100 years) during this period. Studies have confirmed significant spatial and temporal variations in magnitude of winter as well as summer warming in different ranges. While windward side of the Pirpanjal and parts of Greater Himalayan and Karakoram ranges have shown statistically significant winter and summer warming, leeward sides of these ranges have not shown much change. The most remarkable finding of this study is the significant decreasing trend experienced at almost all stations above equilibrium line (>5300 m in altitude) in winter warming as well as winter precipitation in higher reaches of the Karakoram Himalayas in last three decades. This is attributed to prevalence of high albedo/permanent snow cover which appears to have influenced the micro-climatology by reduced snow/ice feedbacks. These studies have significant bearing on the mass balance of the glaciers in the region and the hydrological behavior of various river systems in the Himalayas.** **Rising temperatures are also responsible for over-all degradation and reduction of permafrost with respect to its areal coverage and thickness. In order to factor impact of rising temperatures, study with regard to decadal variability in Land Surface Temperature (LST) over Karakoram Himalayas was also undertaken. Landsat 5- TM data, both in visible and thermal bands, have been used to compute land surface temperatures (LST) in the present study.**

			It is inferred from the study that the area experienced a decrease in snow areas with an increase in surface temperature of 0.690K per year. A distinct rise in LST values were found to be for slopes above 30 degrees. Mean LST computed for areas covered with glacier ice below273oK shows upward trend, indicating general rise in ground summer temperatures from 1991 to 2012. Warming-induced permafrost degradation has led to an increase in number of incidences of mass movements, snow avalanches and ice avalanches in the Karakoram Himalayas in the recent past.

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Melting Third Pole: Driving Factors and the Consequences

Glacier behavior in the Himalayas has to be understood and interpreted in light of the multiple driving factors; topography, climate and anthropogenic factors. The observed changes in Himalayan glaciers indicates that the glacier response varies across different ranges. The use of satellite images (1990-2015), DEM, altimetry data supported by selective field campaigns, to map the changes in glacier boundaries, snout, ELA, AAR, volume, thickness, debris cover and several other glacier parameters, show that the glaciers across the six ranges of Pir Panjal (PR), Greater Himalaya (GH), Shamasbari (SR), Zanaskar (ZR), Leh (LR) and Karakorum (KR) showed quite varied changes. It was observed that the glaciers in the KR show the least glacial area recession (1.59 per cent) primarily due to the extreme cold winters with -18oC average temperature. Other glacial parameters like snout, ELA, AAR and glacier volume also showed very little changes in the KR during the period. The glaciers in the LR, with an average winter temperature of -6 ^{o}C, have shrunk, on an average, by 4.19 per cent during the period, followed by the glaciers in the ZR showing a loss of 5.46 per cent. The highest glacier retreat of 7.72 per cent and 6.94 per cent was observed in the GH and SR with the average winter temperature of -1.3 ^{o}C and -6.2 ^{o}C respectively. In the PR (J&K), almost all the glaciers have vanished during the last 6-7 decades due to the increasing winter temperatures. The glaciers in Kashmir showed an overall recession of 26.40 per cent in area which is one of the highest reported in terms of Himalayan glaciers. The glaciers in the valley showed the maximum reduction in thickness (2.56 m) using the IceSat data from 2000-08 while the Karakoram glaciers showed the least reduction in thickness (0.53 m).

Climate change signals are quite loud and clear in the region and the higher rates of recession are due to the significant increase in the observed minimum winter temperatures. In Kashmir, precipitation is falling more as rain than snow due to the warming in winter.

			Further, the concentration of black carbon in the valley is highest compared to the other high altitude stations in the Himalaya (5.9 μgm^{-2}). All these factors are responsible for the decrease in the volume and extent of the glaciers in the Kashmir Himalayas. The streamflow have significantly declined in the upper Indus basin particularly since the 1990s. There is a lack of credible knowledge about a melting third pole as is evident from the contradictory reports about the status of the glaciers in the region. The depleting Cryosphere and the stream flow observed in the upper Indus basin, if not understood in the right earnest, have the potential to complicate the already tense security situation in the South Asian region.

D. P. Dobhal,
Wadia Institute of Himalayan Geology, Dehra-Dun

Climate Change and Glacier Response: Special Reference to the Himalaya

Climate change is causing significant loss of glaciers in high mountain areas of the world. Although glacier systems show a great amount of inherent complexity and variation, there is clear evidence indicating glaciers are retreating. A number of noticeable impacts have already been documented. The most widely reported retreat is the reduction in size (length, area and volume) of glaciers due to the rapid melting. This in turn has short and long-term implications on water storage in the river basins and in various ways is affecting the livelihood of people, flora and fauna. In addition, the continuous recession of glaciers has been inducing fast reduction in their size and many of them (<1 Km^2) may eventually disappear. The reduction in size of the glaciers is also anticipated to have significant impacts on geo-environmental hazards, like snow/ice avalanches, glacial lake outburst floods (GLOF), flash floods, landslides and debris flows. The direct consequences of such processes will also be exaggerated by a variety of direct/indirect effects in mountain ecology.

Glaciers are sensitive to the temperature and precipitation changes that accompany climate change, the rate of their retreat or growth can serve as an indicator of regional and global climate change. In addition, glaciers and snow cover are key components of mountain hydrology and its adjoining areas as well as climate change. Measuring changes in snow cover extent and mass volume of glaciers on an appropriate time scale is a direct way of determining the effect of climate change. Enhanced recession rates of glaciers reported during the recent years has initiated wide spread discussions, especially in context to global warming and its effects on glacier systems. However, the rate of recession and amount of volume change are different from other mountain glaciers of the world. This is mainly due to different magnitudes of climate and topographic conditions. European Alps have lost about 30 to 40 per cent of their surface area and about half of their volume since 1850 (Haeberli and Beniston, 1998). Similarly, glaciers in Central Asian regions have been reported to be rapidly retreating since 1950 (Fitzharris, 1996; Meier, 1998).

			A study of 466 glaciers in Himachal Himalaya also shows that glaciers are receding like the rest of the glaciers in the world (Kulkarni et al., 2007). A study of 466 glaciers in Himachal Himalaya also shows that glaciers are receding like the rest of the glaciers in the world (Kulkarni et al., 2007). This study attempts to investigate change of glaciers for the period from 1962 to 2012 in the Indian Himalayas. The morphological and anatomical changes have been correlated with temporal affinity in relation to length, area and mass/ volume of the glacier. The study reveals that most of the Himalayan glaciers are retreating with an average annual rate of 10 - 20 m. The continuous recession of the glaciers in length, area and mass/ volume are attributed to climatic influence and play an important role in the processes of nourishment and reduction of the glacier.

Amit Dharwadkar,
Polar Studies Division, Geological Survey of India

The Himalayan Saga: Ladakh Chapter

The significance of the lofty Himalayas in the context of the Indian sub-continent cannot be understated. The rise of Himalaya, apart from lending a unique identity to our nation, shares borders with Pakistan, Afghanistan, Bhutan, Nepal, Myanmar and Bangladesh. The 2400 km long rugged mountains between the Nanga Parbat syntaxis in Tibet and the Namche Barwa syntaxis forms a natural barrier and is host to several superlatives. The Himalaya-Tibet region supplies freshwater for more than one-fifth of the world's population. It is the source of some of the greatest rivers and the highest concentration of glaciers outside of the polar regions.

Resulting due to a collision between two continental tectonic plates, which is still continuing, it boasts of the highest rate of uplift (nearly 10 mm/year at Nanga Parbat). The Himalayan region holds the record for highest erosion rates ranging from 2–12 mm/yr. The copious sediments generated are responsible for the fertile plains of Indo-Gangetic plains. The Himalaya mountain chain provides unparalleled opportunity to examine the complex ways in which continents respond to collisional tectonics, active fold-thrust system, formation of duplexes, seismogenesis and neotectonism in one of the youngest orogenic belts of the world. The evolution of Himalaya spans a long history encompassing the break-up of East Gondwana around ~250 Ma to the final closure of Tethys and continent-continent (India-Eurasia) collision at ~47 Ma. Traditionally, the Himalayas have been divided into five geotectonic elements. From South to North they are:

- **SUB-HIMALAYA – Siwalik (Dagshai/Kasauli/Subathu)**
- **LESSER HIMALAYA – Rampur-Berinag/Shali/Simla/Blaini-Kroll-Tal**
- **HIGHER HIMALAYA – Crystallines / Tethys Himalaya**
- **INDUS-TSANGPO SUTURE ZONE (ITSZ) ophiolite / Ladakh granitoids**
- **TRANS HIMALAYA –Karakoram granitoids / associated sediments**
- **The Ladakh Region of Jammu & Kashmir- the cold desert, exposing the ITSZ and Trans-Himalayan units, holds the key to the collisional processes. It is characterized by lofty mountain chains with broad open**

intermontane valleys dotted with saline water lakes and hot springs. Ladakh lies on the rain shadow side of the Himalayan region and has both arctic and desert climatic conditions, which in combination with the high altitude, poor oxygen and vegetation, low humidity as well as high solar radiation, make the region inhospitable. The nine storey Leh Palace is a distinguished historical monument of 17th century Tibetan architecture and is said to have inspired the famous Potala Palace of Lhasa.

Geologically, the area is bounded by the Karakoram Ranges in the north and the Zanskar Ranges in the south. From South to North, the Ladakh Himalaya is broadly divided into three litho-tectonic units.

