A Report on

Proceedings of Conference on
Science & Geopolitics of Himalaya-Arctic-Antarctic
Focussing Climate Change

Held on November 30 & December 1, 2017
at JNU Convention Centre,
Jawaharlal Nehru University, New Delhi.

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ACKNOWLEDGEMENT

The LIGHTS Research Foundation would like to place on record the guidance received from the esteemed patrons without whose blessings the IV Conference on Science and Geopolitics of Himalaya-Arctic-Antarctic (SaGHAA-IV) would not have been possible. We are indebted to them for their persistent bond, help and valuable suggestions.

Throughout the duration of the conference, from the concept building to its execution, we banked highly on the guidance and advice that we received from the members of the Advisory Committee. We are grateful to them for their time and patience with us.

The LIGHTS would also like to appreciate the Organizing Committee of SaGHAA-IV for the smooth and flawless management of the event that recorded active participation of scientists, legal expert and the policy makers.

We extendour warm gratitude all the session chairs, distinguished speakers, participants and guests for sharing their enlightening research concepts, participating in the discussions and contributing to the recommendations. The SaGHAA-IV owes its success to their contributions and participation.

The conference was supported by the various organizations without whose generous financial support it would not have been possible to manage the conference expenses on accommodation, transport, auditorium, stage and refreshments etc. We are grateful to all of them.

Last but certainly not the least, we thank all our office staff for their uninterrupted enthusiasm and support for contributing to the success of the Conference.

The composition of various Committees, mentioned above is given below:

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EXECUTIVE SUMMARY

Prelude

The 4rth Conference on Science and Geopolitics of Himalaya, Arctic and Antarctic (SaGHAA IV, 2017) was organised at Convention Centre, Jawaharlal Nehru University, New Delhi, India on November 30 and December 1, 2017 in continuation of previous SaGAA conferences of 2015, 2012 and 2011. These three Polar Regions have drawn the attention of scientists and researchers in the last few decades like never before due to the unprecedented changes in environment and morphology and emergence of political interventions and strategic scientific developments Arctic Region is transforming fast as the change in climate has increased melting of sea ice and opened accessibility in otherwise frozen Arctic. The growing demand for energy resources has further encouraged exploitation in these parts raising the concern of environmentalists. Loss of ice shelves in Antarctica too has increased over the past few decades.. Calving of great portions of Larsen ice shelf has demonstrated the impact of global warming on sensitive ecological parts of our Earth. Himalaya – the Third pole, analogous to Polar Regions, needs increased attention as nearly 1.3 billion population of the world depends upon its resources, especially the water, for sustenance of the life. Three of the world's major rivers—the Indus, the Ganges and the Brahmaputra—originate in the Himalayas. Any major stress on water availability either under the climate change scenario or because of greater demand can only lead to conflict between the countries sharing the resources. The decreasing snow and ice cover and the impact on the the regional climate and consequent global cimate due to tele-connections is a matter of concern.

Objectives

The main objective of the conference was to evolve a synergy between scientists and social, political and legal experts working in the cryosphere of three Polar Regions i.e. – Himalaya, Arctic and Antarctic. The Conference also aimed at providing a networked platform for scientists, discuss the policy issues and the role of developing countries like India in Polar Regions as also to develop capacity building and outreach for students.

The Themes

The SaGHAA-IV bounded the issues of science and geopolitics with special focus on climate change. These themes helped enhancing our understanding of the issues dominating the cryospheric realms of the world. The two days of deliberations covered five broad themes which were divided into nine technical and one valedictory sessions
as follows:

a. Climate Change: current assessment, national and international response and policies.
b. Geopolitics of Poles.
c. Arctic and Antarctic Science and cold Response Technologies.
d. Climate Change and Dynamics of Himalayan Glaciers, ecosystem and Biodiversity. e.Ocean Research.

A special session was devoted to capacity building and outreach where young researchers were given an opportunity to present their research results in short.

Focus

The climate change is causing concern world over, more so due to visible impacts on sensitive Polar Regions. The conference discussed several key issues such as melting of ice shelves in Antarctica, depleting sea ice in Arctic and its consequences, opening of new maritime routes, health and dynamics of Himalayan glaciers, fishery development etc. A need to assess the changing storage capacity of water in glaciers, rate of glacier retreat and velocity, prediction of Glacier Lake Outburst Flood (GLOF), mass movements, surge anomalies, extreme events, climate modeling, teleconnections of climate etc was also taken up. The social, legal and political experts shared their views on adaptation of hill population to changing climate, geopolitical scenario in Arctic and Antarctic and pointed out that ushering of a new epoch of Anthropocene requires suitable policy decisions to keep pace with changing times.

Support and Participation

An event like SaGHAA which attracted experts and researchers from all over the country and some foreign nations was possible due to generous support from several government

departments and organizations. These were: Ministry of Earth Sciences and its autonomous institutions-NCAOR, NIOT, INCOIS, CMLRE, IITM, NCESS; Ministry of Environment, Forest & Climate Change; Science and Engineering Research Board, SPLICE of Department of Science and Technology, National Institute of Oceanography, National Geophysical Research Institute, National Remote Sensing Centre, Geological Survey of India, National Biodiversity Authority, Central Institute of Fisheries Technology , Department of Biotechnology, Indian Space Research Organisation, Indian Council of Agricultural Research, Directorate of Cold water Fisheries Research , Royal Norwegian Embassy and CN Technology.

The success of SaGHAA IV was essentially due to participation of reputed, well known scientists and delgates such as Dr M N Rajeevan, Dr Shailesh Nayak, Dr P S Goel, Dr K J Ramesh, Dr M Ravichandran, Dr S C Shenoi, Dr Sunil Kumar Singh, Dr M Sudhakar, Dr M A Atmanand, Dr V M Tiwari, Dr I M Bahuguna, Dr Rasik Ravindra, Prof C R Babu, Dr M R Bhutiyani, Dr Ashwagosha Ganju, Dr R Krishnan, Dr Rajeev Nigam, Dr Amit Dharwadkar, Dr S P Shukla, Dr S C Kar, Prof Bimal N Patel, , Dr Gopal Iyengar, Dr E N Rajagopal, Dr S Rajan, Dr N Tuteja, Dr G A Ramadass, Dr S Sathyakumar, Dr Rajeev Mehajan, Dr Sujata Das, Dr S K Nandi, Dr Luther Rangreji, Dr Renoj Thayyen, Dr Nisha Mendritta, Dr Malti Goel, Prof R Ramesh, Prof N C Pant, Prof A L Ramanathan, Prof Sanjay Chaturvedi, Prof A P Dimri, Prof S A Romshoo, Prof Sarfaraz Alam, Dr Thamban Meloth, Dr S C Tripathy, Dr Manish Tiwari, Dr Susheela Negi, Dr Parmanand Sharma, Dr Sandip Kumar Roy, Dr Sharat Dutta, Dr Ashit Kumar Swain and others. Among the notable foreign delegates were H E Nils Ragnar Kamsvag, Dr Nalan Koc and Dr Arild Sundfjord from Norwey and Dr Walter Roest from France.

INAUGURAL SESSION

The inaugural session of SaGHAA IV 2017 began with a welcome address by Dr. Rasik Ravindra, Chairman, SaGHAA Organising Committee and former Director, ESSO – National Centre for Antarctic and Ocean Research (NCAOR), Goa. The Guests of Honours - Dr. Shailesh Nayak, Distinguished Scientist, Ministry of Earth Sciences (MoES), Dr. P.S. Goel, Raja Ramanna Chair Professor, Indian Space Research Organisation (ISRO), Dr. Nalan Koc, Research Director, Norwegian Polar Institute (NPI), Norway and H.E Nils Ragnar Kamsvag, Ambassador, Royal Norwegian Embassy, India addressed the gathering subsequently. The presidential address was given by Dr. M N Rajeevan Chief Guest and Secretary, Ministry of Earth Sciences (MoES), which was followed by the vote of thanks by Ms Sulagna Chattopadhyay, Convenor SaGHAA IV 2017 and President LIGHTS Research Foundation,

The highlight of the inaugural function was the presence a galaxy of luminaries and whos- who in the field of Cryosphere research in India. Among the distinguished guests who attended the inaugural session were, Dr. K J Ramesh, DGM, India Meteorological Department (IMD), Dr. M Ravichandran, Director, National Centre for Antarctic and Ocean Research (NCAOR), Dr. Walter Roest, Former Member, UN Commission on LCS, Dr. M R Bhutiyani, Director, Defence Terrain Research Laboratory (DTRL), DRDO, Dr. Ashwagosha Ganju, Director, Snow & Avalanche Study Establishment (SASE), DRDO, Dr. S C Shenoi, Director, Indian National Center for Ocean Information Services (INCOIS) & National Institute of Ocean Technology (NIOT), Dr. Sunil Kumar Singh, Director, National Institute of Oceanography (NIO), Dr. M Sudhakar, Director, Centre for Marine Living Resources and Ecology (CMLRE), Prof Bimal N Patel, Director, Gujarat National Law University (GNLU), Dr. E N Rajagopal, Director, National Centre for Medium Range Weather Forecasting (NCMRWF), Dr. Luther Rangreji, Director, L&T Division, Ministry of External Affairs (MEA),

Govt. of India, Dr M K Rao, Consultant MEA, India, Prof Sanjay Chaturvedi Punjab University, Prof A L Ramanathan, Jawaher lal NehruUniversity, New Delhi, Dr. R Krishnan, Director, Centre for Climate Change Research, IITM, Dr Atmanand, NIOT, Chennai, Dr S. Rajan, Former Director, NCAOR,, Dr Nitesan, Deputy Director General Geological Survey of India, Dr. Amit Dharwadkar, and Dr S P Shukla Directors, Polar Division, Geological Survey of India (GSI), Dr B R Arora, former Director Wadia Institute of Himalayan Geology, Dehra Dun , Prof Tanu Jindal. Director, Amity School of Antarctic Studies, Amity University, NOIDA, among others. The ceremonial session started by the introduction of the key personalities by Ms. Sapna Gupta, Master of Ceremony, SaGHAA IV 2017, LIGHTS Research Foundation.

Welcome address by Dr. Rasik Ravindra

Former Director, National Centre for Antarctic and Ocean Research (NCAOR), Chairman, SaGHAA IV 2017

Dr. Rasik Ravindra welcomed the Chief Guest, Dr M N Rajeevan Secretary Ministry of Earth Sciences (MoES); Guests of honour- Dr Shailesh Nayak Distinguished scientist MoES; Dr P S Goel, Raja Ramanna Professor ISRO;, Dr. Nalan Koc, Research Director, Norwegian Polar Institute (NPI), Norway and H.E Nils Ragnar Kamsvag, Ambassador, Royal Norwegian Embassy, India; delegates, researchers and students who were gracing the Conference. He said that while excellent science is being done in India and abroad in various fields of Polar sciences by various institutes; scientists generally feel shy in bringing geopolitical angles to light.. In this regard he applauded the efforts of SaGHAA for being instrumental in evolving the synergy between Scientists and Geo-politicians. He recalled continued support of Royal Norwegian Embassy in India for the SaGHAA events in past too, and welcomed H E the Ambassador Nils Ragnar Kamsvag as also thanked him for his interest in fostering Indo-Norwegian collaboration in the field of science and technology. He mentioned that the conference would not have been possible without the support and financial assistance of Ministry of Earth Sciences and other Government Departments and the well wishers. Dr Ravindra noted the gracious presence of nearly all the Directors of leading organizations from across the nation which are active in the field of atmospheric sciences, glaciology, oceanography and socio-legal sciences in the Conference and welcomed them all.

