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Newsletter of the

DIVECHA CENTRE FOR CLIMATE CHANGE

International Conference on State of the Cryosphere in the Himalaya

Interaction with Mr. P. D. Rai, Hon. Member of Parliament, Sikkim

The 13th Jeremy Grantham Lecture

Meeting with Honorable Members of Parliament on Water Security

Holistic Electric Mobility Project



Indian Institute of Science
Bengaluru
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FROM THE CHAIR

Greetings!

The Divecha Centre for Climate Change was established at the Indian Institute of Science in January 2009 with a generous financial contribution from Arjun and Diana Divecha and the Grantham Foundation for Protection of the Environment.

The primary goal of this Centre is to understand climate variability and climate change, and their impacts on the environment. The Centre continues to pursue experimental and modelling studies in this direction. It has identified technologies to mitigate / reduce the severity of climate change in collaboration with entrepreneurs and different engineering departments in the Indian Institute of Science. The Centre is also working with the Grantham Institute for Climate Change at the Imperial College London, on the impact of aerosols on climate and the impact of climate change on water. In addition, the Centre has also undertaken outreach activities to create awareness among students, general public and policy makers about climate change and its consequences. This has been done through workshops, lectures and quiz contests. An annual invited public lecture, called the 'Jeremy Grantham Lecture on Climate Change', has been held for the past eight years. We organize lectures and training courses aiming at capacity building to address issues related to climate variability and climate change. The Centre also provides advice to ministries and departments of the Government of India to develop national and international policies related to climate change.

One of the goals of the Divecha Centre is to develop the knowledge required for societies to face challenges posed by global environmental change and to identify potential solutions. We have started a new initiative for creating awareness among the members of parliament on important issues related to climate change policy. This is an effort to influence the government policies on climate change, mitigation and adaptation, which is one of the important objectives of the Centre. The first in this series was organized on 27th March, 2018 at Constitution Club of India, New Delhi. The topic was "Himalayan Glaciers and Water Security of the Indo-Gangetic Plains". Thirteen parliament members from Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, Sikkim, Assam, West Bengal, Goa, and Orissa attended this session. The bureaucrats from various ministries were also present in this meeting. The Himalaya are the most dominant geographical feature of India and the snow and glaciers on them maintain the perennial waters in the world's major rivers, the Indus, the Ganges and the Brahmaputra and the combined catchment basin of which is home to around 800 million people, relying on the perennial waters from these rivers for agriculture, industries and domestic use.



S. K. Satheesh

CONFERENCE ON STATE OF THE CRYOSPHERE IN THE HIMALAYA



Prof. J. Srinivasan (far left), Prof. Anil Kulkarni (second from left) with other speakers.

An international conference on state of the cryosphere in the Himalaya was held in Gangtok, Sikkim on 19th-20th February, 2018.

The aim of the conference was to highlight the gaps in knowledge and challenges in the field of cryosphere in the Himalaya and formulate a research oriented scientific programme for Sikkim, to adapt to climate change.

The international conference saw the participation of 257 scientists, 6 keynote speakers and 47 presenters from 35 national and international organizations. The deliberations from the two-day conference brought out the need to address the following.

Assessment of water security:

A need to understand the contribution of glacier melt, snowmelt and precipitation to river discharge and groundwater recharge. A need to study drainage patterns to estimate water supply and ground water availability. Suggestions for the Dhara Vikas programme, in order for it to be better grounded in science.

Science for farmers:

Need to install a network of Agricultural Meteorological Stations (Agro-met) at village level to help farmers with early weather forecasts, including forewarning of hazardous weather events (hailstorm, drought and cloudburst). A need for the generation of soil wetness maps and weather forecast based information on

soil moisture status to guide farmers.

Better techniques to monitor cryosphere: Advanced tools to monitor snow and glaciers and glacial lakes, such as Drones mounted with cameras and spectrometer, Microwave Remote Sensing and remotely controlled bathymetry equipment. A network of automatic weather stations to be installed, especially at higher elevations, to help understand and model future changes in climate.

Monitor air quality:

Soot and dust can contribute to snowmelt and hence there is a need to mitigate these at regional levels. They not only affect the health of the glaciers, but also

human health.