(i) Continental passive margin sediments, (Tethyan -Zanskar-Spiti)

(ii) Indus Suture Zone (Ophiolites and related sediments) Ladakh-Gangdese batholith (calc-alkaline magmatism)

(iii) Shyok Suture Zone (suturing of magmatic arc and the Asian margin and Karakoram Granitic Complex

The present studies concentrated in three areas to unravel the geological evolution of the area.

SHYOK – NUBRA

- Shyok Suture Zone (SSZ) separates the Karakoram block (Eurasian Plate) from the Ladakh Oceanic Arc (Asian Plate)
- Ophiolitic mélange (volcano-sedimentary sequence with minor ultramafic rocks) observed along the Shyok-Nubra valleys.

NIDAR OPHIOLITE

- More or less complete igneous ophiolitic sequence.
- Flysch sediments including radiolarian chert.
- Mollasse sequence

SPONTANG OPHIOLITE and Dras Volcanics

- Ophiolite sequence with ultramafics
- Dras volcanics
- Flysch sediments

			Geological investigations in this area have yielded significant insights concerning the timing and evolution of the SSZ-ITSZ, the mechanism of subduction, obduction and emplacement of the Supra-Subduction Ophiolite suite and evolution of processes associated with continental collision as well as products generated as a result. Studies indicate that the Indian-Asian plate collision is not a simple subduction of Indian plate below the latter, as earlier surmised, but is a result of complex evolutionary process involving multiple episodes of subduction along with associated magmatism.

	Argha Banerjee, Indian Institute of Science and Education Research, Pune	**Scientific challenges in a warming Himalaya**	**The high Himalaya is warming up steadily. This is driving an ongoing shrinkage of Himalayan glaciers over a century or so. In fact, a clear climate signal can be extracted from glacier length-fluctuation data. The detailed nature of the response of Himalayan glaciers to this changing climate is becoming clearer with recent scientific progresses. However, some relatively less-understood and under-studied processes like seasonal snow-cover variability, and avalanche contribution to glacier mass balance requires concerted efforts. Our ability to tackle the consequences of a shrinking seasonal to perennial snow/ice resources in the Himalaya may depend on a better understanding of some of these factors.**

	Professor M.S. Nathawat, Professor of Geography & Director School of Sciences, Indira Gandhi National Open University, New Delhi	**Need of CODATA initiative to facilitate Geo-Spatial Data Sharing in HKH region to study the effect of climate change**	**The Himalaya, the youngest and fragile mountain system of the earth, has direct influence on climate control, regional hydrology and environment of our subcontinent. About 17% of its mountain area is covered by glaciers. These glaciers are receding faster than those in other parts of the world. Change in climate directly affects glacier mass and thereby, the water resources. Global climate change is believed to have an early and large response at high latitudes and thus proxy observations on climate change in the Himalaya region could serve as an early-warning system for global climate change. Although the glacier monitoring is important, it has been restricted only to a small number of glaciers due to laborious field measurements. In HKH region the details of the climate normal, and their variability and trend are still poorly understood. Inventory of rain gauge data available in the HKH region, Hydro-met Database Development and Current Status of Rain gauge Station of entire HKH is fragmented and different countries are collecting these data have variations in data standards. Data gaps exert major hindrance in the study of climate change and impact, although those subjects need more thorough investigation. Information and data sharing are key issues regarding bridging this gaps in the HKH region and it is felt necessary that there should be some development of modality and regional platform for sharing of information and data which is very urgently required among the neighboring countries to understand the climate change impact in holistic manner.** **Keeping in view to understand the faster rate of glacier retreat in various parts of the Himalaya, in the present study we selected Doda valley, which forms is parts of Zanskar basin and have number of large and small glaciers. It is evident that due to increase of temperature of earth surface or due to global warming these glaciers must be receding at faster rate since past 5-6 decades. This study is mainly focus to estimate the changes in glacier morphology and their retreat in Doda valley and the importance of glacier dynamics and subsequent implication on climate change. The present study was carried out using multi-temporal satellite data as well as topographical maps. The satellite data was processed to acquire information about glacier morphology and to delineate the location of snout. Topographical maps were used to derive information about past disposition of various glacier and their elevation changes over time.**

	S. P. Shukla[1], Rakesh Mishra[2] and Ajai Kumar[3], 1.Polar Studies Division, Faridabad, 2. PSS-PM : Technical Co-ordination, Shillong, 3. PSS-PM : Monitoring-7, Kolkata	**Glacier melt water characteristics of Hamtah glacier, Lahaul & Spiti District, Himachal Pradesh, India**	**Himalayan glaciers are considered as the water towers of Asia. These water towers provide water to perennial rivers emanating from the Himalayas. In order to understand the process of the generation of glacier melt from a glacier and its appearance at the snout, a glacier discharge measurement was undertaken on Hamtah glacier, Lahaul & Spiti district, Himachal Pradesh. The highest and lowest average daily discharge values for three common observation fortnights, viz. August (II), September (I) and September (II), were found to be $0.25x10^6$ m^3 and $0.20x10^6$ m^3 recorded in 2003 and 2002, respectively.** **Hourly melt water discharge data collected during the period between August – September spanning over eight years, from 2000 to 2007 was analysed to understand the role of meteorological parameters and surface ablation from the glacier. The studies indicate close linkages with temperature and surface ice ablation.** **The day-night time discharge variations were also studied to understand the storage characteristics of the glacier. The study revealed that there is no significant lag between ice melt generation and its release into the glacier melt stream suggesting lack of any storage in the melt channel drainage network.**

	Ashit Kumar Swain, Geological Survey of India, SU: Sikkim	**Glacier stress pattern as an indicator for climate change**	**In the Polar Regions, the effects of climate change are a matter of global concern. Climate change is intimately associated with the thinning and retreat of glaciers. The dynamic nature of the glaciers depends upon various factors like their thickness, surface slope and the bedrock slope. The movement of the glaciers builds up stress in the glaciers. Under impending climate change, the change in the glacier ice thickness as well as the rate of change in the surface and bedrock slope changes the stress pattern in the glaciers. Accordingly, the stress pattern remaining unequal throughout the glacier body is responsible for the formation of crevasses and tend to change their shape and intensity. In the northern hemisphere, Ny-Alesund area in the Svalbard archipelago and in the southern hemisphere, the Polar ice sheet near the Schirmacher Oasis in central Dronning Maud Land of Antarctica were studied for stress calculation. These studies were carried out by estimating the ice thickness and bedrock slope using Ground Penetrating Radar. At present about 60 per cent of the land is covered by the glacier and perennial snow covers the Svalbard archipelago located within the Arctic Circle. The Vestre Broggerbreen (VB) glacier system in the Ny-Alesund area of this region is separated into the southern VB-I and the northern VB-II glaciers by a medial moraine with overall extension towards ENE. The glacier stress for the VB glacier system is calculated to be in the order of 20 to 60 kPa. In the VB-I glacier the highest stress of 60 kPa is calculated in a constricted zone towards the upper reach, whereas the least stress of 20 kPa is concentrated towards the glacier snout. In the VB-II glacier, the highest stress of 50-60 kPa is observed in a very small area towards the upper reaches. There are two distinct least stress zones observed both in the upper as well as lower reaches in VB-II glacier whereas a majority of the area in the upper reaches experiences 40-50 kPa. The Polar ice sheet of Antarctica near the Schirmacher Oasis however shows a different type of stress pattern.**

			This area show a variation in the ice sheet stress in the range of 25-100 kPa, but contrary to the case of the Arctic glaciers, the change in the stress pattern is uniform in the Polar ice sheet. The stress gradually reduces towards the northern side of the Polar ice sheet, which is in contact with the Schirmacher Oasis. The ice sheet thickness gradually increases towards the south, and the bedrock slope does not change abruptly over a large region. However, the change in the rate of surface slope drives the crevasse pattern. This study shows that the stress pattern in this glacier system is more dependent upon the bedrock slope than the surface slope, though the later one is responsible for the formation and modification of the crevasses.