Address by Dr. Shailesh Nayak

Distinguished Scientist, Former Secretary, Ministry of Earth Sciences

Dr. Shailesh Nayak in his brief address said he was happy to participate in the Conference especially as it was discussing all the three cryosphere regions i.e. Himalaya, Arctic and Antarctic together. He said that in the past decades we have realized the importance of Polar Regions and their role in modulating the global climate. He added that while we have, by and large, understood the role of ocean and atmosphere in modulating the climate but contributions of Polar Regions in modulating the climate is still not clearly understood. He cited the example that dust generated from outside the Polar Regions such as Argentina & Chile is influencing the Polar Regions It is not enough to control human activities in Polar Regions but it is equally important to monitor such activities outside the regions to preserve the pristine environment.. He stressed that we need to understand the natural and human induced changes to our environment by looking at the past climate i.e. to know what happened in glacial and inter glacial periods during Quaternary and Holocene in particular. The understanding of palaeoclimate is mostly coming from ice-core studies from Antarctica and Arctic but very little coring for ice has been achieved in Himalaya due to difficult accessibility and very high altitudes... He was sure that discussions and useful deliberations during the conference would lay the foundation of futuristic studies in Arctic-Antarctic and Himalaya.

Address by Dr. P.S. Goel

Raja Ramanna Chair Professor, Indian Space Research Organisation

Dr. P. S. Goel recalled his first meeting with the Convener of SaGHAA, Ms Sulagna Chattopadhyay in 2005 when he was the Secretary of

MoES. He shared his earlier doubts about the role of an NGO like LIGHTS Research Foundation in the field of science and geopolitics in the regions such as Arctic and Antarctic as he thought at that time such issues lay in the realm of national institutions He said that later he realized that in the domain of diplomacy we need an independent platform where free and frank pinions can be shared. which may not be possible in an official forum. He was happy that both of his successors Dr. Shailesh Nayak and Dr. M N Rajeevan have continued to support this particular platform. He also announced that proceedings of, SaGHAA Conference held in 2015 have been published by Springer which confirms the important role that SaGHAA is playing in this field. He appreciated theme based conference as he felt that having a same theme every time may not keep the interest of scientists alive. The theme of Climate change therefore was conceived for SaGHAA IV 2017 Since the tele-linkage between Himalayan regions the Arctic and thus our monsoon are now well established, this theme will be well received by scientists.. He further suggested that LIGHTS should consider themes such as Technologies of human habitability for its future conferences.. He said that he was overwhelmed by such good response to conference.

Address by Dr. Nalan Koc

Dr. Nalan Koc, Research Director, Norwegian Polar Institute (NPI)

Dr. Nalan Koc expressed her gratitude to the organizers for inviting her to participate in SaGHAA IV 2017. She expressed her concern about rapid rise of Carbon Dioxide in the atmosphere that has soared to over 400 ppm. The warming globe is affecting Polar Regions too, especially as melting of sea ice in Arctic has reached a critical stage. She added that atmosphere, ocean, ice and ecosystem component of climate are all coupled in a global system.. So, the Arctic, Antarctic and Himalaya are not independent systems but are being influenced by what is happening in rest of the world and vice-versa, making the entire situation complicated and complex to understand. She emphasized that since a single country may not have enough resources to address these questions, therefore international cooperation is the only solution. In regards to India, she mentioned about long standing collaboration and close cooperation between Norwegian Polar research community and Indian scientific institutions despite geographical distances. She gave an example of a joint Indo-Norwegian research project-MADICE, where scientists of two countries are working hand in hand in Antarctica.

Address by H.E Nils Ragnar Kamsvag

H.E Nils Ragnar Kamsvag, Ambassador, Royal Norwegian Embassy, India

H.E Nils Ragnar Kamsvag spoke about the growing concern and attention that the themes of the present conference is drawing both politically as well as economically. He said that what is happening in Arctic, Antarctic and Himalaya has global implication in term of climate, politics and security. As per him the present conference was the strong example of importance of issues that will be discussed and also of the requirement of strengthening of global fraternity in this field. He outlined the Norwegian approach to research with Arctic strategy which includes five pillars viz international cooperation, business development, knowledge development, infrastructure and environmental protection with, emergency preparedness. He informed the audience that Norway and India were running joint projects in these fields. He mentioned that new research vessels were going to be part of the Norway research shortly which will greatly enhance the ability to carry out research in Polar Regions. He added that private and public sector collaboration is being solicited in the field of research and development of technologies. He also talked about joint research activities with India and appreciated Indian contributions in term of resources in the polar research. He concluded his talk by revealing about possible future research cooperation i.e. upcoming "Horizon 2020" call which will also be financing joint Indo-Norway Projects.

Chief Guest Address by Dr M N Rajeevan

Dr M N Rajeevan, Secretary, Ministry of Earth Sciences (MoES)

Dr M N Rajeevan congratulated the team

of LIGHTS for organizing such an important event as he said that any change in cryospheric system can affect the climate balance and lead to consequent changes in global climate. He added that melting of Arctic sea ice at unprecedented rates was an example in this regard Himalayan glaciers are also retreating and that could have bad impacts on biodiversity, hydrological cycles, surface runoff, etc. He mentioned that many research papers point towards relationship of Arctic sea ice melting with extreme weather events especially in Europe and even in East Asia. Arctic ice melting has tele links with Indian Monsoon too.. According to IPCC climate change projections, by 2060-70 there will be no sea ice in Arctic. He stressed the need for documentation of these changes and to develop a climate policy including adaptation and mitigation measures. He then talked about India's presence in Antarctica with two operational research stations and one new polar research vessel which is being procured for polar research. He informed the gathering that a research station named HIMANSH has been established near Batal in Lahaul-Spiti district of Himachal Pradesh to study glacier dynamics. He also described India's climate research efforts such as establishment of a centre for Climate Change Research at IITM and declared that India's air modeling system will be the part of IPCC climate change assessment and it will be a big milestone in India's history. He also announced that for strengthening climate change modeling, India is going to establish base climate reference stations.. He encouraged other institutes to come up with research ideas.

Vote of Thanks by Ms. Sulagna Chattopadhyay

Ms Sulagna Chattopadhyay, Convenor, SaGHAA IV 2017 and President, LIGHTS Research Foundation

Ms Sulagna Chattopadhyay gave heartfelt thanks to all the distinguished guests, speakers and all the delegates for their participation in the conference. She gave special thanks to Dr. P.S. Goel for his guidance which she said SaGHAA has been receiving right from its inception. She appreciated Dr. Shailesh Nayak's valuable inputs and his presence since first SaGAA to the current one. She thanked Dr. M N Rajeevan and Dr. M Ravichandran for their support and Dr. Nalan Koc for making special effort to attend the SaGHAA-IV. Me Sulagna Chattopadhyay said she was grateful to H E Nils Ragnar Kamsvag, Ambassador, Royal Norwegian Embassy, in India for his presence and support. She said SaGHAA has greatly benefitted by the presence of scientists such as Dr S C Shenoi, Dr M Sudhakar, Dr. R Ramesh, Dr V M Tiwari, Dr Sunil K Singh, Dr Rajeev Nigam, Dr. S Rajan, Dr. Arild Sundfjord, Dr. Einar, Dr Bhutiyani, Dr Romshoo, Dr Thamban, Dr Tiwari, Dr. Atmanand and others. Who have spoken abvout their recent work in the conference. She also paid compliments to Prof Bimal Patel, Prof Sanjay Chaturvedi, Prof N C Pant and Prof Ramanathan for their efforts and guidance. She thanked the delegates and participants for contributing their papers to the conference which are going to play main role in making the Conference on Science and Geopolitics of Himalaya, Arctic and Antarctic (SaGHAA IV 2017) a success.

SESSION 1: Synergy between Himalaya-Arctic-Antarctic

Theme 1: Climate Change Current Assessment, International/ Indian response and policies

Chaired by Dr. Shailesh Nayak, Distinguished Scientist & Former Secretary, Ministry of Earth Sciences (MoES) and Dr. K J Ramesh, DGM, India Meteorological Department (IMD).

The session started with Dr. M Ravichandran's paper on "Present and Future directions of Polar research by India". This was followed by Dr. I M Bahuguna's paper on "Observing Himalayan and Polar cryosphere through Indian satellites", Dr. E.N Rajagopal's paper on "Polar Sea-Ice Simulation with a Coupled Model at NCMRWF" and Dr. R Ramesh's paper on "Identifying melt water signatures in Polar Regions using oxygen isotopes". Two other papers presented in the Session were: Dr. Nalan Koc's paper on "Changing Arctic sea-ice regime: regional and global consequences" and Dr. Parmanand Sharma's paper on "Glacier response to climate in Arctic and Himalaya during twenty first century: a case study from Svalbard, Arctic and Chandra basin, Himalaya".

Dr. M. Ravichandran

Director, National Centre for Antarctic and Ocean Research (NCAOR)

Dr. M. Ravichandran mainly presented activities of NCAOR in Polar Regions i.e .to plan, promote, co-ordinate and execute scientific research in all three Poles (Antarctic, Arctic and Himalaya) as well as in surrounding oceans. He stated the 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.. He also discussed the key future questions such as : augmenting Polar research vessel, renew/build new Maitri station, strengthening observations in all three poles, dedicated atmospheric/astrophysics lab, polar biology lab, National polar data center, 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, sea ice, tele-connection between poles and tropics and others, where India will focus in the future.

Dr. I M Bahuguna

Scientist G, Space Applications Centre, ISRO

Dr. I M Bahuguna presented the contribution of Space Application Centre (SAC) to the development of techniques for the collection and extraction of relevant information on snow, glaciers, ice sheets and sea ice derived from earth observation data acquired by sensors on board Indian satellites over decades.. He briefly discussed about main contributions of SAC towards Himalayan and Polar Cryosphere with examples such as creation of Himalayan glacial inventory, development of Himalayan glacier information system (HGIS), 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, 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. He also mentioned that SAC scientists also carry out field validation of data in Himalaya and Antarctica.

Dr. E N Rajagopal

Head, ESSO-NCMRWF, MoES

Dr. E N Rajagopal spoke about NCMRWF's coupled model that is being used under Monsoon mission, and highlighted polar sea-ice simulation during his presentation. He briefly discussed NCMRWF's current Operational Data Assimilation systems and Unified models that are being used for global, regional and convective scales. He said HadGEM3AO model has been implemented at NCMRWF and is being run in real-time for polar prediction. The global coupled model have UM, NEMO, CICE and JULES as the respective sub-models for the atmosphere, oceans, sea-ice and land surfaces respectively. He also presented various results of coupled modeling forecasts of the mean sea-ice concentration, extent and thickness in both the poles, simulation of inter-annual variability in Arctic, etc. with verifications and comparisons.

Dr. R Ramesh

NISER, Bhubaneshwar

Dr. R Ramesh in his paper explained how to identify melt water signatures in Polar Regions using oxygen isotopes. He presented some examples from Arctic and Himalayas. He explained the linear relationship between the salinity and the $\delta^{18}O$ of the surface ocean changes and how it can be used to trace melt water signatures in oceans too. Basically, ice/snow melt reaches the surrounding oceans and reduces the surface salinity as also the $\delta^{18}O$, since the freshwater in the Polar Regions is extremely depleted in $\delta^{18}O$. He spoke about the developed theoretical model through which the changes can be quantified through knowing changes in the slope and intercept of the salinity-$\delta^{18}O$ relationship of the surface ocean and described how the melt water flow into the Bay of Bengal from the Himalaya and also the Arctic was calculated. We noted that this was a useful method to complement satellite data.

Dr. Nalan Koc

Research Director at the Norwegian Polar Institute, Tromso, Norway

Dr. Nalan Koc presented results from Arctic region stating that the data was open for sharing to research community.She showed that not only the sea-ice cover of Arctic has changed drastically over the decades but also the thickness of sea-ice has changed. She was concerned over the Arctic sea-ice melting and stressed that many questions such as what melts the ice, how does the thinner ice respond to atmospheric forcing, what are the effect of the changed sea ice system on ice-associated ecosystem etc. need to be answered. She then discussed the N-ICE2015- Norwegian Young Sea ICE cruise expedition to Arctic in 2015 and its main findings that include – unexpected thick snow cover, new and growing ice formed with little snow, stroms slowing ice growth, ocean heat flux increased twofold during storms, early phytoplankton blooms below thick snow-covered sea ice, etc. She concluded by saying that the warmer Arctic is changing Northern Hemisphere weather patterns.