Need for capacity building:

Training programmes and course in glaciology in various institutions across Sikkim should be introduced to help create a pool of young researchers.

In view of the recommendation of the experts, a course of action was proposed. Establishment of a Regional Glaciology Centre in Sikkim, and formation of an expert group and formulation of a programme in consultation with glaciologists, hydrologists and climate model experts.



Scientists participating in the international conference at Sikkim.

INTERACTION WITH Mr. P. D. RAI, HONOURABLE MEMBER OF PARLIAMENT FROM SIKKIM

Prof. Anil Kulkarni had a detailed discussion with Mr. P. D. Rai, Hon. MP from Sikkim on 6th February, 2018 at his residence in New Delhi. The discussions covered wide range of topics related to the state of the cryosphere in Sikkim, the impacts of changing cryosphere and climate on mountain communities, creation of institutional mechanism to advise state government on key scientific

developments, and integration of new knowledge to solutions and policies.

Since this will need continuous interaction between the scientific community, policy makers and political leadership, a need for an institutional mechanism was felt. The Honorable MP requested Divecha Centre for Climate Change to develop this idea further.



Prof. Anil Kulkarni (right) with Mr. P.D. Rai, Hon. Member of Parliament from Sikkim.

THE 13TH JEREMY GRANTHAM LECTURE ON CLIMATE CHANGE



Professor Jeff Dozier delivering the lecture.

The 13th Jeremy Grantham lecture on climate change was delivered on 22nd February, 2018, by Prof. Jeff Dozier, Distinguished Professor and Founding Dean, Bren School of Environmental Science & Management, University of California, Santa Barbara, USA, at Divecha Centre auditorium. His lecture focused on global hydrological cycles and water resources as observed from space.

He discussed the report of the US National Academies of Sciences, Engineering and Medicine on climate science for the next decade. He showed that understanding of aerosols, clouds, convection, precipitation, geology and

hydrology were necessary to predict climate change. To achieve these objectives a new NASA program mission was designed and developed.

The importance of Earth-observing satellites that provide critical information for mitigating disasters was emphasizing. Focusing on the water cycle, Prof. Dozier stressed the need to consider the amount of snow and rain as well as groundwater extent. The water and energy cycles are coupled since if the water evaporates at some place it condenses at another. Some designated observations by the NASA flight programs, using robust technologies for measuring aerosols, cloud convection, precipitation, surface

biology, and other parameters were recommended. In addition, “Earth Systems Explorer” missions were identified. Some observables that could not be measured with present technology, such as atmospheric winds, planetary boundary layer, surface topography and vegetation including aquatic ecosystem were put together in included incubation program where technology was meant to be developed with a new approach for measuring these observables. As higher resolution data is essential, measurements using radar, LIDAR, and microwave technologies were recommended.

In general, observations needed to run applications can differ from the

observations needed to do science. To enable innovation, timely achievement of critical objectives is a major priority. The “Earth System Explorer” is one of the measurements necessary to achieve these objectives. Therefore to implement all of these programs budgetary planning is very important and hence decision rules were put into place for this purpose. Prof. Dozier concluded that there were several benefits in this program for science and its applications. The program will help understand better the distribution of aerosols and clouds, impacts of changing cloud cover and precipitation, and quality growth or shrinkage of glaciers and ice sheets.



Professor Jeff Dozier answering questions from the audience.

WORKSHOP ON SUSTAINABLE CONSUMPTION IN ASIA

Dr. Rajiv Kumar Chaturvedi, a Senior Researcher with Divecha Centre for Climate Change, visited Research Institute for Humanity and Nature (RIHN), Kyoto, Japan over 14th-18th January, 2018 to participate in the Future Earth Workshop on Sustainable Consumption in Asia. Dr. Chaturvedi also attended the Regional Advisory committee (RAC) meeting of the Future Earth (Regional Centre for Asia), on behalf of Prof. S. K Satheesh.