	Sujata Dash, TS Rawat, Anitha Revi and M R Bhutiyani, Defence Terrain Research Laboratory	**Exploring Landsat Images for Glacier Monitoring: an indicator of climate change occurrence in Himalaya**	**The complex terrain of the Himalaya along with its glaciers is undergoing rapid changes due to changing climatic conditions. Remote sensing offers a vital tool to establish the glacier-climate relationship in this terrain.** **In this study, Multi temporal Landsat Images of Karakoram region (of path & row for 148-35 scene) are studied to estimate snow cover conditions vis-a-vis the prevailing surface temperature derived from Land Surface Temperature (LST) estimation values. The satellite data from 1991 to 2017 (starting June to Oct months) pertaining to summer season are used as the terrain received maximum solar radiation and also maximum snow ablation during this period. LST has been calculated using thermal bands adopting both single and split window algorithms. Both Landsat data and the Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) DEM of 30 meter data are used to delineate the snow equilibrium line (ELA) and further examine the temperature variation with respect to elevation for the region pertaining to peak summer seasons (considering Aug-Sept months).** **The studies indicate that the there is a rise of 0.7^{O}K over the snow region causing depletion in its surface area. Similarly, the fluctuation of the snow line is in tune with the observed LST. Since the terrain has strategic importance for military planning and operations hence the probable vulnerable sites causing mass movement pertaining to summer seasons has been identified and displayed in a GIS environment.**

Chairs: Dr P S Goel, Raja Ramanna Professor, NIAS, ISRO and H E Nils Ragnar Kamsvag, Ambassador Royal Norwegian Embassy to India

	Dr. Bimal N. Patel, Director and Professor of Public International Law, Gujarat National Law University	**A quest for international environmental law stability and certainty in the Arctic Waters: Is Antarctic Environmental Regime suitable and feasible?**	**Recognising climate change and vulnerability because of human influence, a common multilateral environmental regime for both polar regions is desired, however, the fundamental legal differences, mainly emanating from the issue of sovereignty, stalls any such attempt. While a strong international environmental protection regime exists for Antarctica, the same is lacking in case of Arctic. Even the Arctic Environmental Protection strategy identifies the issues which threaten the Arctic environment and enlists steps, much less a binding regime. Although environmental disputes have not emerged in these two regions, the lack of dispute settlement mechanisms in case of the Arctic is a cause of concern. Thus, the question arises about the efficacy of the strict environmental regime of Antarctica versus the flexible and non-legally binding regime of the Arctic vis-à-vis the long term protection of the Polar region, impacts on climate change and dispute settlement, especially, when economic and commercial interests in the Arctic will come to become fully exploited. Arctic states have an opportunity to introduce innovative features and action plans but whether competing and conflicting sovereignty and other state claims over the region will pave the way for such mechanisms remains to be seen. Furthermore, is there any role for a country like India which has now gained observer status in the Arctic?**

	Walter R. Roest, Senior geophysicist, Ifremer, Brest, Franc	**Geoscience Advances in the Arctic Ocean**	**Article 76 of the United Nations Convention on the Law of the Sea provides coastal States with the opportunity to expand their continental shelves beyond a distance of 200 nautical miles from their coasts, if they can demonstrate that the submerged prolongation of the landmass reaches that far. It turns out that proving such prolongation can be quite a challenge, particularly in complex geological areas. Adding the harsh climate conditions in the Arctic, one can imagine the tremendous efforts Arctic coastal States had to make in order to establish the outer limits of their continental shelf.** **The Arctic Ocean is an example of a region where the Law of the Sea has led to significant investments in new research, as coastal States had the obligation to submit particulars of the limits of their continental shelves to the Commission along with supporting scientific and technical data as soon as possible but in any case within 10 years of the entry into force of this Convention for that State.** **Over the last 20 years, significant geoscience research was conducted to map and image the Arctic seafloor and subsoil, often involving close collaboration between the Arctic coastal States. These States are now in a position to prepare well substantiated submissions to the Commission on the Limits of the Continental Shelf as to the extent of their continental shelves. This includes the development of technology to facilitate operations in deep water, in remote areas and under harsh conditions.** **The international collaboration and cooperation has resulted in a tremendous increase in our collective understanding of the Arctic within only a few decades. In this presentation, I will discuss some of the major geological and tectonic features that make up the Arctic Ocean and its surrounding continental shelves. Recent large scale data compilations allow to have a general view of the geology and geophysics of the Arctic.**

			The seafloor spreading history of the Eurasian Basin along the Gakkel Ridge appears to be well constrained. However, the mode of opening of the Amerasia Basin is still a matter of debate, notably because of the lack of readily identifiable seafloor spreading magnetic anomalies, notably in the Canada Basin. Detailed surveys and sampling of rocks provide additional information on the nature and evolution of many of the seafloor highs, including the Lomonosov Ridge, the Alpha Ridge and the Mendeleev Ridge.

	Uttam Kumar Sinha, Fellow, Institute for Defence Studies and Analyses	**Observing the Arctic: Visit to Svalbard**	**It is an unforgettable experience to land at Ny-Alesund, 1234-km from the North Pole, the centre for international Arctic scientific research and the world's northern most human habitat. Ny-Alesund is a great place to observe climate change and is unique in many ways with scientists from different nations and various streams conducting polar research and experiments. As observed through my visit and interactions with polar scientists as well as policy makers, I will discuss the following:** ● **Need for collaborative Arctic research** ● **Relevance of integrated, coherent and policy-relevant Arctic science.** ● **Reasons for India to engage in the Arctic region** ● **India-Norway cooperation in the Arctic**

Richard T. Haworth,
Adjunct Professor, Dalhousie University, Canada

Politics of Arctic Geoscientific Activities

Exploration of the Arctic has a rich history of international competition. In Canada, the post-1600 history focuses on the race between Samuel de Champlain of France and Henry Hudson of England to describe and exploit the northern half of North America, and to find a profitable passage to the Orient. Successive expeditions had varying degrees of success before the eventual triumph of Amundsen 400 years later. Suffice it to say that most of these expeditions were conducted with a spirit of competition.

In recent years, the prospect of a less hazardous passage through the Arctic along the less icebound northern coast of Russia stimulated interest in the reality of a shortened time of passage between the west Pacific, eastern North America and Europe. As that route supported more traffic and the extent of Arctic ice cover decreased, so has interest increased in navigating the Northwest Passage through Canada's Arctic Archipelago.

From the pioneering transit of the Manhattan through the Passage in 1969, to the transit by passenger vessels since 2016, a new era of Arctic transportation is upon us. I believe that this era heralds a significant change from one of competition in the Arctic to one of international cooperation and collaboration. Nowhere has this been more evident than in the geosciences and their contribution to tackling contemporary Arctic challenges.

Arctic coastal States are now in a position to prepare well substantiated submissions to the United Nations as to the extent of their continental shelves. This has been made possible by unparalleled collaboration between those countries, often in the development of technology to facilitate operations in deep water in remote areas under harsh Arctic conditions.

Those States are also facing severe impacts on their coastal habitats because of changing climatic conditions and human induced pollution. This necessitates long term continuous monitoring of conditions throughout the Arctic, requiring coordination in observationalprotocol and collective interpretation of the results incorporating traditional knowledge.

			The stimulus for much of this work has been the multifaceted mineral resource potential of the Arctic. This requires the development of infrastructure in a manner that is sensitive to changing environmental conditions. **The geosciences have a large role to play in tackling each of these challenges.While citizens may hear through the media of conflict between Arctic States, often sensationalized and sometimes imagined, the reality is that international collaboration and cooperation has resulted in a tremendous increase in our collective understanding of the Arctic within only a few decades.**

	Ashwaghosa Ganju, Snow and Avalanche Study Establishment, DRDO	**Implications of Changing Climatic Pattern on the Geopolitical Situation of North Western Himalaya, India**	**The Indian Himalayan region has shown significant rise in mean air temperatures in the last few decades. Precipitation in winter has varied considerably all these years with increase in liquid precipitation and decrease in solid precipitation at all places except in the higher regions of Karakorum Himalaya. While lower Himalayan ranges have shown significant increase in total seasonal precipitation in the last three decades, the reverse is true for Higher Himalayan ranges. However, total seasonal snow precipitation has decreased everywhere except marginally in the Karakoram Himalaya. This may demand investigations on the role of aerosols brought about by weather systems affecting the Himalayan belt and that of anthropogenic aerosols and their impacts on the Himalayan cryosphere. It will also help in the study of changing temperature patterns. Deforestation and land degradation may have an impact on the precipitation variability, which needs to be investigated. The asymmetrical warming of minimum and maximum temperatures can also be attributed to factors like cloud cover, soil moisture and precipitation, feedback processes and land use/land cover, which is all interrelated with precipitation. The snow cover area has decreased everywhere in Indian Himalaya except in Karakoram where it has increased marginally. All this coupled with the increase in number of occurrences of extreme precipitation events in past few decades has brought in a new climatic shift, which may have far reaching consequences on human settlements and the geopolitical situation in the Indian Himalayan region in the near future.** **Warming leading to reduced snowfall and recession of glaciers is likely to pave way for easy access through glaciated mountain passes, which seem impregnable at this time. With this development the accessibility to the farthest and remotest regions would ease leading to better mobility and placement of better equipment for defending borders. However, dryness in such high altitude regions may accelerate Himalayan desertification in many other regions of Himalaya.**

With the depleting snow cover area, the albedo of the region would decrease and may bring in weakening in radiative cooling effect, which has happened during 2001-2014 because of reduced snow cover and may pose a challenge in snow melt water use and flood prediction. What would be the consequence of such a situation would form an important research area in years to come bringing out consequences of different scenarios that may develop in the Himalayan region. At present snow cover variability over the region and its impact on the energy budget remains largely unknown.

Predicting and diffusing extreme weather events may be a future research area as no nation can afford the damages caused due to such events, which may eventually lead to funding on developing tools for modification of weather bringing about extreme situations. On the other hand, every drop of scarce melt water would be counted for by construction of many reservoirs in the Himalayas for the purpose of harvesting snow and strong control on its consumption and usage. An increase in rainfall amounts vis-à-vis snow and frequent rainfall events may prove very disastrous in the regions where the mountain's soil cover is loose and dry. The rapid earth movement from mountain slopes would give rise to many other hazards downstream. Extreme winter weather situations may produce extensive avalanches, which may travel for kilometers to cause extensive damage in hitherto seemingly safe areas.