Dr. Parmanand Sharma

Scientist, Cryosphere Science Division, ESSO-National Centre for Antarctic and Ocean Research, Goa

Dr. Parmanand Sharma talked about Glacier response to climate in Arctic and Himalaya with a case study from Svalbard, Arctic and Chandra basin, Himalaya. He presented results on various glacier parameters such as ice density, annual/cumulative mass balance, mean annual temperature and precipitation, etc. obtained from different glaciers in Chandra basin and Svalbard. He concluded his presentation with the result that 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. Arctic 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.

Outreach & Capacity Building: Students Rapid Shot Session/Career opportunities

Chaired by Prof. N C Pant, Professor, Department of Geology, Delhi University and Prof. Sarfaraz Alam, Associate Professor, Banaras Hindu University

The session began with an address by Prof. Sarfaraz Alam on geopolitics. His address was followed by the presentation of Mr.Amir Khan on "The Water budget of the Himalayan river system-gaps and the strategic significance of Cryosphere and Hydrosphere". The other presentations were made by Mr. Rupendra Singh, Ms Neelu Singh, Mr. Virendra Bahadur Singh, Mr. Ankit Pramanik, Mr. Prashant Pandit, Mr. Sathiyaseelan R, Ms Padma Ladonand Ms. Seema Rani.

Prof. Sarfaraz Alam spoke in detail about geopolitics and its significance in careers. He began with the history, different interpretations and misuses of the concept and described the geopolitical scenario. Subsequently he gave a detailed presentation on career opportunities as a geopolitical analyst. He also discussed significance of geopolitics in context of climate change,business and trade.

Mr. Amir Khan

Research Scholar, Delhi University

Mr. Amir khan spoke about the major components of hydrological budget of Himalayan Ecosystem. Beginning with importance of Himalayan Water to Asia, he presented data on precipitation and glacial melt from different areas of Himalayan region. He gave estimate of glacial melt, ice volume, thinning, etc. from upper Ganges, Alaknanda and Bhagirathi basin along with model used.

Mr. Rupendra Singh

Research Scholar, Sharda University

Mr. Rupendra Singh spoke about people's perception of climate change in Shyok Sub-Basin. He described his study area, objectives and methodology used to collect the data (sampling – group discussion) from local population. Few results from this study such as snowfall/rainfall increase in winters/summers, use of solar energy and air pollution were shown. He concluded his presentation by saying that people of Shyok have accepted that climate change and have adopted to new techniques to raise the agriculture productivity.

Ms. Neelu Singh

Research Scholar, NCAOR

Ms. Neelu Singh spoke about Impact of Climate change on fate and transportation of (Persistent Organic Pollutants (POPs) in the Arctic. She explained the global transportation and sources of POPs, its release in atmosphere from glacier under climate change etc. She also presented evidences of climate change and its impacts on POPs in the Arctic i.e. influence of ice cover on the sear-air exchange of α-HCHfrom her study in Ny-Alesund, Svalbard.

Mr. Virendra Bahadur Singh

Research Scholar, School of Environmental Sciences, JNU

Mr. Virendra Bahadur Singh presented his work on glacial runoff characteristics of the Chhota Shigri Glacier of Himachal Pradesh. He described the study area and methodology used for estimating runoff and showed

the results for different time periods. He presented new data on discharge, storage characteristics of glacier runoff, diurnal variation, hydro-meteorological relationship i.e. strong relation between temperature and runoff which lead to increasing trend of melt water from June onwards to maximum value in July and August, melt water decrease in early part of ablation season that reduces with progress in melt season and minimum runoff during morning and maximum in the evening.

Mr. Ankit Pramanik

Research Scholar, NPI

Mr. Ankit Pramanik presented his talk on Glacier mass balance and associated fresh water flux in the Kongsfjord Basin of Svalbard. Study area charcteristics such as land and marine terminating glaciers, DEM,Mass balance evolution of entire glacierized area (1980-2016) andquantification of fresh water flux to the fjord were explained. Motivation behind study, approachand results on glacier mass balance and fresh water flux were also discussed. A coupled energy balance-snow model used to simulate mass balance and runoff of glaciers around Kongsfjord, model was calibrated with AWS and stakes measured winter and summer balance data. Glaciers in Kongfjord basin show variability in mass balance. Glaciers in south and east show more negative mass balance. Investigations on hydrology and a runoff routing model to quantify fresh water flux to the fjord was done which indicate that Kronebreen and Kongsvegen contributes maximum fresh water to the fjord.

Mr. Prashant Pandit

Research Scholar, The Energy and Resources Institute, New Delhi

Mr. Prashant Pandit presented his Master's thesis work on deriving glacier velocity of Polar Record Glacier (PRG) of east Antarctica using SAR Interferometry and discussed its significance for understanding the glacier dynamics. Results on velocity estimates of PRG indicating very high velocities were shown. He concluded that the velocity of PRG is approx. 3m per day in tongue portion and nearly 1m at upper inland part, eastern part having slower rate than the western part. Estimated average velocity of the PRG was approximately ≈400 m/year which varies from ≈100 to ≈700 m/year. PRG moves with a velocity of ≈700m/year in lower parts whereas the upper inland area flows with a velocity of ≈200m/year. The western part of the glacier was moving faster in comparison with the eastern part of the glacier.

Mr. Sathiyaseelan R

Research Scholar, Indian Institute of Technology, Delhi

Mr. Sathiyaseelan presented his work on modelling of the past and future mass balance of the Himalayan Glaciers and described the model mass balance of glaciers to understand the drivers of past changes and hydrological implications and model future changes to glacier mass balance in the Himalayas. The glaciers selected for the study, observed annual specific mass balance on these glaciers, datasets used and mass balance model applied were explained. He showed the comparison between observed and modelled mass balance and discussed the biases in detail. Modelled historical and RCP 4.5 and 8.5 projections results were also compared and discussed. He stated that few glaciers with long record of mass balance observations are available for the Himalayas. Glaciers with longer record of mass balance observations are better for modeling. He further asserted that model errors in precipitation larger than temperature errors, affects mass balance calculations and the RCP 8.5 scenario shows a comparatively larger loss of ice mass at the end of century than RCP4.5.

Ms. Padma Ladon

Ms. Padma Ladon presented a talk on Traditional Knowledge Systems (TKS) that helps in adaption to the climate change. She explained the Himalayan climate change scenario and its impacts and explained how traditional knowledge can contribute to climate change adaptation. She then explained various weather related adaptation practices such as fragmented land holdings,

high agrobiodiversity within different agro-climatic zones, identification of safe habitation, introduction of new crops, etc. with example from various regions across Himalaya. She concluded her presentation with facts that TKS have the adaptive capacities which can be harnessed by the formal systems. She said documentation on whole range of TKS in IHR is in progress for creating a sound database for formal system to take advantage of this traditional wisdom.

Ms. Seema Rani

School of Environmental Sciences, JNU

Ms. Seema Rani presented her findings from study on response of streamflow under climate and land cover change Scenarios in the Upper Be as Basin. The study was undertaken with an aim to assess the response of stream flow in the basin under different climate and land cover change scenarios by mid-century. Study area, Methodology and data sources used for the study were subsequently explained. Results from Soil & Water Assessment Tool (SWAT) modelling such as seasonal variation in snow cover area (SCA) of the study area, temperature, precipitation and land cover change under different climate change scenario were presented. Detail methodology, calibration, and validation along with uncertainties were also explained. Parameterization and results on simulated annual cycle of streamflow by month in response to various changes in temperature andrainfall,change in annual mean flow etc. were discussed.

SESSION 2: Climate Sciences

Theme 2: Climate Change and Health of Himalayan Glacier

Chaired by Dr. Ajit Tyagi, Air Vice Marshal (Retd.) & Former DGM, India Meteorological Department (IMD) and Dr. Rajeev Mehajan, Head & Advisor – EAS Division, SERB

The session started with Keynote address by Dr. R Krishnan from Indian Institute of Tropical Meteorolgy, Pune , who presented his paper on "Understanding non-monsoonal precipitation response in the Karakoram and Hindu Kush Himalayas to climate change". Subsequently Prof. AP Dimri gave a talk on "Indus: Climate and Water Budget" followed by Dr. S C Kar presenting his paper on "Dynamic Down scaling of Climate over the Himalayas".

Dr R Krishnan

Scientist G, Executive Director, Indian Institute of Tropical Meteorology, Pune, Maharashtra

Dr R Krishnan talked about importance of the western disturbances to Himalayan cryosphere that bring precipitation in Winter-to-early spring in the western Himalayas (WH). He mentioned that the large-scale dynamical controls on the non-monsoonal wintertime precipitation response to climate change are largely unclear thus need better understanding. He presented the study conducted with long-term high-resolution climate change simulations with and without anthropogenic forcing elements. He showed results that indicate the rising trends in surface temperature over the Himalayan region during the 20th century are largely

attributable to anthropogenic effects. He showed that 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..He concluded by saying that with the increased WD activity we can expect snowfall enhancement in higher elevations of Hindu-Kush Himalaya.

Prof AP Dimri

Prof. School of Environmental Sciences, JNU

Prof AP Dimri presented preliminary analysis of Indus River Basin (IRB) and discussed the changing climate and its impact

on the water budget. He discussed the methodology that include regional climate models (REMOs) coupled with the MPI-ESM-LR global model from the present (1970-2005) and future (till 2099) under 2.6W/m^2 and 8.5 W/m^2 representative concentration pathways (RCPs). He then explained the model outputs and showed that there is likely increased precipitation over upper (and decreased for lower) IRB. There is heterogeneous warming over the region also. These changes in basic climate variables will have a huge impact on the corresponding water budget. He raised serious concern over the higher (lower) evapo-transpiration over the lower (central) IRB that will lead to water issues. He mentioned that the linkages with corresponding snowmelt, runoff and total water budget indicate depleting water over the southern IRB. He said in the coming future lower Indus basin will be drier whereas upper Indus Basin will have comparatively higher water storage.

Dr S C Kar

Scientist-G, National Centre for Medium Range Weather Forecasting, Noida, Uttar Pradesh

Dr S C Kar talked about dynamic downscaling of Climate in Himalayas and its importance in context of extended range, seasonal time scales, predictions etrc. He showed the variability in satellite derived snow data with that of atmospheric re-analysis data and discussed the mechanism of snowfall and snowmelt variability of the western Himalayas. He discussed the variability in temperature and precipitation in Karakoram Himalaya. He also showed the results of dynamic downscaling simulations using a high-resolution WRF model and a regional climate model (RegCM) and enlightened sensitivity of cloud microphysics schemes in the WRF model that allows simulation of snowfall over the high mountain top or on the slopes. Mid-21st Century Climate Projections over Western Himalayas was also discussed by him. He demonstrated results of surface hydrology model (SWAT) that simulated stream flow due to snowmelt and rainfall in Sutlej River.

SESSION 3:

Theme 3: Himalayan Ecosystem and Biodiversity, Climate Change, Mitigation and Adaptation

Chaired by Prof. AL Ramanathan, Professor, School of Environmental Sciences, Jawaharlal Nehru University and Dr. Malti Goel, CEO, Climate Change Research Society.