The Workshop on Sustainable Consumption in Asia was organized by the Future Earth (Regional Centre for Asia) over 15th-16th of January, 2018. This included a public symposium on the 15th in collaboration with the Kyoto University, and a workshop at the Research Institute for Humanity and Nature (RIHN) on the 16th of January. The event aimed to strengthen the Future Earth Knowledge-Action Network on Systems of Sustainable Consumption and Production (KAN-SSCP). The main purpose of the workshop was to develop a framing of sustainable consumption that

is meaningful across the globe (i.e. in the global South and North) and to provide input to region-specific engagement strategies for this expanding global network of scholars and practitioners. On the second day of the workshop, Dr. Chaturvedi presented Divecha Centre's recent work on the co-benefits of decarbonisation of India's power sector. The full work is available at: http://dccc.iisc.ac.in/Policy_Brief_January_2018.pdf

Dr. Chaturvedi, on the 17th January, 2018 participated in the RAC meeting of Future Earth Asia region. He presented the annual progress report of Future Earth's South Asia regional office hosted in DCCC to the Advisory Committee members. At the RAC meeting the request for granting more permanent status to the regional office in Divecha Centre was unanimously agreed upon by the members. Additionally, the members provided useful suggestions related to the need for a separate website of South Asia FE office, a regional committee, and the need for continued communication via virtual media platforms.



Future Earth Asia Regional Advisory Committee members and observers.

IMPLEMENTING ENERGY AND ENVIRONMENTAL POLICIES IN CHINA

Prof. Yuan Xu visited Divecha Centre on the 12th and 14th March, 2018, to interact with students and faculty and gave two talks on China's environmental policy. Prof. Xu is an associate professor in the Department of Geography and Resource Management and leads the Environmental Policy and Governance Programme at the Institute of Environment, Energy and Sustainability at The Chinese University of Hong Kong.

The first talk was broadly about China's environmental policies. An overall theme being examined was why China's enforcement and compliance on its energy and environmental policies is good in some occasions, but worrisome in



Prof. Yuan Xu delivering his talk.

others. While on the one hand, China has been effective in implementing policies to rapidly improve energy efficiency, install pollution control facilities, and develop renewable energy, there are also failures of policy enforcement such as non-compliance. Through case studies on emissions trading markets, energy conservation, water pollution in shale gas development, and improving energy efficiency of coal plants, Prof. Xu examined the various factors leading to policy successes and failures. A common lesson was that it is not only important to design policy well, but also mobilize the implementers of policy and take into consideration how those who are regulated would make decisions. In China, implementers of policy are mainly county and municipal governments as they spend a large fraction of government revenue.

The second talk was about factors leading to lowering of China's sulfur dioxide (SO₂) emissions from coal power plants during the past decade, despite continued increases in coal consumption and the larger context of limited enforcement capacity. The factors identified in this reduction are the establishment of province-level reduction goals, strict penalties for not running or operating SO₂ scrubbers at each plant, and independent monitoring and site inspection with financial incentives for monitors. The talk also described China's development of a domestic industry in scrubbers through incremental improvements in SO₂ removal rate, in order to meet overall capacity and cost constraints.

MEETING WITH HONORABLE MEMBERS OF PARLIAMENT ON WATER SECURITY



Honorable Members of the Parliament discussing at the Constitution Club.

Prof. S. K. Satheesh, Chairman, Divecha Centre for Climate Change along with Prof. Anil Kulkarni and Prof. J. Srinivasan, met with Honorable Members of Parliament (MPs) at the Constitution Club in New Delhi on 27th March, 2018. This meeting was organized by the Integrated Mountain Initiative (IMI), Swiss Agency for Development and Cooperation, Indian Himalayas Climate Adaptation Program and Divecha Centre for Climate Change. The primary purpose of the meeting was to discuss the impact of climate change on the Himalayan glaciers and water security of the Indo-Gangetic plains.

Mr. P.D. Rai, Hon. MP from Sikkim outlined the main purpose of the meeting and requested Mr. Rajiv Pratap Rudy, Chairman of the parliamentary committee on water to make the opening remarks. Mr. Rudy expressed his concerns about the impact of climate change on water resources in India and requested Prof. Anil Kulkarni to make a short presentation on the impact of retreating glaciers on water security. Prof. Kulkarni highlighted the fact that small glaciers were retreating rapidly and hence reducing the water available to mountain communities near these glaciers. Global warming has led to the formation of new glacial lakes which

will increase the probability of glacial lake outburst floods (GLOF).