All this is a projection of the impact of climatic change in cryosphere region of Himalaya, and its geopolitical fallout consequently. While such situations can be modeled and projections drawn, an assessment of ground situation is largely missing. Though remote sensing data has helped immensely, yet there is a need to augment it with surface data. A comprehensive plan on monitoring cryospheric region of Himalaya either with dense network of automatic observatories or with dedicated crysopheric centered satellite observation systems is the need of the hour. Understanding of glacier response to changing ISM and westerlies with the help of satellite based mapping supported by field validation is also required.

	H E Nils Ragnar Kamsvag, Ambassador, Norwegian Embassy	**Indo-Norwegian polar collaboration, amongst other things in the field of research and technology**	**Ambassador Kamsvåg will introduce the Indo-Norwegian polar collaboration, amongst other things in the field of research and technology. He will also present Norway's recently launched Arctic Strategy and outline potential focus areas of mutual interest for the bilateral relationship going forward.**

	Sanjay Chaturvedi, Centre for the Study of Geopolitics Panjab University, Chandigarh	**A Critical Geopolitics of Anthropocene and the Antarctic Climate Dilemma**	**The new geological epoch of *Anthropocene* carries profound physical as well as ideational/policy implications for the Southern Polar Region and effectively questions the proclaimed exceptionalism and legal-political-ethical boundaries of the Antarctic regime. Moreover, climate change has registered itself on an increasingly complex and crowded domain/agenda of three-tiered Antarctic governance at a critical juncture of the evolution of Antarctic Treaty System (ATS). Some of the key questions that demand and deserve serious attention, that too sooner than later, are: What is it that is being challenged or threatened by climate change in the Antarctic: ecosystems, power-knowledge equations, national interests, interests of humankind, values, claims or rights to territorial sovereignty? How come the powerful graphic visualization of Antarctica and its ecosystems at the 'receiving end' of climate change, with far reaching regional and global impacts/implications of collapsing ice sheets, has so far failed to act as a catalyst for both individual and collective behavioral change? Can the current Antarctic climate discourse be broadened, deepened and reconfigured to give visibility and voice to global peripheries, especially in Global South? The paper argues that it is not a question of *whether* but *when* the evolving climate change discourse at the Antarctic Treaty Consultative Meetings (ATCMs) would be questioned by a critical geopolitics of the Anthropocene for its limited and limiting engagement with the ethical as well as geopolitical considerations surrounding the knowledge-power interface, sustainability of core values of the ATS and questions of authority, legitimacy, effectiveness, representation, responsibility and accountability.**

	Luther Rangreji, Director, Ministry of Economic Affairs	**"India's efforts towards a National Law governing Antarctica: An International Legal Perspective**	**India has been a Consultative Party of the Antarctica Treaty since 1983 and is also a member of SCAR and a party to the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) in 1986. In1997 she became a party to the Protocol on Environmental Protection to the Antarctic Treaty. At present India has research stations (DakshinGangotri, Maitreyi and Bharti) in Antarctica. Becoming party to international treaty regimes, under our constitutional scheme requires effectuation at the domestic level by a national enabling legislation. While the demand and effort for a national legislation has been a long standing one, it is only recently that a Expert Committee appointed by the Government of India has submitted the draft of a national legislation on Antarctica. The effort of this article would not be to analyse the draft act, but to look at it from the perspective of international law-to strengthen the treaty regime, bring legal certainty to various activities of India and also look at legislation of other parties to the ATS. This article is purely an academic exercise and seeks to provide a clearer understanding of India's obligations and the challenges under the Antarctica treaty regime.**

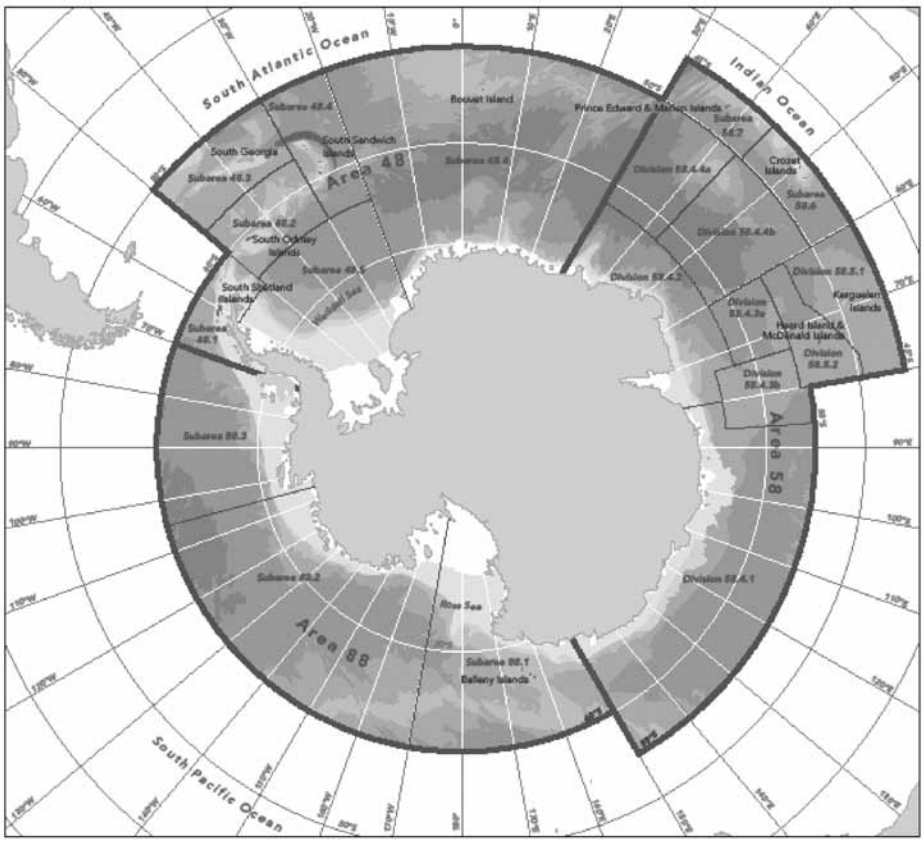
Dr. M Sudhakar and N. Saravanane,
Centre for Marine Living Resources and Ecology

International Conservation Law – CCAMLR System of Governance in Southern Ocean

Southern Ocean living resources are managed sustainably since 1982 adopting "Ecosystem Approach" by Commission for Conservation for Antarctic Marine Living Resources (CCAMLR) which is one of the 18 regional seas programs of the United Nations Environment Program (UNEP) that has been established for regulation and management of resources in the areas beyond national jurisdiction. The CCAMLR is a multilateral convention with 25 countries as permanent members and 11 as acceding to it later. The Commission, while adopting ecosystem approach for conservation of the whole living resources of southern Ocean, allows for harvesting certain ecosystem components (Krill and fin fishes) as long as such harvesting do not affect ecosystem functions and resilience and thereby contribute to the global food security. The objectives are framed to balance "Conservation" and "Rational Use" of living resources while maintaining existing ecological relation with each individual organism. CCAMLR members have achieved this through the conduct of long-term research and integrated actions associated with the acquisition of operational-level fishery data, fishery-independent observation, and the collection and analysis of biological and environmental data. Majority of the management responses of the commission are based on precaution and an ecosystems approach which include catch limits (for target species and by-catch), by-catch mitigation practices, temporal and spatial closures, prohibited fishing gears and sustained efforts over more than 15 years to combat illegal, unreported and unregulated IUU fishing.

The fisheries in the Convention Area of Southern Ocean currently target Patagonian tooth fish (*Dissostichus eleginoides*), Antarctic toothfish (*Dissostichus mawsonic*), mackeral ice fish (*Champsocephalus gunnari*) and Antarctic Krill (*Euphasia superba*). CCAMLR's Convention Area extends from the coast of Antarctica to the Antarctic Convergence at approximately 45–60^{O} South. The Convention Area is circumpolar and encompasses the southern sectors of the Atlantic Ocean (Statistical Area 48), Indian Ocean (Statistical Area 58) and Pacific Ocean (Statistical Area 88).

Each statistical area is divided into subareas or divisions. Out of the three major fishery region, the Atlantic Ocean (48 sector) and Indian Ocean (58 sector) are only opened for fishery with the Atlantic Sector alone contribute to more than 80 per cent of the total catch. The set catch limit for krill is at present 620 000 tonnes which is one percent of the total estimated catch for the year 2016. The krill catches have been increasing slowly, but only recently, catches have again surpassed the 200,000 tonnes. In the past decade (2005–2014), 41 per cent of the total catch has been taken by Norway, 21 per cent by Korea and 11 per cent by Japan (CCAMLR, 2016).