The session on Himalayan ecosystem and biodiversity had a key note paper and three scientific papers. It started with Key note paper of Dr Nisha Mendiratta on "Addressing S&T capacity building in climate change for the Indian Himalayan Region: DST Initiatives". This was followed by Dr. S K Nandi's paper on "Need for reorienting climate change debate in the Himalaya – Balancing the Approach". Subsequently, Dr. Sharat Dutta spoke on "Responses of Indian Summer Monsoon (ISM) dynamics and late quaternary fluvial development: Records from Yamuna River valley, NW-Himalaya" and Dr Susheela Negi gave a talk on "Assessing vulnerability and risks due to climate change for the Indian Himalayan Region (IHR)".

Dr. Nisha Mendiratta

Adviser and Associate Head, Climate Change Programme, SPLICE Division.

Dr. Nisha Mendiratta talked on objectives and initiatives taken by DST about addressing S&T capacity building in climate change fo the Indian Himalayan Region under the NMSHE (National Mission for Sustaining the Himalayan Ecosystem) mission..She described the major programmes and projects launched under NMSHE that include establishment of Centre of Glaciology at Wadia Institute of Himalayan Geology, 6 Thematic Task Forces in 6 lead institutions, State Climate Change Centres in 11 out of 12 Himalayan States, Inter-University Consortium of 4 universities and Indo-Swiss Capacity Building Programme in glaciology and related areas. She finished her talk with discussion over impacts and benefits gained by society, new programmes for building human and institutional capacity for Indian Himalayan Region (IHR) under NMSHE mission.

Dr. S K Nandi

Scientist 'G' & Group Head, G.B. Pant National Institute of Himalayan Environment and Sustainable Development

Dr. S K Nandi addressed the issue of need for reorienting the climate change debate in Himalayan region. He described the importance and resources of the Himalaya and raised the current and future concerns of climate change and its impacts on Indian Himalayan Region (IHR). He showed that climate projection studies have been centred on the HKH region which is largely dominated by grasslands of the Tibetan plateau and hence may not reflect true IHR scenario. He stated that intensive investigations in IHR, would be necessary to give future climate change projections of this region. He showed the forest cover changes from 2001 to 2015 along with status of dense forest/ threatened plant species in IHR. He also mentioned various projects being under taken ,under NMSHE mission such as Long Term Ecological Monitoring sites in Forest ecosystems and Long-Term Observation Sites (LTOS) in Alpines and activities such as database of plants, campaigns for vegetation assessment, assessment of changes in forest cover and uses of forest resources and documentation and validation of adaptations to cope up with climate change, etc.

Dr. Sharat Dutta

Senior Geologist, TL/OSL Laboratory, Geological Survey of India, Faridabad

Dr. Sharat Dutta from Geological Survey of India spoke about late quaternary sedimentary deposits along glacial fed Yamuna River and feedback mechanism of Glacial-Interglacial cycles to Indian Summer Monsoon (ISM) dynamics and resultant fluvial development since MIS-5a (Interglacial) period. He presented his work on geomorphological and sedimentological studies and absolute chronology of these deposits. He showed that 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) has distinct patches of fluvial deposits signifying limited glacial advance and fluvial sediment transport and deposition of gravel facies followed by incision. Similarly, aggradation (Phase II, III, and IV) with age, their correlation with prevailed climatic conditions and deposits (Terrace level-T1, T2, etc.) during that period was described by him. He also showed a significant finding that the late quaternary sedimentary archives in the valley across MCT and correlation of aggradation and incision phases correlate well with ISM dynamics ($\delta^{18}O$ record), and profound control of glacial interglacial cycles since MIS-5a.

Dr. Susheela Negi

Principal Scientific Officer at the Ministry of Science and Technology, Govt. of India

Dr. Susheela Negi spoke about vulnerability, its need and risk assessment due to climate change in the Indian Himalayan Region (IHR). She showed what DST was doing under NMSHE mission in various Himalayan states and its contributions in the development of science backed developmental planning to minimize risks due to climate change. She also briefed about risk assessment based approach for understanding climate vulnerability and climate induced hazards, risks for adaptation planning and the establishment of State Climate Change Cells. She explained the vulnerability & risk framework and key findings from studies from Kullu and Uttarakhand and showed how DST has put together efforts to create a seamless sub-district level vulnerability and risk assessment atlas for the entire Indian Himalayan Region.

SESSION 4:

Theme 4: Himalayan Ecosystem and Biodiversity

Chaired by Prof. C R Babu, Professor, CEMDE, Department of Environmental Studies, Delhi University

The session had three talks. It began with a defining talk by Dr. N Tuteja on "Improvement on Crop Productivity under climate change: special reference to Himalayan Region". It was followed by the presentation of Dr. S Sathyakumar on "Assessing impacts of climate change on wild fauna and micro-flora of the Indian Himalayan Region". The third and the final talk of the Session was by Dr. Renoj Thayyen on the "Need for a Paradigm Shift in Research in Himalayas". The Chairman, Dr Babu concluded the session by giving his impressions on global climate change opining that anthropogrenic reasons have played a big role in reshaping the environment.

Dr. N Tuteja

Visiting Scientist, International Centre for Genetic Engineering and Biotechnology (ICGEB), New Delhi

Dr. N Tuteja spoke about how the crop productivity could be increased under different stresses (Abiotic and Biotic) such as salinity and drought. He emphasised that since global warming can reduce crop productivity it is necessary to obtain stress-tolerant varieties to cope with possible future problem of food security. He focussed on improvement of crops through - non-transgenic and transgenic (GM) approaches citing various examples of crop improvement and explaining how GM crops are important in future. He further stated that improved methods developed by ICGEB (International Centre for Genetic Engineering and Biotechnology) for transgenic plants show that genes such as P. indica (PiCypA), PDH45 and Ca-ATPase (OsACA6 can induce stress tolerance to salt, drought and cold in many crops.

Dr. S Sathyakumar

Scientist-G, Wildlife Institute of India (WII), Dehradun

Dr. S Sathyakumar from Wild Life Institute of India talked about how wildlife and micro flora are getting affected

by climate change in Indian Himalayan Region by showing examples of Red fox, an inhabitant of temperate regions moving into Arctic and killing Arctic fox for food and spotting of a monkey at about 5500 m elevation in Uttarakhand region He then described the five year project on Assessment and Monitoring of Climate Change Effects on Wildlife Species and Ecosystems for Developing Adaptation and Mitigation Strategies in the Indian Himalayan Region taken by Wildlife Institute of India (WII). He explained methodologies adopted in the three river basin viz the Beas Basin, Bhagirathi Basin and Teesta basin in the project that included collecting fine scale weather information, soil and lichen sampling, establishment of Landscape Ecology & Visualization Laboratory (LEVL) etc. among others. He finished his talk by mentioning future plans such as development of robust spatial and inter-operable database and undertaking climate change scenario analyses.

Dr. Renoj Thayyen

Scientist, National Institute of Hydrology, Roorkee

Dr. Renoj Thayyen talked about the gaps in the Indian cryospheric research studies that include diminishing focus (programmes/ funding) on Himalayan glaciers/ Cryosphere research, non starting of specialised institute for Himalayan Glaciology, lack of response to the changing perception on the role of Himalayan glaciers, lack of policy relevance of research outcomes, role of snow in water availability, role of permafrost etc. He expressed concern over lack of the glaciology related programme in key cryospheric region of Ladakh where almost 70% of Indian Himalayan glacial resources are present. He stressed on a need for policy input from glacier centric research programmes and linkages of orography to Snow/glacier discharge with downstream hydrology. He also spoke about research programme of NIH in Ladakh such as research on cryosphere system response to runoff, implications of ground ice thawing, characteristics of temperature lapse rate etc. in Indian Himalayan Region. At the end he discussed missing winter mass balance measurements in the Himalaya that is limiting our ability to link glacier regimes with downstream hydrology and emphasised that research focus should also extend to key glacier resource areas to make it policy relevant Nationally and Internationally.

SESSION 5:

Theme 5: Climate Change and Dynamics of Himalayan Glaciers

Chaired by Dr. Ashwagosha Ganju, Director, Snow and Avalanche Study Establishment (SASE), DRDO

The session began with a Keynote address by Dr. N Tuteja on "Mass variability over Himalayan glaciated region". His address was followed by Prof. AL Ramanathan's talk on "Present health and dynamics of glaciers in the Arctic and the Himalayas". Six more presentations were made in the session by leading glaciologists that included Dr. M R Bhutiyani, Prof. S A Romshoo, Dr. Amit Dharwadkar, Dr. S P Shukla, Dr. Ashit Kumar Swain and Dr. Sujata Das. The papers related to high altitude warming, Driving factors for melting in Himalayas, geology of Ladakh, melt water characteristics of Hamtah glacier, glacier stress patterns and use of Landsat images for glacier monitoring.

Dr. V M Tiwari
Director,

CSIR-National Geophysical Research Institute (NGRI), Hyderabad

Dr. V M Tiwari in his key note address explained how gravity field measurements can be used to estimate mass variability of glaciated regions of Himalaya. He said that Gravity Recovery & Climate Experiment (GRACE) mission will improve mass change observations with high spatial and temporal resolutions. He described the working concepts, limitations and advantages of GRACE with specific examples such as monthly terrestrial water storage changes between 2002-2015, Greenland ice sheet melting rate over 200 cubic km per year, groundwater depletion in Northwestern India at the rate of 54 cubic km per year etc. between 2002-2010, Arctic and Antarctica ice mass loss and trend of mass changes in Indian Subcontinent (2002-2016).

He also presented results from analysis of GRACE data over Himalayan regions that included causes of seasonal mass accumulation in Western (dominated by snow), Eastern (dominated by rainfall) and Central (combination of both) Himalayan Regions. A separate analysis of Western Himalaya showing strong correlations of both snowfall and temperature to the mass accumulation in this region was also discussed.

Dr. A L Ramanathan
Professor, SES, Jawaharlal Nehru University, New Delhi

Dr. A L Ramanathan described the present climate scenario of Himalaya and spoke about importance of glacier in Western Himalaya along with latest glacier mass balance and elevation changes in Himalaya. Drawing examples from previous and recent studies on status of mass balance, he showed significant mass loss during later phases of little ice age in Himalaya. He informed the gathering about studies being conducted in Himalaya and Arctic Region by Jawaharlal Nehru University in collaboration with other agencies.. He discussed long term annual and seasonal mass balances (MB) and meteorological conditions of Chhota Shigri glacier between 2002 and 2016 where there is a cumulative glaciological Mass Balance 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". Similar, results of mass balance from Vestre Broggerbreen glacier in Arctic were shown. He stressed on need for further work that included comprehensive long term in-situ monitoring of

glacial melt and its contribution to rivers, robust attempts to better understand the glacial complexities, ice core drilling and to reduce scientific uncertainty, intra and inter scientific cooperation etc. to accurately assess regional climate change impacts on Himalayan glaciers.

Dr. M R Bhutiyani

Director, Defence Terrain Research Laboratory, New Delhi

Dr. M R Bhutiyani presented part of his PhD work, that included

use of remotely sensed satellite data. He discussed about elevation dependent warming (EDW) that can accelerate rate of change in mountain ecosystems, cryospheric systems, hydrological regimes and biodiversity. He emphasized on change in temperatures in Himalaya and mentioned that globally minimum temperatures have risen whereas in Himalaya even maximum temperatures have gone up in comparison to minimum temperatures. He presented data analysis on precipitation and especially on temperature in Himalaya, giving good insight of High altitude warming in Himalayan region. He also showed changes in equilibrium line in Siachen glacier, which has gone up in recent years. In regards to rise in temperature in Himalaya, he correlated it with few mass movement events on Siachen and North Terong glacier that took place in middle of the winters. He concluded his talked with remarks that there are perceptible evidences of climate change in the North West Himalaya, significant warming has happened during winters in all ranges except for upper Karakorum Himalaya leading to depletion of snow cover and incidences of rock avalanches and ice avalanches even in winters. He mentioned that winter cooling phenomenon at altitudes above ELA in Karakorum needs to be better understood.