Prof. Srinivasan highlighted the increase in heat waves and extreme rainfall events during the past 60 years. He argued that the local climate in India is influenced by global warming as well as air pollution and urbanization. Prof. Satheesh highlighted how solutions to these problems are being worked on through the newly created “Future Earth” regional office at Divecha Centre for Climate Change.

During the discussion Mr. Rajiv Pratap Rudy showed how climate change in Nepal has an adverse impact on floods in Bihar. Some members pointed out that the increase in heavy rainfall events and deforestation has led to more landslides in the Himalayas. In his concluding remarks Mr. P. D. Rai underlined the need for more consultations between scientists and legislators to solve problems posed by climate change.



Prof. Satheesh (far left), Dr. Akhilesh Gupta (Second left), Prof. J. Srinivasan (fourth from left), Prof. A. V. Kulkarni (fifth from left) with two Honorable Members of Parliament.

ONE-DAY EXPERT MEETING ON IPCC SPECIAL REPORT



Dr. J.R. Bhatt (Advisor, Ministry of Environment, Forest and Climate Change, Govt. of India) interacting with the experts.

The Intergovernmental Panel on Climate Change (IPCC) released its second order draft of 'Special Report on Global Warming of 1.5 °C for government and expert review'. The Ministry of Environment, Forest and Climate Change, Government of India, requested Divecha Centre for Climate Change to organize a one-day meeting of experts to provide comments on the IPCC Special Report. The meeting was held on 12th February, 2018 in the DCCC Seminar hall. Experts from Tata Institute of Social Sciences, IIT Gandhinagar, The fourth Paradigm Institute of CSIR, Indian Institute of Tropical Meteorology, National Institute for Advanced Studies, Ashoka Trust for Ecology and Environment, Centre for Science Technology and Policy, Ministry of Environment, Forests and Climate Change, Ministry of Finance, Indian Meteorological Department, and NITI Ayog and Divecha Centre for Climate Change took part.

There was intense discussion on various issues highlighted in the report. The participants disagreed with the

statement that "past emission do not commit substantial future warming". They disagreed with the conclusion that "Carbon budgets may refer to cumulative emissions from 2016 until peak warming or until warming returns to 1.5°C after a temporary overshoot". They were concerned that aerosols and methane were clubbed together although the lifetime of methane is more than 10 years while that of aerosols is one week. The technologies that are needed to abate the emission of methane and black carbon are very different. The report projects that "The share of primary energy from renewables increases rapidly in 1.5°C scenarios, becoming the dominant source of energy by 2050 in most pathways". The participants pointed out that the real data shows that the share of fossil fuels as a source of energy has remained constant at 80% for the past 20 years. After the meeting, the comments of all the participants were compiled and sent to the Ministry of Environment, Forests and Climate Change for onward transmission to the IPCC secretariat.

INTERACTION WITH THE GRANTHAM INSTITUTES

Dr. Rajiv Kumar Chaturvedi, Senior Researcher with Divecha Centre for Climate Change, visited the Grantham Institutes at the Imperial College London and London School of Economics and Political Sciences over 19th-24th March, 2018, and participated in four collaborative meetings and workshops.

The first meeting at Imperial College was with Prof. Ralf Toumi. Divecha Centre is working with Prof. Toumi's research group to propose a collaborative research on Early Warning System for Land Degradation and Desertification in India. An Early Warning System for Land Degradation and Desertification is essential for India as it is estimated that about 32% of India's total land area is currently facing the threat of degradation and the estimated annual loss is more than 20 billion US dollars. The second meeting was with Dr. Jeremy Woods, Dr. Woods had collaborated with Dr. Chaturvedi in the COP21 calculator project. They discussed ways in which COP21 calculator can be improved by including sectoral details in the calculator.