Commission for the Conservation of Antarctic Marine Living Resources - Convention Area

	Sulagna Chattopadhyay, President, LIGHTS, Editor, geographyan-dyou.com	**India on backfoot in science diplomacy?**	**Scientists sometimes have to make value judgments in the global arena, whether they like it or not. One such example can be cited from IPCC 2007 which raised considerable angst about health of the glaciers of the Himalayan region. Contrasting views on such issues are unavoidable because of the diversity of terrain and data, added to the lack of standard parameterization. This leads to a grey area for forging policy directives. Though India is very active in scientific research in Arctic and Antarctic, where science is deeply entwined with geopolitics, we require an informed country-level think tank to guide the operational wings of the nation. Sadly, we lack authority to drive policy as a nation when it comes to sensitive and time-bound issues pertaining to these fields. India's opting out from the UN Commission of Limits of Continental Shelf is an example. Though India ranks 9th in terms of volume of scientific publications from 1996 to 2016 and 22nd if H index ranking is considered, out of 239 countries as per the Scimagojr country rank index- Scopus compilation (http://www.scimagojr.com/countryrank.php), yet their participation in the decision making leaves much to be desired. This highlights a necessity for synergy between scientists and policy makers for drafting a robust participation role in the global scenario in strategic and other areas.**

Chairs: Dr S C Shenoi, Director, INCOIS and Dr S K Singh, Director, NIO

	S C Shenoi, Director, INCOIS	**Climate Change Adaptation and Mitigation – Climate Change and the Oceans**	**Climate change poses an extremely wide-ranging set of risks. Quantifying and aggregating these climate impacts in a meaningful way is extremely challenging, owing to the complex uncertainty that pervades the coupled human-Earth system. The long time horizon of the problem with temporal dynamics such as thermal inertia and other lags, and the heterogeneous nature of climate makes impacts across regions, sectors and generations. Under the Paris Agreement 195 nations made pledges known as nationally determined contributions (NDCs) which indicate how the national governments are evaluating climate risk and policy opportunities. Because the ocean plays critical roles in climate mitigation and adaptation it is necessary to look into the oceans in detail.** **Ocean warming, acidification, de-oxygenation, and the change in primary productivity are considered the four main climate change stressors of marine ecosystems, and occur simultaneously, creating high risk for synergistic impacts. Coral reefs, mangroves, sea level, coastal erosion and the inundation of coastal plains are the other impacts. The Paris Agreement commits nations to limit global temperature rise to well below 2^{o}C, while pursuing efforts to limit to 1.5^{o}C. Oceans are not only becoming more prominent in climate negotiations, but countries are actively including marine ecosystems in their national climate plans. This talk looks at the changes that are happening the oceans, especially in the Indian Ocean, and the visible impacts that might have on the weather and climate, and hence the socio-economy of the region.**

	Sunil Kumar Singh, CSIR-National Institute of Oceanography, Goa	**Evolution of the Himalaya, Biogeochemistry of the Indian Ocean and Climate Change**	**The origin and evolution of the Himalayan mountain belt has a profound impact on reshaping the continental morphology, influencing the ocean biogeochemistry and global climate change. It established the monsoon system in the Indian continent and is responsible for transporting large amounts of dissolved and particulate material to the adjacent ocean thereby influencing global climate. It has influenced global climate by obstructing the direct water movement between the Indian and the Atlantic Oceans, by sequestering CO_2 from the atmosphere due to chemical weathering and organic carbon burial and by altering the biogeochemistry of the Indian Ocean by supplying nutrients and other elements to the Indian Ocean. Studies carried out on the river systems of the Himalayas reveal the enhanced sequestration of CO_2 due to weathering and burial of organic matters in the Indian Ocean, a net sink of CO_2 on longer time scale. Recent studies carried out in the Indian Ocean suggest large inputs of trace elements and isotopes from the erosional products from the Himalaya to the oceans. These supplies are contributing significantly to the trace elements and isotope budgets such as Sr, Nd, Si, Mo isotopes of the Indian and the global oceans. Studies carried out in the Ganga plains and in the Indian Ocean suggest that the Himalaya has been impacting global climate since its origin. The details will be discussed in the talk.**

	S C Tripathy, ESSO-National Centre for Antarctic and Ocean Research, Goa	**Role of Southern Ocean in global climate change: perspectives from Indian Southern Ocean Expeditions**	**Each oceanic region has a different significance in influencing the global climate change scenario with their potential for drawing-down the atmospheric CO_2. In this context, the Southern Ocean (SO), being the world's largest high-nutrient low-chlorophyll (HNLC) regions, plays a significant role as a sink for atmospheric CO2 via its solubility and prevailing biological pumps. It thus plays a pivotal role in the global carbon cycle and climatic regulations through biogeochemical fluxes of carbon, nutrients etc. from the ocean surface to the deep interior. The efficiency of the biological pump depends on a range of environmental and biological factors (such as type of phytoplankton / zooplankton inhabiting), which in turn are influenced by climate change. It is observed that the productivity in SO regions is closely related to the hydrodynamics across the fronts and convergence zones, thereby varying the phytoplankton, the prey-predator relationship and food-web structure and biogeochemical cycle.** **Scientific insight gained from physicochemical and biological studies performed during Indian Southern Ocean Expeditions (ISOE) in the last decade highlights some interesting findings and emphasizes India's research activities in the SO region for better understanding of the SO processes, biogeochemical cycles, marine productivity and global climate change scenario. This talk would include some of the salient findings of ISOE which highlights: causal mechanisms of variability in phytoplankton community structure and productivity among frontal regions [i.e., Subtropical Front (STF), Sub-Antarctic Front (SAF) and Polar Front (PF)], patterns of phytoplankton biomass distribution within and among the fronts, role of diatoms in deciphering environmental change, food-web dynamics, bio-optical characterization of water column, response of bacteria and phytoplankton to micronutrient amendments etc. in this lesser-understood region in the SO.**

	Rajiv Nigam, National Institute of Oceanography, Goa	**Foraminifera in marine sediments off west coast of india- a tool for paleoclimatic reconstructions**	**The present global scenario poses multiple environmental problems associated with global warming due to the green house effect. Anthropogenic contributions are now considered as a cause for accelerated sea level rise, changes in monsoonal rainfall pattern, increase in intensity and frequency of storms etc. Obviously, In order to foresee the future variability in climate, there is need for an increased awareness about the past climatic changes. However, climate prediction is a very delicate task and needs a thorough knowledge about the past. Past records have been maintained for not more than past 100-150 years, beyond which we would need proxies to give us information about the past climate. During the past few decades, microfossils, especially foraminifers have become the prime source to paleoclimatic reconstructions.** **In order to obtain knowledge about past changes in the relative sea levels, a two-fold strategy should be adopted. We have to look for the position of past sea levels with respect to the present day sea level: (i) when sea level was higher (for this coastal areas explored for erosion or depositional features), and (ii) when sea levels was lower (for this sea floor sediments examined for shoreline movements and depth variations). Armed with the above information, we have generated an updated sea level curve for Late Pleistocene-Holocene sea level fluctuations. This corresponds to the time interval - last 15000 years. We successfully demonstrated that as compared to the present, sea level was lower by 100 m about 14,500 years BP (Before Present), and 60 m about 10,000 years BP. It has been reported that since the last 10,000 years, three major episodes of sea level variation have resulted. Similarly, we have gleaned evidences that attest to higher strands of sea level 6000 years BP.**

			Utilising the sea level curve and occurrence of foraminifera (exclusively marine microfossils), it was conclusively established that the rectangular structure at Lothal (a Harappan Settlement, near Ahmadabad) was a dockyard (first Naval dock yard of the world as claimed by archaeologists) and not, as earlier proposed, a fresh water storage tank. Further, with the help of this sea level curve, we have explained the discovery of Neolithic settlements (at 30-40 m water depth) in the Gulf of Khambhat - the oldest civilisation site known to man, particularly in the Indian subcontinent. Similarly, occurrence of foraminifera in subsurface sediments at Dholavira (Gujarat) indicated the possibility of tsunami and knowledge of which prompted ancient Indians to built unusually thick (18m) wall around citadel – the world's oldest tsunami protection measures. Similarly, paleomonsoonal studies on core samples off Karwar, west coast of India showed the clear signals of marked high rainfall around 4000 and 3500 years BP and reversal of rainfall condition since 3500 B.P. with a marked low at 2000 years BP. These findings gathered support from palynological investigations of the same core and foraminiferal studies off Oman, western Arabian Sea. In addition to this, a cyclicity of approximately 77 years in concentration of drought years was deciphered which is possibly regulated by Gleissberg cycle in the radius of the sun.

	C N Ravishankar, Director, ICAR-Central Institute of Fisheries Technology	**Adaptation to Climate Change: a Fishery Technology Perspective**	**Fisheries play an important role in the food supply, food security and income generation for millions of people. Issues related to climate change will further impact these resources which are already stressed with issues like overfishing and diminishing returns. There are reports regarding the far-fetching impacts on the safety and quality of seafood, especially the increase in bioburden on algal toxins, organic chemical residues and toxic metals which are related to climate change. Technologies that can reduce the contributing factors, like the emission of GHGs, together with responsible fishing operations and reduction in efforts in fishing, can make a significant dent in reducing emissions related to fishing. Adaptation is always involved for benefitting from these issues and an interdisciplinary approach cutting across different disciplines is a pre-requisite for developing mitigation measures.**