Prof. S A Romshoo

Professor and Head, University of Kashmir, Srinagar, Jammu & Kashmir

Prof. S A Romshoo shared his thoughts and scientific challenges such as climate change in Upper Indus Basin (UIB), depleting cryosphere and its geopolitical consequences, low water storage capacity and water issues that could complicate the South Asian security, heterogeneity in Indian Himalaya Cryosphere, decline in stream flows, Black Carbon (BC) factor of climate change, etc. He then discussed about glaciers (size and volumes) in Jammu & Kashmir where only a few glacier have been studied and that too mostly with the use of Remote Sensing. He showed gaps in different glacier inventories using remote sensing and raised the issue of consistency in scientific data. Dr Romshoo gave details about a Benchmark Glaciers where studies on mass balance, bed rock topography, snout position, stream flow, linkage to climate change, snow/ice melt; Black Carbon, etc. are being done by Jammu and Kashmir University . He briefly discussed the Indus water sharing treaty with a neighboring country and its geopolitical consequences under the changing climate scenario.

Dr. Amit Dharwadkar

Director, Polar Studies Division, National Centre of Excellence in Geoscientific Research (NCEGR), Geological Survey of India, Faridabad.

Dr. Amit Dharwadkar appraised the gathering about GSI's geological investigations in Ladakh. He described the history and processes involved in the development of Himalaya and then discussed geology and stratigraphy, of Shyok/Nubra valley of Ladakh region followed by deep seated geothermal influx and tectonic evolution of Ladakh and Indus-Tsangpo Suture Zone.

Dr. S P Shukla

Director, Polar Studies Division, GSI, Faridabad.

Dr. S P Shukla presented the studies carried on Hamtah Glacier located in the Spiti Valley. He presented the meteorological data including maximum/ minimum temperatures, precipitation, humidity, wind speed and cloud cover near

glacier and the discharge data collected over the period of 8 years between 2000- and 2007 and presented the result of correlation between discharge, precipitation and temperature. He concluded that daily discharge is well correlated with temperatures whereas correlation with precipitation is not very well established for all the years. He also drew inferences that fortnightly discharge has significant and strong correlation with ablation and fortnightly temperature, but no significant correlation between daily discharge and precipitation. Diurnal variations and storage characteristics were also discussed by him..He concluded that glacier melt water discharge has strong positive and significant correlation with temperature and ablation.

Dr. Ashit Kumar Swain

Geologist, Geological Survey of India, SU, Sikkim

Dr. Ashit Kumar Swain talked about climate change and its relation with glacier stress patterns. He mentioned different type of forces such as traction and stresses and strains that occur in glaciers. Ice thickness measurements using GPR in Vestre Broggerbreen (VB) glacier (Svalbard) and its results were then discussed. Using bedrock slope, surface slope and the ice thickness maps, he displayed the stress patterns in different parts of glacier. Similar studies carried out in a part of Antarctica were also discussed by him.

Dr. Sujata Das

Scientist F, Defence Terrain Research Laboratory (DTRL), DRDO, New Delhi

Dr. Sujata Das presented her work on the dynamics of

Karakorum Himalaya using remotely sensed satellite imagery. Her work included generation of Land Surface Temperature (LST) using Landsat data, correlation of LST with type of surface cover and identifying probable mass movement sites, subsequently. She explained the methodology to estimate temperature deviation (between 1991 and 2017) over snow and non-snow areas using LST and NDSI (Normalized Differential Snow Index) and subsequently the results for Siachen as well as for Karakorum as a whole. The results showed that there is substantial increase in LST over Siachen glacier for both snow and non-snow areas and even mean LST over all elevation ranges has increased. A positive trend in both maximum and minimum temperature has been observed. Similar results were obtained for Karakorum area with a key finding that Minimum temperature distribution of 2017 showed relatively cooler disposition as compared to 1991 at above the height of 6500m.

SESSION 6:

Theme 6: Geopolitics of Poles

Chaired by Dr. P S Goel, Raja Ramanna Professor, NIAS, ISRO and Former Secretary, MoES and H E Nils Ragnar Kamsvag, Ambassador, Royal Norwegian Embassy, India.

The session began with a Keynote address by Dr. Bimal N Patel on the topic "A quest for international environmental law stability and certainty in the Arctic Waters: Is Antarctic Environmental regime suitable and feasible". His address was followed by the Dr. Walter Roest's talk on "Geoscience advances in the Arctic Ocean". Dr. Ashwagosha Ganju presented his paper on "Implications of changing climate pattern on the Geopolitical situation of North Western Himalaya, India". H E Nils Ragnar Kamsvag spoke on "Indo-

Norwegian polar collaboration, amongst other things in the field of research and technology". Prof. Sanjay Chaturvedi presented his paper on "A critical geopolitics of Anthropocene and Antarctic Climate Dilemma". Dr. Luther Rangreji and Dr Sudhakar gave their talks on " India's efforts towards a National Law governing Antarctica: An International Legal Prespective " and "International Conservation Law-CCAMLR System of Governance in Southern Ocean" respectively.

Prof. Bimal N Patel

Professor of Public International Law,
Director, Gujarat National Law University, Gandhinagar

Prof. Bimal N Patel spoke about laws governing the Arctic and Arctic regimes and said that Antarctica Treaty System (ATS) is highly developed, progressive and comprehensive whereas the same qualitative attributes are missing from Arctic Environmental Protection Strategy (AEPS).

Geopolitical issues are primarily responsible for creation of these two regimes. A brief of different articles governing these regimes and comparison between ATS and AEPS was drawn subsequently. He addressed the three main issues related to military, territorial claim and emerging risk to environment. He explained various articles related to these issues such as article 1.1 stating demilitarization of Antarctic with examples. In this context he talked about what could be future trend of India in Arctic and Antarctic.

Dr. Walter Roest

Senior Geophysicist, Ifremer, Marine Geosciences,
Ifremer Centre de Bretagne, France

Dr. Walter Roest discussed gave an account of the history of the exploration in Arctic Ocean from past to recent. He stated that the competitive search for a profitable passage was the first reason to explore Arctic that almost ended by mid of 19th century and in modern times lots of passages have been explored.

Decreasing sea ice cover in Arctic Ocean has brought new passages - Northeastern (Russian) and Northwestern (Canada) routes to the light. Another major change has been the coming in force of UN Convention on the Law of Sea (UNCLOS) which defines different sovereignty regimes for the oceans i.e. natural prolongation of the landmass to the outer edge of the continental margin defining the legal continental shelf which various coastal state can explore for natural resources. He then showed decrease in shipping duration and reduced distances for various countries benefitting from newly opened sea routes. He touched upon the potential of Arctic Region for oil and gas exploration, United Nations Convention on the Law of the Sea (UNCLOS) and Article 76. He gave examples from submission by various countries such as Norway, Denmark, Russia, Canada and US to Commission on Limits of Continental Shelf (CLCS). Then data types required for mapping continental shelf beyond 200 nuaticles mile and difficulties in obtaining such data with joint Canada - US survey and its results were shown by him. In the end he concluded his talk with a message that given severe conditions, collaboration and cooperation is paramount to success of the geosciences in the Arctic Ocean.

Dr. Ashwagosha Ganju

Director, Snow and Avalanche Study Establishment, Chandigarh.

Dr. Ashwagosha Ganju spoke about temperature rise, precipitation variations, apparent climate shift, etc., their causes – anthropogenic, aerosol increase, green house gas and/or deforestation along with their effects such as warming, extreme weather, wildfires, shifting tree line among many others. He was of the opinion that the science behind advancing glaciers, energy budget etc. has not been properly investigated which creates gap in the knowledge of the short and long-term implications of the impact of climate change on water and hazards in the Himalaya. He mentioned that difficult accessibility and complex topography has resulted in having lack of adequate rain gauge, AWS and other instrumentation. Positive and negative outcome of the geopolitical consequences were highlighted.. An action plan such as snow/water harvesting, robust early warning systems, afforestation and advanced research in Himalayan Cryosphere etc. was also suggested by him.

H.E. Nils Ragnar Kamsvag

Ambassador, Norwegian Embassy, New Delhi

H.E. Nils Ragnar Kamsvag spoke about Indo-Norwegain collaboration in research and technology with special emphasis on Arctic and discussed importance of Arctic in context of India for resources such as oil & gas, fisheries, minerals and shipping. Growing importance of Arctic in terms of opening of new short sea routes and access to resources due to melting of sea ice was highlighted by him. He also mentioned that there may be geopolitical conflicts for such resources. Importance of Arctic development in sustainable manner by Norway was also explained by the facts that 10 % of Norway's population lives north of the Arctic Circle, 80% of maritime traffic in the Arctic passes through Norwegian waters and 90% of export revenues are from resources and activity in sea areas, etc. In this regards it was stated that peace, stability and international cooperation is a prerequisite in Arctic. He stated that Norwegian goals for the Arctic are three fold i.e. to Keep the peace, stability and predictability. This is possible by ecosystem based management that is overreaching, international cooperation and law, strengthening employment, value adding and welfare.. Importance of Arctic Council in terms of involvement of Arctic countries and observers ,such as from Asia. was explained and discussed too. He illustrated the cooperation in Arctic on various fronts such as economic,, cultural and , scientific research..He cited examples of various Indo-Norwegaian Collaborative projects in the field of energy, environment, polar and geohazard, etc. and underlined the fact that scientific research in these fields and cooperation in several others will be central key for developing relationship with India.

Prof. Sanjay Chaturvedi

Professor, DPS, Panjab University, Chandigarh

Prof. Sanjay Chaturvedi argued that the Anthropocene, the era we are currently in, calls for new visions and understanding of both geography and politics. With quotes from various eminent experts he laid down importance of Antartica Treaty and discussed the key questions such as : what is it that is being challenged or threatened by climate change in the Antarctic, how come the powerful graphic visualization of Antarctica and its ecosystems at the receiving end' of climate change, what will be the far reaching regional and global impacts/ implications of collapsing ice sheets etc.? The current Antarctic climate discourse need to be broadened, deepened and reconfigured to give visibility and voice to global peripheries, especially in the Global South? He also argued 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 critical geopolitics of the Anthropocene for its limited and limiting engagement with the ethical as well as geopolitical considerations surrounding the knowledge-power interface and sustainability of core values of the ATS? He concluded on the note that India's post colonial challenge which was picked up in early 90's is still in need to be fully addressed and scientific and geopolitical presence of India in Antarctic is as critically important now as it was then.

Dr. Luther Rangreji

Director, L&T Division, MoEA, Govt. of India.

Dr. Luther Rangreji referred to the Draft Antarctic Act of India under preparation and spoke mainly about necessity of having such an act for Antarctic in accordance with annexure of Madrid Protocol. He elaborated on principles of this draft Act and said that it would not only bring legal certainty but also ensure that India's international obligations with respect to Antarctica are well defined. He mentioned that this act is not only important for scientists or policy makers but also for general public at large. In this regard, he discussed principles of international and environmental laws in general and covered topics such as nationality, jurisdictions, permit system, environment impact assessment, waste disposal, liability, etc. He summed up by saying that act would be only half the job done. Real challenge would lie in implementation of the Act.

Dr. M Sudhakar

Director, Centre for Marine Living Resources and Ecology, Kochi, Kerala.

Dr. M Sudhakar talked about International Conservation Law – CCAMLR System of governance in Southern Ocean. He briefly discussed Antarctic Treaty and mentioned multilateral agreements governing living resources from Southern Ocean e.g. The International Whaling Commission, The Convention for the Conservation of Antarctic Seals and Convention on Conservation of Antarctic Marine Living Resources (CCAMLR) and its objectives and purpose. He discussed in detail about the rational use and evolutionay structure of CCAMLR. Exploitation of southern ocean by Contracting countries was also highlighted. Subsequently he discussed fisheries resources available such as Antarctic krills, its spatial distribution and statistics on catch.

SESSION 7:

Theme 7: Ocean Research

Chaired by Dr. S K Singh, Director, National Institute of Oceanography (NIO) and Dr M A Atmanand, Former Director, National Institute of Ocean Technology (NIOT).

The session began with a Keynote address by Dr. S K Singh on the topic "Evolution of the Himalaya, Biogeochemistry of Indian Ocean and Climate Change". His address was followed by the Dr. S C Shenoi's talk on "Climate Change Adaptation and Mitigation – Climate Change and the Oceans". Dr. S C Tripathy then presented his paper on "Role of Southern Ocean in global climate change: perspectives from Indian Southern Ocean Expeditions .Last paper of the session was presented by Dr. Rajeev Nigam on "Foraminifera in marine sediments off west cast of India - A tool for paleoclimatic reconstruction".

Dr. S K Singh

Director, National Institute of Oceanography

Dona Paula, Goa

Dr. S K Singh described the origin and evolution of Himalaya and its impact on the global short term and long term climate. He mentioned that rising Himalaya and its weathering brought a huge pile of sediments to the Bay of Bengal through the Himalayan Rivers. Tones of these dissolved sediments have short and long term climate impacts. He explained role of heat transfer by ocean circulation in climate control and how it impacts the global climate. He also explained the role of Tethys Sea in heat transfer. Due to the closure of Tethys Sea, heat transfer was stopped and temperatures dropped about 80C. He also mentioned that erosion/weathering may also lead to temperature decrease in oceans and explained the science behind it. He then explained how much of CO_2 is being consumed by the silicate weathering, stating that as compared to other global rivers the consumption of CO_2 as well as weathering is very high.. He was of the opinion that CO_2 degassing in Himalaya releasing CO_2

due to metamorphism of rocks need to be studied to establish what is the net amount of CO_2 being consumed by silicate weathering. Role of particulates from Indian rivers controlling biogeochemistry and salinity of the Indian Ocean and hence the temperature, was also explained by him.

Dr. S C Shenoi

Director, ESSO- Indian National Centre for Ocean Information Services (INCOIS) Hyderabad.

Dr. S C Shenoi spoke about ocean and its warming and said ocean and atmosphere are both warming and causing climate change. He mentioned that most of heat is being accumulated in ocean (93%) and in glaciers (3%) – which is alarming as sea ice is melting in Arctic. He then demonstrated importance of oceans in terms of resources, fish, trade, etc and said that warmer world ocean will behave differently as its physical characteristics are going to change. He described ocean stratification and its effects on productivity. Affects of warming on sea levels with emphasis on Indian Ocean was also explained by him with the help of Sea Surface Temperature (SST) data. Different Mechanisms involved in Indian Ocean warming and their affects such as intensification of cyclone in Arabian Sea, decreasing number of monsoon depression over Bay of Bengal, changing rainfall patterns, decrease in productivity, oxygen depletion (Deoxygenation) and ocean acidification etc were presented

Dr. S C Tripathy

Scientist, ESSO-National Centre for Antarctic and Ocean Research (NCAOR), Goa

Dr. S C Tripathy presented details of the findings and significance of the NCAOR expeditions to the Indian sector of the Southern Ocean (S.O.). As S.O. connects all ocean basins, it is the site of key water mass formation, drives global ocean circulation, sink of atmospheric carbon dioxide, and plays a role as biological pump.. He showed the ship tracks followed in nine expeditions conducted so far by NCAOR., their broad scientific objectives along with major findings such as freshening/ decrease in salinity of Antarctic Bottom Water, enhanced phytoplankton population and controlling factors, increased organic matter production, etc.

Dr. Rajeev Nigam

Fmr Chief Scientist, National Institute of Oceanography, Goa

Dr. Rajeev Nigam tracked the sea level rise scenario since Holocene stating that the sea level rise happened in the past too. Devoting his talk to geoarcheology, he cited changes in water budget and its affects through examples of Fatehpur Sikri and Dholavira. He explained the importance of paleoclimate data in archeology and the role of foraminifera-a sea organism-in deciphering the palaeo-sea level.. He presented many interesting findings of previous sea levels higher than the today's sea levels with evidences and interesting interpretations such as finding of dockyard in ancient Lothal city which is presently 12 km away from current position of sea. He explained how the palaeo-sea levels have been established citing examples from Goa, Dholavira, Myanmar and West coast of India.

SESSION 8: Antarctic Science and Technologies

Theme 8: Arctic and Antarctic Science and Cold Response Technologies

Chaired by Dr. Nalan Koc, Research Director, Norwegian Polar Institute and Prof. R Ramesh, Senior Professor, National Institute of Science Education and Research.

The session began with a Keynote address by Dr. M A Atmanand on "Indian Arctic multi-sensor mooring (IndARC) observatory". His address was followed by the Dr. Manish Tiwari's talk on "Possible Errors in Marine v/s Terrestrial Carbon Sequestration Budget for the Arctic Region". There were two presentations from Norwegian experts, namely Mr. Tonny Algroy and Dr. Arild Sundfjord on :"Recent advances in hydroacoustic technology for ecosystem monitoring" and "Coastal and regional circulation in Svalbard; cross-scale needs for data and numerical model tools" respectively. Three papers read subsequently were by Dr. S Rajan on "Let not the ice melt in Svalbard"; Dr. Einar Vegsund on "Designing Polar Research Vessels: A collaboration between industry, scientists and Government; and Dr. G A Ramadass on "Underwater Technology for Polar Research".

Dr. M A Atmanand

Former Director of National Institute of Ocean Technology, Chennai.

Dr. M A Atmanand introduced the Indian Arctic Observatory established at Kongsfjorden. He covered a wide spectrum of subjects viz - need for the Arctic mooring, nature of the mooring system, deployment and retrieval of mooring, parameters measured, its qualification, data analysis etc. Data sets collected on temperature/salinity, ambient noise, corrosion from Arctic using IndArc I, II, III and IV for three years using various sensor were presented and described in details. Results such as spectrogram, ice berg cracking/calving and those from, anthrophony and biophony were also discussed. He emphasized that such data acquisition from Arctic has to be a continuous process drawn on a long term basis.

Dr. Manish Tiwari

Scientist, National Centre for Antarctic & Ocean Research (NCAOR), Goa

Dr. Manish Tiwari presented the results of Joint Indo-Norwegian research Project " Plieocence Arctic Climate Teleconnnections (PACT)" and discussed the possible errors in marine vs. terrestrial Carbon sequestration budget for the Arctic Region. Results about the dentrification and productivity variability related to south Asian monsoon were discussed. Carbon sequestration mechanism, importance of Arctic in the terrestrial carbon sequestration and methodology to estimate marine and terrestrial carbon in sediments was discussed in details. The study conducted in Kongsfjorden region of Arctic and its results on TOC, TN, $\delta^{13}C$, $\delta^{15}N$ and SOM variability were presented.. He also discussed role of bound Nitrogen and Higher $\delta^{13}C$ values in Arctic sediments despite high terrestrial organic matter contribution. He reported that marine organic matter was unusually more depleted in 13C (–24.2‰) than the terrestrial organic matter (–22.5‰).

Mr. Tonny Algroey

Kongsberg Maritime

Mr. Tonny Algroey talked about underwater acoustics and gave brief introduction of his organization – KONGSBERG. He went on describing the underwater acoustic technology, its uses, etc. He showed how the acoustic instruments were used in Indian ocean using Research Vessels for mapping ocean processes. History of SIMRAD (SIMonsen RADio established in 1947) and subsequent technology developments were discussed by him. He drew examples from EK80 Wideband system- a new technology with its applications and advantages such as increased range resolution,,long range, continuous target frequency response, KM Ocean Observation System - Scientific Multibeam Systems for 3D and 4D information, omni-directional Sonars etc. In the end various platforms such as WBAT mounted on CTD probe, surface drone, etc and applications of such senors/systems were presented.

Dr. Arild Sundfjord

Research Scientist, Norwegian Polar Institute, Tromsø, Norway

Dr. Arild Sundfjord spoke about the cross-scale needs for data and numerical model tools for coastal and regional circulations with reference to Svalbard. He described the fresh water model simulation of Svalbard and talked briefly about tide water glaciers as source of fresh water melt and as habitat of Arctic wild life. He argued for a necessity of having more such numerical models on both fine-scale and regional scale. Simulation of freshwater circulation from Svalbard glacier using different models at different resolution were shown and discussed by him He also .presented results from rapidly retreating glaciers around Svalbard and bedrock depths under glaciers. He explained why the glacier runoff plumes under certain conditions are attractive feeding hotspots and laid stress on importance of data sharing across disciplines for improved understanding as well as for developing models.

Dr. S Rajan

Co-ordinator, International Indian Ocean Expedition-2, INCOIS, Hyderabad

Dr. S Rajan in his talk, raised two questions i.e. how significant was Svalbard with regard to the short climate variablity at seasonal, annual or sub- decadal scale and secondly, the suitability of Svalbard as the best location for studying the sensitivity of climate change in Arctic. He pointed out that SWIPA assessmment report 2017 has demonstrates clearly that the Arctic Climate is shifting to new state i.e. it is getting more warmer, wetter and more variable. Arctic (surface air) temperatures are rising twice as fast as the temperatures and decline in sea ice extent and thickness was continuing with year-to-year variations. Probable reasons for such variability i.e green house gas, black carbon, increased downwelling longwave radiation, etc were discussed. He focussed on ervidences of affects of climate change as seen around Svalbard. whicch makes it special for climate change studies, highlighting that Svalbard recorded average air temperature 4.64oC warmer than the 1981-2010, 30-year base period.,in September 2017, which makes it the place with highest rate of warming on the Earth.

Dr. Einar Vegsund

Vice President, Ship Design, Rolls-Royce Marine AS, Norway

Dr. Einar Vegsund presented the role of M/S Rolls Royce in designing new polar research vessels. He stressed the importance of communication and collaboration between scientists, government and industries in such matters.. He showed examples of two advance research vesseals being constructed by the company taking into considerations

various challenges, requirements, time factor integrating the expectations of different stakeholders, including the successful sea ice trials.

Dr. G A Ramadass
Senior Scientist, National Institute of Ocean Technology (NIOT), Chennai
Dr. G A Ramadass spoke about requirement and technology of underwater vehicles. He discussed the use of underwater vehicles in carrying out near-ice Inspection and mapping, boundary layer Investigations, sediment sampling, ice shelf cavity studies etc. giving details about genesis, specification, hydrostatic, stability, frame, etc. of Remotely operated Vehicles (ROV), its integration and testing ,mission plan, operations etc. He demonstrated problems encountered during trials at Priyadarshini Lake in Antarctica.

SESSION 9: Antarctic Science

Theme 8: Arctic and Antarctic Science and Cold Response Technologies

Chaired by Dr. M Ravichandran, Director, National Centre of Antarctic and Ocean Research (NCAOR) and Dr. M Sudhakar, Director, Centre for Marine Living Resources and Ecology (CMLRE).

The session began with a Keynote address by Dr. Thamban Meloth on the topic "Exploring the dynamics and past climate of the coastal ice shelves and ice rises of Antarctica". His address was followed by talks of Dr. Tanu Jindal and Dr. Sandip Kumar Roy on "Persistent Organic Pollutants in Biotic and Abiotic components of Antarctic Pristine Environment" and "Glaciological observations in and around Schimacher Oasis, cDML, East Antarctica" respectively.

Dr. Thamban Meloth
Scientist & Group Director (Polar Sciences), ESSO-National Centre for Antarctic & Ocean Research, Goa.

Dr. Thamban Meloth spoke about NCAOR's research project concerning the ice dynamics and past climate of Dronning Maud Land region in east Antarctica under MADICE project. Warming in Antarctic and its consequences such as loss of ice shelves, generation of ice bergs, etc were discussed. He dealt in depth about the objectives and field campaigns involving GPR , DGPS and geophysical surveys, ice core drilling, etc and described how ice rises can provide stability to ice shelves., He illustrated results of work done on Digital Elevation Models, Ice Thickness, deformed ice layers, response of ice shelf to warming etc. He emphasized importance of shallow ice core studies in providing high resolution records that are making significant difference in our understanding of the climate history of last 2000 years.