	Rahul Mohan and Shramik Patil, National Centre for Antarctic and Ocean Research, Goa	**Response of cocco-lithophores to the carbonate chemistry and Ocean Acidification**	**Oceans are one of the major sequesters of natural as well as anthropogenic carbon dioxide. It is estimated that about one third of the carbon dioxide released in the atmosphere through human activity has been absorbed by the oceans. Recent studies indicate that in the past 250 years, anthropogenic carbon dioxide influence has changed the seawater carbonate chemistry that resulted into decrease of ocean pH ('Ocean Acidification'). Model as well as instrumental measures predicted that, by end of this century concentrations of atmospheric carbon dioxide will rise from 400 µatm to over 750 µatm which will intensify changes in the ocean carbonate chemistry and lower the pH of the oceans. This increase in ocean acidification will affect the eco-physiology of marine ecosystems particularly calcifying organisms such as corals, foraminifera and coccolithophores which play a major role in the marine carbon cycle. In the other hand, an increase in atmospheric (subsequently oceanic) temperature will impact phytoplankton physiology, productivity and growth rates. Indirect effects such as enhanced thermal stratification will constrain nutrient availability and ultimately limit primary productivity in the sunlit ocean surface layer. Assessing coccolithophores' key role in marine ecosystem studies on coccolithophores ecology and biogeography were carried out in the Southern Ocean between 2004 and 2017. Our studies document rapid shifting of biogeographic boundaries of coccolithophores with rapid frontal movements and adaptation of coccolithophores to lowering pH conditions south of the polar front. Based on our studies, we hypothesize that in the future, coccolithophores may show diverse responses to change in carbonate chemistry and ocean acidification. The coccolithophores will show variations in calcification and probably will replace calcium by magnesium to cope with the changing pH conditions. Tropical-subtropical phytoplankton communities will be dominated by lower photic zone coccolithophores which would possibly emerge as a different kind of ecosystem in these regions. Such changes could therefore have their own repercussions and could alter the marine carbon cycle and affect carbon sequestration in the near future.**

Chairs: Dr Nalan Koc, Director, Norwegian Polar Institute, Tromso and Dr R Ramesh, NISER, Bhubaneshwar

	Dr. R Venkatesan, Dr. M. A. Atmanand, Dr. G. Latha, National Institute of Ocean Technology, Ministry of Earth Sciences, Chennai	**Indian arctic multi-sensor mooring (IndARC) observatory**	**The first Indian Arctic multi-sensor mooring (IndARC) observatory in Kongsfjorden of Arctic waters was established in July 2014. The Ministry of Earth Sciences evolved a unique moored observatory 'IndARC' with suite of sensors for physico-chemical and oceanographic in situ long-term data collection. The Arctic Ocean plays an important role in governing the earth's climate and also faithfully records its past climatic history and represents a significant gap in ocean observations. There exists a hypothesis that Indian monsoon is related to the Arctic regions. To prove or disprove this, it is necessary to have a mooring in the Arctic region, measuring the oceanographic parameters on a continuous basis. Also, the ambient noise in the region will pave the way to understanding the ice melting process, and long term data would indicate climate change. With this background, an indigenously designed and installed observatory IndARC, for the first time, collected various parameters from July 2014 to July 2015, further on in 2016 and 2017. The moorings currently are equipped with acoustic transducers apart from conventional sensors like ADCP, DO sensor, etc. The uniqueness of this system, the challenges faced and results from data collected will be presented.**

Manish Tiwari,
ESSO-National Centre for Antarctic and Ocean Research, Goa

Possible Errors in Marine vs. Terrestrial Carbon Sequestration Budget for the Arctic Region

Carbon sequestration, especially in the Arctic region, helps offset a part of atmospheric CO2 increase by locking them within the buried sediments. The Arctic region holds a disproportionate importance in the global carbon cycle and climate system owing to its uniqueness compared to other world oceans. With a mere 2.5 per cent of world ocean area, it accounts for nearly 7-11 per cent of the world's organic carbon burial flux. This is largely due to greater preservation of terrestrially sourced organic matter and its transportation through its massive shelf area via sea-ice. Marine production plays a limited role, which is less than the global average due to ice-cover in most parts of the region. However, in a global warming scenario and its projected amplified response in the Arctic, sea-ice cover is expected to shrink drastically and run-off patterns are expected to alter. These combined may change the relative marine vs. terrestrial organic carbon deposition in the region. It is therefore important to have an accurate estimate of relative burial flux as well as its careful monitoring in response to the ongoing changes in the region.

Organic-geochemical bulk parameter based source characterization of sedimentary organic matter (SOM) is required for understanding the regional marine vs. terrestrial carbon budget. The δ13C and C/N ratio are the most widely used tracers for provenance-based studies. These proxies that are so reliable in other parts of the world have significant limitations in the Arctic region due to various proxy-specific uncertainties. As such, gross differences in organic matter source characterization exist between previous works. Here, we devised a unique approach to overcome the uncertainties associated with end-member isotopic composition of SOM by sampling surface sediments along a productivity gradient with ample terrestrial input. This allowed us to better constrain the marine end-member carbon isotopic composition, which we found to be anomalously more depleted than usually assumed.

			We find that the bound inorganic nitrogen (ammonium attached to the clay minerals) forms a significant proportion of total nitrogen concentration (~77 per cent in the inner fjord to ~24 per cent in the outer part). On removing the bound nitrogen, the C/N ratio shows that the SOM in the inner fjord is made up of terrestrial carbon while the outer fjord shows mixed marine-terrestrial signal. We further show that the marine organic matter is unusually more depleted in 13C (~–24‰) than the terrestrial organic matter (~–22. Per cent). This particular result also provides the explanation for the high δ13C of SOM from central Arctic despite a high terrestrial input, as reported by previous studies and remained a puzzle since. Using these new values, we find that the terrestrial contribution to the organic carbon deposition in the Kongsfjorden is severely under estimated, which may well be true for the entire Arctic region as it is known for its high clay content.

	Dr. Frank Reier Knudsen, Norway	**Recent advances in hydroacoustic technology for ecosystem monitoring**	**With a sharper focus on ecosystem health, the practice of non-invasive, remote and long term monitoring of water bodies is becoming increasingly important. Acoustics is one technology rapidly adapting to this development. Traditionally, fisheries echosounders are used by scientists to assess the size of fish stocks and regulators use these estimates to set the fish quota. The standard frequency for fisheries acoustic surveys is 38 kHz. However, the number of frequencies used in acoustic surveys increases. From the single 38 kHz, a modern research vessel can today combine up to 6 frequencies spanning from 18 to 333 kHz. The major advantage of using multiple frequencies is species separation and species identification. By using a low and a high echosounder frequency, fish and zooplankton can be separated and individually measured. A combination of more than two frequencies has proven valuable for species identification since each species has a unique acoustic frequency response (acoustic signature). Increasing the number of discrete frequencies is one way of improving the acoustic signatures. Recently, wide band acoustic sweeps have been introduced, further improving the resolution of acoustic signatures and the ability to resolve single targets.** **The classical echosounder has its acoustic beam pointing in a narrow beam from the hull of the vessel towards the bottom. The advantage is quantitative measurements with high resolution, but the disadvantage is low sampling volume particularly near the surface. Fishermen are using sonar as a supplement to look for fish near the surface in the echosounder blind-zone. The sonar has a 360° horizontal acoustic beam covering the near surface water volume up to several kilometers around the vessel. The horizontal beam can be folded, just like an umbrella, to scan the whole water column. The fisheries sonar is now being turned into a scientific instrument by providing calibration and data storage.**

			The alternative instruments developed taking into account both the quantitative qualities of the echosounders and the sampling volume of the sonar are the new scientific multibeam systems. They combine several hundred narrow acoustic beams into a side looking matrix or a down looking swath. These instruments provide a high resolution and large 3D sampling volume in the water column and improved resolution of fish near the sea floor. Improved resolution near the sea floor is also needed for reliable mapping of fish habitat like vegetation and coral reefs. **Further advances in ecosystem monitoring technology are remote sensor platforms like sail drones and wave gliders, landers fixed on the bottom or in the water column and AUVs. Long term remote monitoring is needed for the full understanding of ecosystem dynamics, species interactions and finally ecosystem health.** **Keywords: echosounders, multifrequency, sonars, multibeams, acoustic monitoring, ecosystem health**

	Arild Sundfjord, Norwegian Polar Institute, Tromso	**Coastal and regional circulation in Svalbard; cross-scale needs for data and numerical model tools**	**Marine-terminating glaciers are a large source of freshwater to the coastal environment in Svalbard, at the gateway to the Arctic Ocean. As the glacial meltwater flows out of the fjord we see that the integrated runoff from many individual glaciers influences coastal circulation, sea ice cover and exchange with the offshore Atlantic Water current. These in turn affect atmospheric conditions over the glaciers, which finally set the stage for snow accumulation in winter and, to complete the circuit, glacial melting and runoff in summer. This presentation connects observations from the vicinity of a glacier with data collected by instrumented moorings and from ships, both in Kongsfjorden and along the nearby continental slope. We will look at results and lessons from a number of projects, including field campaigns, time series from moorings as well as numerical modeling.** **Modelling aspects include high-resolution runoff plume modelling, fjord-scale circulation and eddy-resolving regional scale ocean and sea ice model efforts.**

S. Rajan[1] & Neelu Singh[2],
1. Indian National Centre for Ocean Information Services, Hyderabad
2. National Centre for Antarctic & Ocean Research, Goa

Let not that ice melt in Svalbard

The Svalbard archipelago, with a land area of 61,022 km^2, slightly larger than the state of Himachal Pradesh, occupies only around 0.4 per cent of the Arctic region. With just 2145 registered permanent residents (as on April 2017) concentrated mostly in Longyearbyen and Ny-Ålesund, Svalbard, like the rest of the Arctic, cannot be considered a significant contributor to global climate change caused by human activities. Yet few places on Earth show the impact of a changing climate in the landscape and the ecosystem as vividly as the Arctic, and in particular, Svalbard and its offshore areas. For instance, the area and thickness of the sea ice which forms and melts each year in the Arctic have been demonstrated to have decreased steadily over the past three decades or so. This has led to a scenario of a vicious circle in the Arctic - delayed ice formation and availability of more open waters leading to warmer air and sea surface temperatures which in effect reduce sea ice formation. Decline in sea ice formation would also drastically impact the large-scale ocean circulation of the North Atlantic which is responsible for the oceanic transport of heat from the equator to high latitudes. While the relative importance of the natural versus anthropogenic factors in driving the recent Arctic sea-ice decline is poorly known and much debated, what is significant is the effect of such recent warming of the atmosphere, ocean and land on Svalbard.