Dr. Tanu Jindal
Director, Amity Centre for Antarctic Research and Studies
Amity University, Noida.

Dr. Tanu Jindal presented her work on the presence of persistent organic pollutants (POP) in Antarctic Pristine Environment. She informed that POPs have been detected in Antarctica despite its geographical isolation and almost complete absence of human settlements.. and that POPs

presence could be due to aerographic effect and/ or through food chain in Antarctic. She then showed the distribution and concentration of POPs in water bodies, atmosphere, sediments, soil, sea ice/ snow, mosses, Lichen, Krills, etc. in Antarctic. She also described the sampling procedure for POPs, methodology and results of the studies undertaken by her team during 34th & 35th Indian Scientific Expedition to Antarctica (ISEA.)

Dr. Sandip Kumar Roy
Superintending Geologist, Polar Science Division
GSI, Faridabad.

Dr. Sandip Kumar Roy presented the work of Geological Surveys of India (GSI) carried out for mass balance studies and focused on the data collected over the years from Antarctica.. The study that was conducted in central Dronning Maud Land (CDML) of east Antarctica, included GPR, DGPS, stake measurement and Total Station surveys and yielded data on velocity, recession rate for part of ice sheet and snow accumulation and ablation patterns. The results of GPR surveys showing Ice thickness profiles and bed rock topography over a region extending for about 100 were also presented.

LIST OF PARTICIPANTS

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, NCAOR

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
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, New Delhi

Dr S C Garkoti
Professor SES, Jawaharlal Nehru University

Dr T S Rawat
Scientist F, Defence Terrain Research Laboratory, DRDO

Dr Vaibhav Garg
Sc/Eng, SE, WRD, IIRS (ISRO)
Dehradun

Shri Kamal Kazim
Former Director, Geological Survey of India

Dr S K Roy Bhowmik Scientist 'F', Indian Meteorological Department

Shri Rahul Saxena
Scientist 'E', Indian Meteorological Department

Dr D R Pattanaik
Scientist 'E', Indian Meteorological Department

Shri Gajendra Kumar
Scientist 'E', Indian Meteorological Department

Dr S D Kotal
Scientist'E', Indian Meteorological Department

Dr P S Biju
Scientist 'D', Indian Meteorological Department
New Delhi

Dr Rajni Bala,
Fmr Director, Adhunik Institute of Education and Research

Dr. T. P. Sabin
Scientist-D, Indian Institute of Tropical Meteorology, Pune
Shri R Bala-subramanian
Scientist 'D', Indian Meteorological Department

Dr V R Durai
Scientist 'D', Indian Meteorological Department

Dr Samanti Sarkar
Scientist 'D',
Indian Meteorological Department

Shri Mohammad Danish
Scientist 'B', Indian Meteorological Department

Mr G Someswara Rao
(ISRO) Scientist/Engineer -SF, NRSC, ISRO

Shri Chandranath Chatterjee
Program Officer, SES, JNU

Inger Midtkandal
Counsellor, Science & Technology, Norway Embassy

Marta Gjørtz
Second Secretary, Economy, Trade & Business Promotion, Norway Embassy

Dr S A I Mustafa
Fmr Director, Geological Survey of India

Academicians

Dr Sajad Ahmad Bhat
Lecturer, School of Civil Engg, Lingayas University,Faridabad

Dr. Bindhy Wasini Pandey
Associate Professor
Department of Geography, University of Delhi

Dr. Seema M. Parihar
Associate Professor,
Kirorimal College, DU

Dr. V.A.V. Raman
Associate Professor
Sheed Bhagat Singh College, DU

Dr. Tejbir Singh Rana
Associate Professor, Reader, Shivaji College

Prof . Akhtar Siddiqui
Professor of Education, Jamia Hamdard College

Dr. Pankaj Kumar
Assistant Professor, Department of Geography, University of Delhi.

Dr. Ushvinder Kaur
Associate Professor, Swami Shraddhanad College

Dr Punam Behari
Associate Professor, Miranda House, DU

Dr Sudeshna Bhattacharya
Associate Professor, Miranda House, DU

Dr Rakhi Parijat
Associate Professor, Miranda House, DU

Dr. Prabhas Kr. Pande
Assistant Professor, Ram Lal Anand College, Department of Geology, University of Delhi

Dr. Sarbari Nag
Assistant Professor, Ram Lal Anand College, Department of Geology, University of Delhi

Dr. Rajeev Kumar
Assistant Professor, Ram Lal Anand College, Department of History, University of Delhi

Dr. Seema Joshi
Assistant Professor, Ram Lal Anand College,

Department of Statistics, University of Delhi

Dr. Seema Gupta
Assistant Professor, Ram Lal Anand College,
Department of Statistics, University of Delhi

Dr. Mukta Datta Mazumder
Assistant Professor, Ram Lal Anand College,
Department of Statistics, University of Delhi

Dr. Rajesh Sachdev
Associate Professor, Ram Lal Anand College,
Department of Statistics, University of Delhi

Dr. Kaushal Kumar Sharma
Professor, CSRD , JNU

Dr Saraswati Raju
Professor, CSRD, JNU

Dr. Padmini Pani
Assistant Professor, CSRD, JNU

Shri S. S. Khaira
Retired HOD,
S. Sciences,Welham Boys' School, Dehradun

Ms. Mona Datta
Teacher, Vasant Valley School

Ms. Patralekha Mazumdar
Teacher, Vasant Valley School

Ms. Lalitha Jha
Teacher, Yuva shakti Model School

Industry Representatives

Dr. Anand Pathak
Tech Expert, Kongsberg

Dr. Thor Erik Harestad
Tech Expert, Kongsberg

Dr. Frank Reier Knudsen
Tech Expert, Kongsberg

Dr. Tonny Algrøy
Tech Expert, Kongsberg

Dr. Per Kristian Furø
Tech Expert, Rolls Royce

Dr. Einar Vegsund
Tech Expert, Rolls Royce

Mr. Shree Verma
CEO, C N Technologies

Mr. Anant Verma
Vice President, Sales & Marketing

Ms. Avneet Kaur
Assistant Manager, Business Development

Ms. Devyani Dey
Executive Assistant to CEO

Research Scholars and Students

Shri Sant Prasad
Research Scholar
Department of Geography University of Delhi

Shri Sagar Khetwani
Research Scholar
Department of Geography University of Delhi

Shri Senaul Haque
Research Scholar
Department of Geography University of Delhi

Ms. Nitu
Research Scholar
Department of Geography University of Delhi

Ms. Anitha Revi
Research Scholar
Defence Terrrain Research Laboratory

Shri Bipandeep Sharma
Research Scholar, Panjab University

Shri Atar Singh
Research Scholar, Sharda University

Ms. Dev Smriti
Research Scholar, Delhi University

Shri Apurva Alok
Research Scholar, Delhi University

Ms. Ananya Singh
Research Scholar, Miranda, Delhi University

Shri Kartikee Malik
Research Scholar, Miranda, DU

Ms. Sarita Yadav
Research Scholar, Miranda House, DU

Ms. Suvasree Chakravarty
Research Scholar, Miranda House, DU

Shri Jatin Dabas
Student, XII, Yuva Shakti Model School

Shri Parneet Dabas
Student, XII, Yuva Shakti Model School

Shri Rajan Mishra
Student, XII, Yuva Shakti Model School

Ms. Tanya Sharma
Student, XII, Yuva Shakti Model School

Ms Simran
Student, XII, Yuva Shakti Model School

Ms. Kritkia
Student, XI, Yuva Shakti Model School

Ms. Aparna Kumari
Student, XI, Yuva Shakti Model School

Shri Aniket Bansal
Student, XI, Yuva Shakti Model School

Shri Aman Dabas
Student, XI, Yuva Shakti Model School

Shri Ritesh Dadarwal
Student, XI, Yuva Shakti Model School

Volunteers

Shri K. Murali,
Research Scholar, School of Environmental Sciences, JNU

Md. Soheb,
Research Scholar, School of Environmental Sciences, JNU

Shri Karuna Rao,
Research Scholar, School of Environmental Sciences, JNU

Shri Om Kumar,
Research Scholar, School of Environmental Sciences, JNU

Ms. Monika Sharma,
Research Scholar, School of Environmental Sciences, JNU

Shri Som Mishra,
Research Scholar, School of Environmental Sciences, JNU

Shri Nijesh,
Research Scholar, School of Environmental Sciences, JNU

Ms. Sanjana,
Research Scholar, School of Environmental Sciences, JNU

Zainab Siddiqui,
Research Scholar, School of Environmental Sciences, JNU

Ms. Akanksha Roy,
Research Scholar, School of Environmental Sciences, JNU

Shri Manish Jangid,
Research Scholar, School of Environmental Sciences, JNU

Ms. Nina Nancy Murmu, Research Scholar, School of Environmental Sciences, JNU

Shri Abhishek K. Verma, Research Scholar, School of Environmental Sciences, JNU

Shri Lala Saha,
Research Scholar, School of Environmental Sciences, JNU

Shri Mayank Krishna,
Research Scholar, School of Environmental Sciences, JNU

Shri Mukesh Kumar,
Research Scholar, School of Environmental Sciences, JNU

Ms. Padma Ladon,
Research Scholar, School of Environmental Sciences, JNU

Ms. Pinky Doley,
Research Scholar, School of Environmental Sciences, JNU

Ms. Shipra Singh,
Research Scholar, School of Environmental Sciences, JNU

Ms. Aisharya Bhattacherjee
Research Scholar, School of Environmental Sciences, JNU

Ms. Sonali Yadav,
Research Scholar, Centre for study of Regional Development, JNU

Ms. Sangeetha Esther,
Research Scholar, Centre for study of Regional Development, JNU

Ms. Ishita Manna,
Research Scholar, Centre for study of Regional Development, JNU

Shri Sandip Tanu Mondal,
Research Scholar, Centre for study of Regional Development, JNU

Shri Rituraj Pegu,
Research Scholar, Centre for study of Regional Development, JNU

Ms. Nian Paul,
Research Scholar, Centre for study of Regional Development, JNU

Shri Suresh Das,
Research Scholar, Centre for study of Regional Development, JNU

SaGHAA-IV Institutional Team

Mr. Ravikant Mahto
Mr. Sachin Tyagi
Mr. Zahid Husain
Mr. Sandeep Kumar Sharma
Mr. Amit Kumar
Mr. Kavish Rai
Mr. Sanjeev Asthana
Mr. Faguni Pandit
Mr. Dhruv Pandey
Mr. Pankaj Kumar
Mr. Megharaj Singh

VALEDICTION FUNCTION

Valedictory session held as the last leg of the Conference began with award distribution to young researcher for motivating and encouraging them.. Mr. Ankit Pramanik, Ms. Neelu Singh and Ms. Seema Rani were awarded for their best paper presentations in three themes viz-Antarctic, Arctic and Himalaya. under the "rapid shot session". A special award was presented to Dr. Shridhar Jawak for organizing and coordinating the rapid shot session in the conference.. This was followed by distribution of certificates to volunteers for putting hard work in assisting the organizing Committee in various activities towards making SaGHAA IV 2017 a success.

Dr. Rasik Ravindra, Former Director, National Centre for Antarctic and Ocean Research (NCAOR) and Chairman, SaGHAA Organising Committee, presided over the valedictory Session. Dr Nalan Koc Research Director, Norwegian Polar Institute (NPI); Dr. Ravichandran, Director, National Centre for Antarctic and Ocean Research (NCAOR), Dr. S P Shukla, Director Polar Studies Division, Geological Survey of India (GSI) and Ms Sulagna Chattopadhyay, President LIGHTS Research Foundation and Convener of SaGHAA-IV constituted the panelists in the Session.