In this paper, we review some of the results of the recent studies carried out on the Kongsfjorden-Krossfjorden system of Svalbard which bring out the sensitivity of this fjord to inter-annual changes in hydrography, hydrochemistry and chemical signatures in the surface sediments over the past few years.

			Although this sheltered fiord system may not be truly representative of the entire Arctic region, by virtue of its accessibility, the delicate balance it maintains between the advection of a "Transformed" Atlantic Water mass (a mixture of the warm and saline Atlantic water and the cold Arctic water) and the glacial runoff from the large glaciers at its head, and the observable increasingly ice-free nature of the fjord throughout the winter for the past few years, it does provide an ideal reference site for long-term monitoring of an Arctic system for short-term climate variabilities. The studies clearly demonstrate that the Svalbard has indeed warmed in recent years; the documented changes in the associated ecosystem also corroborate this trend. A warming Svalbard could be an anomaly, or it could be the manifestation of the sensitivity of the oceanic circulation to fluctuations in temperature and salinity and/or in atmospheric circulation brought about by a rapidly changing climate. If the latter, these changes can influence the climate far removed from the Arctic itself. Let not that ice melt.

G. A. Ramadass and S. Ramesh,
National Institute of Ocean Technology

Underwater technology for polar research

Eastern Antarctica with its surrounded sea ice is exposed to the vast southern ocean on the northern side which extends into the equatorial region of Indian Ocean. The Antarctic Ice area changes are seasonal due to freezing in winter and melting in summer because of the extension of the sea ice to open ocean environment heat flux variations. The available data shows that the sea ice cover in Antarctica varies between winter to summer with a maximum of about 19 million km^2 and to a minimum of just 3 million km^2 respectively. Apart from seasonal fluctuations, strong westerly winds along with high waves and frequent storms are the prime factors which shape up the sea ice cover in Antarctic regions.

The thickness of the Antarctic sea ice is getting restricted in thickness due to high surface heat flux and heat supplied from the warm circumpolar deep water currents. Even though the extent and variability of the Antarctic sea ice coverage has been studied over the decadal time period through satellite oceanography, a reliable estimate on thickness of ice is lacking to understand the variability of the climate forcing mechanism and its impact. To understand further, it is important to know about pole ward westerly winds, tropospheric ozone depletion, mechanisms like Ekman transport, upwelling etc to establish the coupling of atmosphere, ocean and polar ecosystem. Apart from ice shelf observations, shallow lakes in the Antarctic continent are least explored to understand the algal mats characteristics at the lake beds to understand the biotic environment in the extreme climates.

In order to quantify such phenomena, it is imperative to develop suitable technologies for taking measurement for the advancement of ice sheets, snow cover, thickness of icebergs, thickness of ice shelf, Lake Floor observations etc. Tethered and un-tethered underwater vehicles plays major role in observations with the recent development in underwater sensor and vehicle technologies. It is possible to understand the ice thickness by continuous measurement and air-ice-ocean interaction studies are now becoming possible by using these vehicles. Hence, autonomous and

			remotely operated vehicles are to be developed for reliable operation in the challenging low temperature environment of Antarctic. These platforms have the potential to modernize our understanding of this remote and under sampled sea ice environment. In the Indian scientific context, this will be the starting step of technologies towards sustained observation of Antarctic ice and shallow lakes to decipher the climate forcing mechanism which will be highly beneficial for polar research community. These types of field-based measurements will bring out the state of ice cover and the potential impact on biota in extreme environment and its surrounding eco-system. This will also facilitate to increase our understanding of Antarctica and also to build our country's engineering capability towards polar science. In the process of technology demonstration, NIOT has developed a proto-type system of Remotely Operable Vehicle for polar temperature and successfully tested in Antarctic ice shelf and lakes. Critical challenges such as material engineering to cater for low temperature environment, under ice navigation, light attenuation characteristics in different continental ices, optimum vehicle design, handling systems etc were noted for further development or optimization. Special variant of ice coring tools were also developed to get interfaced with underwater water vehicle for ice core sampling below the ice shelf. Quantitative measurements are possible from the underwater vehicle variants to monitor the ice shelf dynamics, Lake Floor observations and also changes in associated biota assemblages to decipher the influence of climate in Antarctica.

Chairs: Dr M Ravichandran, Director, NCAOR and
Dr M Sudhakar, Director, CMLRE

Thamban Meloth1 & MADICE Project Team1, 2,
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Exploring the dynamics and past climate of the coastal ice shelves and ice rises of Antarctica

The trillion ton iceberg which recently broke off from the Larsen C ice shelf in Antarctica has got the world talking about the imminent risk it poses. Understanding the mass balance and evolution of Antarctic ice shelves is crucial for a better understanding of the Antarctic contributions to the global sea-level changes. The coastal ice shelves and ice rises are inter-connected systems and provide a buttressing effect to Antarctic ice sheet stability and needs to be investigated. Ice rises are also useful sites to investigate the proxy records of Antarctic climate and their linkages with the global change. To undertake a detailed study of ice shelves and ice rises of coastal Dronning Maud Land (DML), an Indo-Norwegian project named MADICE (Mass balance, dynamics, and climate of the central Dronning Maud Land coast, East Antarctica) was initiated in 2016. The project involves active collaboration between the scientists from National Centre for Antarctic and Ocean Research and the Norwegian Polar Institute. The MADICE project investigates the ice dynamics, current and past changes in atmospheric and sea ice dynamics of the central DML coast using remote sensing data, geophysical field measurements, and ice core based climate reconstruction.

As part of the MADICE project, major field campaigns are undertaken on the dynamics and climate records of coastal ice rises along the central DML coast of Antarctica. During the 2016-17 field campaign, the glaciology team conducted a range of glaciological and geophysical surveys to examine ice

			shelf dynamics and ice rise evolution in the past. The campaign made detailed kinematic GPS surveys over the two ice rises to precisely measure surface elevations. Deep-and shallow-sounding ice-penetrating radar were deployed to map the bed topography and ice stratigraphy. Autonomous phase-sensitive radar (ApRES) surveys were also made and reoccupation of some these sites in future will provide evidence of ice-thickness changes and/or basal melting rates of ice shelf. Two ice core drillings (122 and 51 m, respectively) were made at the summits of Djupranen and Leningradkollen ice rises. Proxy data from these cores would enable us to examine the past climate records and their link to the ice dynamics and oceanic processes. **The second field campaign related to MADICE will be undertaken during 2017-18 Antarctic season.**

	Runa Antony and Meloth Thamban, ESSO -National Centre for Antarctic & Ocean Research, Goa	**Abundance and dynamics of organic carbon in the polar ice sheets**	**Roughly six petagrams of organic carbon are stored within the world's polar ice sheets and mountain glaciers. Dissolved organic matter (DOM) in glacial ecosystems originates from *in situ* primary production, as well as, from the deposition of terrestrial, marine, and anthropogenic organic material, and is thought to be highly bio-available. Models of glacial carbon cycling indicate that ice sheet interiors in general function as sinks of carbon dioxide (activity of primary producers convert carbon dioxide into organic carbon), whereas ice sheet edges and small glaciers act as a net source (microbes break down organic carbon into carbon dioxide which is released back into the atmosphere). *In situ* field studies show that microbial communities are the primary driver for labile dissolved organic carbon production and recycling on glacier surfaces. Furthermore, field observations suggest that biological processes in supraglacial environments can affect the physical behaviour of glaciers by changing surface reflectivity. Thus, a comprehensive understanding of the fundamental processes that control the cycling of DOM is critical. This is especially important now, as the ongoing loss of ice from glaciers and ice sheets around the world has the potential to expedite the magnitude of glacial run off and export of highly bio-available DOM to coastal environments, with unforeseen consequences for coastal food webs.**

	Laxmikant Bhardwaj, Anuj Ranjan, Abhishek Chauhan, Tanu Jindal, Amity Centre for Antarctic Research and Studies Amity University, Noida	**Lake Water Contamination Studies of lakes in Larsemann Hills over East Antarctica**	**More than 150 lakes at different islands and peninsulas are situated in Larsemann Hills, located halfway between the Vestfold Hills and the Amery Ice Shelf on the South-Eastern coast of Prydz Bay. The Larsemann Hills area is an ice-free (50 km^2) oasis on the Ingrid Christensen Coast of Princess Elizabeth land in East Antarctica that includes Bharati Island, Broknes Peninsula, Stornes Peninsula, Fisher Island, McLeod Island and several other islands. The ice-free area consists of two major peninsulas (Stornes and Broknes), 130 near- shore islands and four minor peninsulas.** **A study was undertaken in areas of Larsemann Hills to know the water quality and impact of anthropogenic activities or orographic effects. Water samples were collected from five selected locations in Broknes Island during 34th and 35th Indian Scientific Expedition to Antarctica (ISEA). Samples were analyzed for the physico-chemical parameters (pH, Temperature, TDS, Conductivity, Total Hardness, Alkalinity, and Dissolved Oxygen), Persistent Organic Pollutants (Pesticides, PCBs and PAHs) and pathogenic microbes such as Coliform, Faecal Coliform and *E. coli*. Though, all the Physico-chemical parameters were found below permissible limits, while trace level of POPs were found above Maximum Residue Limit (MRL). Four lakes water samples were found to be contaminated with Coliform bacteria, however, Faecal coliform and *E.coli* were not observed. After evaluating physico-chemical parameters, POPs and pathogenic microbes in lake water, it has been observed that the lake water samples have trace impact of anthropogenic activities.** **However, the presence of trace amount of contaminants in the samples indicates an alarming situation and need to be investigated further in view of pathogenic contamination that may lead to spread of diseases. An array of measures are required to be implemented at such locations.**