Dr Ravindra expressed great satisfaction at the successful completion of conference. He remarked that it was gratifying to note that hard work put in by LIGHTS, various Committees and scientists had borne fruits. He added that it was encouraging to find that webcasting of the conference attracted 250,000 and 285,000 viewers on first and second day respectively, even though the subject of the conference was very specific in nature.

Observation by Dr. Nalan Koc,

Dr. Nalan Koc said that she was impressed by the quality of the papers and presentations, especially those that were made by the young and upcoming generation She added that she was impressed to see high quality of research being done by India in the Himalayas – the Third Pole and hoped to increase the collaboration in future in this region too as it had lot of research Potential.

Observation by Dr. Ravichandran,

Dr. M Ravichandran remarked that that it was his first participation in the SaGHAA series and that he greatly appreciated the synergy between science and geopolitics themes covered in the conference. He commended the efforts put in by young researchers in presenting their findings, especially in the field of international collaboration, in very lucid form in shortest possible time. and urged scientists to expand it further to have more and more collaboration with other countries. He said he was looking forward to work with a team that could address and seek answers to new research questions... He also urged and suggested LIGHTS to start a Himalayan Circle similar to the "Arctic Circle" so that all the stakeholder could be brought together to work for a common cause.

Observation by Dr. S P Shukla

Dr. S P Shukla said that conference saw a good set of presentations on subjects varying from the field of glaciology to remote sensing and climate change. He appreciated the vast data shared and presented during the conference but felt that tight schedule and paucity of time prevented the in depth discussions.. He remarked that since there are more than 9000 glaciers in Himalaya we cannot do justice to them only by field glaciology and suggested that it is better to have faster coverage using high resolution remote sensing data with field validations. He felt that this may help in overcoming contradictory results from different glacial inventories. He also talked about limited work in the north western Himalaya, particularly Shyok Basin, that covers more than 50% of glacier area of Indian Himalaya and said that in order to answers questions like Karakoram anomaly and allied questions, we need to have more data from these regions.

Concluding remarks by Ms. Sulagna Chattopadhyay

Ms Chattopadhyay, while thanking the participants, delegates and guests said that the conference has served its purpose in raising the awareness and highlighting the concerns about the climate change scenario in the three Polar Regions. She added that "LIGHTS" are on and we will keep burning the "Idea". She was confident that the SAGHAA Series would continue to excite participation again with renewed force in 2019 to focus on new questions under newer themes.

FEEDBACK

Dr. Shyamal Kumar Nandi

It was indeed an excellent gathering along with the participation of well-known scientists/academics in the relevant fields of Science and Technology. Not only could we gather knowledge but we had a fruitful interaction. Hope the next SaGHAA Conference would also be as equally productive.

Dr. S S Khaira

The SaGHAA Conference was a great event that brought many intellectuals together. It was a golden opportunity for ambitious people to learn, enhance and update themselves with the changes happening in the planet which is continuously evolving. The earth is the only living planet so far, hence it needs attention. We are all responsible for its degradation and our duty is to repair it which is possible by finding solutions in such conferences. All the presentations were excellent and thought provoking. I congratulate the entire team who put their brains together and their hard work depicted grand success. I look forward to more such conferences in the near future.

Dr. Sharadindu Mukerji

Several years ago I had attended SAGAA - when I was still in service. After retirement my hobby took me away from active participation in scientific forums. This year it was a great honor to receive an invitation from you to attend SaGHAA - IV. I have thoroughly enjoyed attending the conference. Quality papers from eminent scientists and other experts in the field of polar studies underlined the serious approach by the organizers towards the theme and purpose of the whole show. The two day conference was conducted / organized in highly admirable manner to say the least. I have reasons to say that the participants were well taken care of as the hospitality was of a very high order. I have one suggestion to make. It is time that scientific meets of this nature be made accessible to students, especially to school students. That way you will contribute effectively in making future generations of polar experts.

Dr. M. A. Atmanand

It was well organized.

Dr. Thamban Meloth

Thanks a lot to Dr. N Prasad and Ms Sulagna Chattopadhyay for the excellent arrangements. It was an excellent conference.

Prof. Sanjay Chaturvedi

I would also like to both thank and congratulate you and Prasad (and all the members of your wonderful team) from the bottom of my heart for the great success of SaGHAA 2017. You may please add me to the list of your fans!! What an effort at such a scale!!! Keep up the good work and you and Prasad will always find me on and by your side. I am really most delighted and proud. Sincere thanks also for inviting me to the conference and taking such good care of me.

Dr. S Rajan

Thanks again for giving me an opportunity to participate in SAGHAA. I relished it.

Prof. Shakil Romshoo

The Conference was well organized and papers chosen were quite relevant to the theme of the conference. I personally found the deliberations of the Conference quite useful. However, I felt that there is scope for increasing the participation of the large community in the conference as the attendance in almost every session was low despite the fact that the venue was JNU. A few of the talks were too general and not relevant to the theme of the workshop and should have been avoided.

Dr. Walter Roest

The event was very well organised and the speakers highly competent, with interesting presentations. However, there was very little time for questions, and presentations of 8 minutes or even less sometimes do not do justice to the speaker, nor the audience. I would suggest that each presentation should be at least for 15 minutes, and 5 minutes to questions and changing over. This means less speakers, or adding half a day to the event, or increasing the number of posters. If more posters, at least 1 hour every day should be reserved to see the posters. For example a long tea break. Finally, I suggest that more key speakers from other countries, if possible, be invited to participate in providing different views on some of the important topics that are addressed. For the rest, I think that this conference is a very exciting event and deals with very significant topics. Keep up this good work.

Dr. Vaibhav Garg

SaGHAA IV raised the very important issue "Focussing Climate Change" mainly for Himalaya, Arctic and Antarctica. I wish the organiser on successful organisation of the conference.

ABOUT PARTNERS

Ministry of Earth Sciences

Ministry of Earth Sciences (MoES) is among the lead organization conducting polar research and conducting expeditions in Antarctic and Arctic. These expeditions are helping in collecting scientific data for various projects in the disciplines of polar science, glaciology, atmospheric sciences, and many others. MoES recently acquired Ice-class Research Vessel with state-of-the art scientific equipments/ instrumentation for exploring polar regions.

Royal Norwegian Embassy

Norwegian polar research is at the forefront in the global arena. Besides conducting scientific research, mapping and environmental monitoring in the Arctic and the Antarctic, Norway, with its extensive scientific and technical capabilities is contributing actively to understanding and predicting the major changes taking place in the Arctic; Svalbard in particular. Norway has recently developed icebreaker research vessel equipped with state-of-the-art scientific instrumentation including moon pool, ROV (remotely operated vehicle) and AUV (autonomous underwater vehicle) and will carry expedition to polar regions starting 2018.

National Centre for Antarctic and Ocean Research

National Centre for Antarctic and Ocean Research (NCAOR) is leading country's research activities in the Polar and Southern Ocean realms. It is engaged in understanding the role and response of cryosphere in climate change through an integrated study on glaciology, biogeochemical processes and ice core records from Antarctic, Arctic and Himalayas. Special focus has been given on studying climate variability of the polar/ Cryospheric regions and its teleconnections to the rest of the globe with emphasis on the Indian region.

Indian Institute of Tropical Meteorology

Indian Institute of Tropical Meteorology (IITM) has performed Dendroglaciological studies in high altitude glacier sites of western Himalaya. They have now planned to do polar study to understand the role played by different sectors of ANSI (Antarctic Sea Ice) as well as ARSI (Arctic Sea Ice) in the overall performance of monsoons, both summer and winter seasons of the year. This study would also bring out the secular trends of Antarctic Sea Ice Extent and Arctic Sea Ice Extent in the current global warming scenario caused by increase in greenhouse gases in the atmosphere.

National Institute of Ocean Technology

NIOT and NCAOR had successfully installed Indian Arctic Observatory (IndARC) in Arctic. It is the country's first multi-sensor moored observatory in the Kongsfjorden fjord of the Arctic, roughly half way between Norway and the North Pole.

Centre for Marine Living Resources & Ecology

CMLRE is coordinating the national programmes relating to Southern Ocean Living Resources - Antarctic marine living resources and is the nodal agency representing India in the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR).

SERB, Dept. of Science of Technology

SERB is supporting study on impact of glacier retreat, glacial chronology - palaeoclimatic reconstruction, estimation and modeling of glacier stored water, measurement of Ice thickness, glacier velocity, mass and energy balance in the Himalaya region.

Indian National Center for Ocean Information Services

INCOIS is providing Global Ocean Analysis data using mathematical models and observations on a daily basis to provide the initial conditions to ocean-atmosphere coupled models used for the prediction of the monsoon and to understand oceanic processes.

National Centre for Earth Science Studies

NCESS is promoting multidisciplinary research in emerging areas of solid earth science, provide services by utilizing this knowledge for earth science applications and generate leadership capabilities in the selected areas.

Department of Science and Technology, SPLICE

SPLICE, under the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) is addressing long term issues related to sustainability of Himalayan Water Resources through conservation measures for water, ice, snow and glacier.

National Remote Sensing Centre, Hyderabad

NRSC is involved in spatio-temporal monitoring of Polar region environment and study of dynamics of surface melting over Antarctica to understand the response of ice shelves to climate change.

Geological Survey of India, Kolkata

GSI's has been conducting Indian Scientific Expeditions to Antarctica for fundamental research in several fields of earth, atmosphere and biological sciences and is involved in monitoring of Himalayan glaciers as well.

Ministry of Environment, Forest and Climate Change

MoEF&CC is leading the environment and climate change studies in India. It has contributed towards snow cover & glacier inventory, mass balance and retreat and advanced study of Himalayan glaciers.

Department of Biotechnology

Promoting large scale utility of biotechnology and developing for all-round development of biotechnology in the country.

Indian Council of Agricultural Research (ICAR)

The Council is the apex body for coordinating, guiding and managing research and education in agriculture including horticulture, fisheries and animal sciences in the India and has played a pioneering role in ushering Green Revolution and subsequent developments in agriculture in India through its research and technology development.
Directorate of Coldwater Fisheries Research (DCFR). It is a premier research institute doing research for the coldwater fisheries and aquaculture in the country and working towards the development of coldwater fisheries sector in the India.

National Biodiversity Authority, Chennai

NBA is involved in facilitating regulatory and advisory functions on issues of conservation and sustainable use of biological resources and fair-equitable sharing and access to benefits of use.

CN Technology, New Delhi

CN Technology is facilitating research, logistics, survey, concept design, reconnaissance, data collection, and more in the Polar Regions.

National Geophysical Research Institute, Hyderabad

NGRI works on seismotectonics and geodynamical processes between Antarctica and Southern Indian Peninsula through continuous GPS monitoring between India and Antarctica.

Central Institute of Fisheries Technology

CIFT is providing basic strategic research in fishing and processing and developing energy efficient fishing systems for responsible fishing and sustainable management.

Indian Institute of Remote Sensing (IIRS)

IIRS is a key player for training and capacity building in geospatial technology and its applications and has been conducting cryospheric research in Himalaya such as Hydrological and Glacier Lake Outburst Flood (GLOF) Modeling, Glacier velocity estimation and glacier zones classification using SAR data, Glacier Mass Balance and many others through its water resources department.

Amity University

Amity has established a specialized centre for polar research i.e. "Amity Centre for Antarctic Research and Studies (ACARS)" and has been carrying out research on several aspects such as Environmental Toxicology, Microbiology and environmental health in and around Indian Antarctic research stations in Antarctica.

LIGHTS Research Foundation
707, 7th Floor, Bhikaji Cama Bhawan, R K Puram, New Delhi-110066
www.lights.org.in | www.geographyandyou.com
Tel: +91-11-46014233, +91-11-26186350