	M. Nuncio and Sourav Chatterjee, ESSO, National Centre for Antarctic and Ocean Research, Goa	**Atmospheric circulations and tele-connection patterns in Southern Hemisphere**	**Sea surface temperature (SST) variability is an important factor influencing the global climate system. On the earth, the tropics receive the maximum amount of heat. The earth's heat balance is maintained by the north-south transport of the heat received by means of various processes. This is mostly achieved by modulation of atmospheric circulation patterns. Some of the tropical variability has a distinct influence on the southern high latitudes as well. The imprints of tropical SST variability can be found in sea – ice, high latitude precipitation, air temperature, etc. More often the tropical teleconnections interact with the southern high latitude processes. Of all the oceans, the Indo-Pacific is the warmest. Among these two oceans the Indian Ocean is warming at a faster rate, a phenomena that has far reaching consequences. Under these circumstances the Indian Ocean processes also undergo changes. Most notably the Indian Ocean Dipole (IOD) has shown more positive polarity in the past two decades. Most of the Indo-Pacific teleconnection to the southern high latitude is strongly felt in West Antarctica, a climatically sensitive region. For example, melting of the West Antarctic ice sheet has the potential to raise the global sea level by 3m. While it is known that tropical Indo-Pacific has perceptible footprint in the southern high latitude, how the recent tropical changes manifest, is ambiguous.** **In this presentation we review the major atmospheric patterns of southern high latitude stele connection patterns from the Indo-Pacific and the recent changes in them.**

	Sharat Dutta[1], S.A.I. Mujtaba[2], R. Bhavani[3], Mohammad Atif Raza[4], R. Chunchekar[5], [1,2,3,4]NCEGR, Geological Survey of India, NH-5P, NIT, Faridabad, India	**Responses of Indian Summer Monsoon (ISM) dynamics and Late Quaternary fluvial development : Records from Yamuna River valley, NW-Himalaya**	**In the NW Himalaya, Late Quaternary sedimentary deposits along glacial fed Yamuna River offers an opportunity to understand thefeedback mechanism of Glacial-Interglacial cycles to ISM dynamics and resultant fluvial developmentsince MIS-5a (Interglacial). Fluvial terraces and alluvial fans contributes to major landforms along River valley from Higher Himalaya (source area) to Sub-Himalayan and comprises of ~10m upto ~180m thick gravel deposit carved into distinct terrace levels (T-1 to T-7; order of increasing height from modern Yamuna R.). In the present work, the geomorphological and sedimentological studiesand OSL based absolute chronology of these deposits constraintsmultiple phases (Phase-I to IV) of sediment dispersal and accretion in the pre-existing valleypunctuated by shorter incision periods.In the narrow upper reaches of the valley (near present glacier) and in the middle reach (Lakhamandal area), oldest fluvial aggradation (Phase-I) recorded during >83ka to ~80ka (MIS-5a) represented by distinct patches of fluvial deposits (T-7). This older aggradation indicative of limited glacial advance and fluvial (meltwater) sediment transport and deposition of gravel facies followed by incision. Phase-II aggradation continued around ~50ka to ~41ka coincides withMIS-3 (Inter-glacial stage) warm and humid climatic condition and preserved as remnant patch of fluvial deposits (T-6) followed by rapid incision owing to lower sediment: water ratio. During~37ka upto ~23ka,major sediment accretion phase (Phase-III) is recorded in the wider parts of valley (between MBT and MCT) in the form of ~120m thick clast supported fluvial gravel. This phase coincides with transitional MIS-3 & MIS-2 (Interglacial-Glacial transition). The sedimentary facies, accretion geometry suggests deposition under braided river environment. Glacier retreat and release of sediment might have responsible for such extensive aggradation under more sediment water ratio and less sediment transporting capacity of Yamuna River.**

			The aggradation phase is carved into distinct degradational terrace levels (T-3 to T-5). Another younger aggradation phase (Phase-IV) represented by discontinuous terrace deposits (T-1 and T-2) is recorded across MCT. The Late Quaternary sedimentary archives in the valley across MCT and correlation of aggradation and incision phases are well correlates with Indian Summer Monsoon (ISM) dynamics (δ18O record), and profound control of glacial-interglacial cycles since MIS-5a.

Late Submission

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IIRS-ISRO Contributions towards Himalayan and Polar Studies

Indian Institute of Remote Center (IIRS), a unit of Indian Space Research Organisation (ISRO), Dept. of Space (DOS), Govt. of India, is a premier training, education and research organization set up since last 50 years for developing trained professionals in the field of remote sensing (RS), geoinformatics and GPS technology and their applications. IIRS has large contribution towards the research studies in Himalayan regions since its inception in 1966 and in Polar Regions from past 2 years. IIRS has created high resolution optical and radar based maps for parts of Antarctica and Himalayan glaciers, which are useful for study of their dynamic characteristics. Institute has expertise in use of differential interferometry for various studies such as glacier velocity, land surface displacement due to seismic and ground water fluctuations. Such studies has been carried out in many glaciers of India as well as Nepal Himalayas. In terms of water availability in Himalayan river basins, characterization of snow pack in terms of its physical properties remains one of the crucial research areas, where IIRS has contributed in developing remote sensing based snow parameter inversion models. In view of extreme rainfall events during past couple of years, the institute has started a research cum operation project on flood early warning system and snow cover mapping. The results of near-real-time rainfall forecast are hosted at IIRS website (www.dms.iirs.gov.in). To support calibration and validation of RS based physical parameters and hydrologic forecast results, IIRS has established a network of 27 automatic weather stations (live hydromet data streaming at www.aws-dwlr.iirs.gov.in), 4 continuous observing GPS reference stations (data receiverat IIRS server via BSNL high speed network), 2 digital water level recorders,

			1 snow pack analyzer, 1 snow water equivalent gauge, and 4 snow depth sensors during 2014-2017 at different complex terrains of Uttarakhand and Himachal Pradesh. All the remote sensing and ground based instruments are a way forward for continuous hydrological and disaster related research in Himalayan region.

ICAR-DIRECTORATE OF COLDWATER FISHERIES RESEARCH

Introduction

The Directorate of Coldwater Fisheries Research (ICAR), erstwhile NRCCWF, was established in September 1987. It is located at Bhimtal, Nainital in the state of Uttarakhand.The directorate is a national facility to strengthen fishery research in coldwater sector encompassing the Himalayan and peninsular parts of the country. The research programmes undertaken by the Directorate are designed with major thrust on conservation and management of open water fisheries and development of hill aquaculture. The Directorate has its own building, research laboratories, working coldwater fish farms, wet labs, aquarium, feed mill and training center. The scientists working in the Directorate are well qualified and expert in their field of specialization. Techniques and technologies have been developed for coldwater fishery, providing services and consultancies to the State Fisheries Departments, Universities, NGOs, farmers, students and other likeminded organization having interest in coldwater fisheries development. The basic and applied research is being carried out at Directorate level and through a network involving ICAR institutes/center, Universities, Fisheries Departments and NGOs working in coldwater sector.

Mandate

1. To conduct basic, strategic and applied research in coldwater fisheries and aquaculture.
2. To develop stock management models and culture technologies for major coldwater fish species.
3. To create awareness and provide training and consultancy.

Mission

To become a national facility of excellence for assessing and managing coldwater fishery resources, develop technologies and models of hill aquaculture and provide critical inputs in formulating strategies for sustainable growth and development of the sector.

Achievements

- Artificial breeding of golden mahseer,*Tor putitora* and designing & fabrication of flow through hatchery for its mass scale seed production.
- Redevelopment of mahseer fishery in Lakes, rivers and streams for conservation and sport.
- Nutritional requirements and Formulation of diets for Golden Mahseer and Rainbow Trout.
- Composite Fish farming system for mid Himalayan region based on major Chinese carps viz., Common carp, Silver carp and Grass carp.
- Polyculture of major Chinese carps in polytanks.
- Induced maturation, breeding and seed production techniques for grass carp and minor carps (*L. dyocheilus, L. dero*) at higher altitude in coldwater.
- Artificial propagation and seed raising of chocolate mahseer (*N. hexagonolepsis*) in NEH region, Arunachal Pradesh.
- Rearing, breeding and production of rainbow trout (*O.mykiss*).
- Ecological management for fishery enhancement in Hill wetlands.
- Genetic characterization of Indian snow trout, *Schizothorax* sp.
- Fish health management and diagnostic.
- Coldwater fisheries resource characterization and database development.

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