During Prof. Satheesh's previous visit to Grantham Institutes in 2016, it was decided that Divecha Centre, Imperial College and the London School of Economics will bring out a joint briefing report for policymakers on the advantages of reduced dependence on coal. Hence, a joint policy brief was one of the key agenda items for Dr. Chaturvedi's visit. In this context, Dr. Chaturvedi held the third meeting with Ms. Alyssa Gilbert, the director of policy and translation team at Imperial College; Simon Levey,

Communications Manager; Abbie Stone, Events, Media and Outreach Officer; and Lottie Butler, Digital Communications Officer. The meeting was also attended by Dr. Ajay Gambhir, a Senior Research Fellow and Climate Policy expert at Imperial's Grantham Centre. From London School of Economics and Political Science (LSE) this meeting was attended by Mr. Bob Ward who is the policy and communications director of the Grantham Research Institute on Climate Change and the Environment at the LSE. At this meeting it was decided that as part of this project (joint policy brief) we will work on understanding the effects of future projections of decarbonisation scenarios in India's power and transport sector into the 2030s and 2050s. This proposed policy brief will also highlight the co-benefits of India's decarbonisation in terms of ambient air pollution reduction and reduction in health risks. At this meeting it was also decided that we would aim to publish this proposed joint policy brief sometime in October this year, in the run-up to the COP24 meeting. It was also decided that experts from Imperial college and LSE will travel to India for a joint workshop highlighting the release of this joint policy brief. This workshop is proposed to be attended by representatives from different government departments including NITI Ayog.

The joint policy brief meeting at Imperial College was followed by the fourth meeting at LSE. During this meeting Dr. Chaturvedi interacted with the colleagues from LSE about the framing of the proposed joint policy brief. This meeting was attended

by Mr. Bob Ward, Prof. Sam Fankhauser, Prof. Nick Robins, Ms. Sini Matikainen, and Ms. Isabella Neuweg. At this meeting the joint policy brief draft as discussed at Imperial College was revisited and looked for ways in which LSE could add value to it. Prof. Nick Robins who specializes in sustainable finance at LSE could add insights and new data on the reduction

of capital cost of the renewables, risk of stranded assets (of fossil fuels) and requirement of banking sector reforms for propelling growth in renewables. The visit of Dr. Chaturvedi will therefore enhance the partnership between DCCC and the Grantham Institutes in London.



Presentation on early warning systems during the meeting at Imperial College.

HOLISTIC ELECTRIC MOBILITY PROJECT



Discussions on the electric mobility project.

Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru, in association with Auroville, Tamilnadu and Go Green BOV, Bengaluru, has initiated a 'Holistic Electric Mobility Project (HEMP)' at Auroville Township, Tamilnadu on 12th April, 2018.

Auroville is a universal township established in Tamilnadu for people all around the world. The concept of Auroville - an ideal township devoted to an experiment in human unity, came into existence in the 1930s. In 1966, the UNESCO passed a unanimous resolution commending it as a project of importance to the future of humanity, thereby giving its full encouragement. The purpose of Auroville is to attain human unity in diversity. Today, Auroville is recognized as the first and only internationally endorsed experiment in human unity and transformation of consciousness, and sustainable living. Auroville has adopted environment friendly technologies like renewable energy parks, electric vehicles (EVs), zero energy buildings and sustainable architecture. Auroville

has about 270 EVs which are used by the residents as well as the visitors.

The objective of the HEMP is to create a benchmark in the field of sustainable electric mobility in townships, through innovation and research. The agenda of the project is to install, commission and operate two Electric Vehicle Smart Charging Stations (commonly termed as Electric Vehicle Charge Supply Equipment - EVSE) at Auroville.

Research and Development in the impact of EVSE on the EVs, the electrical grid and its fleet and the environment, air-quality and public health are being done. Performance of EVSE, its viability evaluation of battery swapping and leasing schemes, evaluation of PV based DC charging for EV, and establishment of a Model for Electric Mobility in Community Living are also being developed.

MEETING OF MAIRS-FE



Meeting of Scientific Steering Committee for Monsoon Asia Integrated Research on Sustainability - Future Earth (MAIRS-FE).

A meeting of the Scientific Steering Committee (SSC) for Monsoon Asia Integrated Research on Sustainability-Future Earth (MAIRS-FE) was held at the College of Environmental Sciences and Engineering at Peking University, Beijing on 19th and 20th April, 2018. The MAIRS-FE is a regional consortium for the integrated study of earth system processes in the Monsoon Asia Region with a vision to advance understanding of the interactions between the human-natural components of the overall environment in the region and implications for the global Earth system, in order

to support strategies for sustainable development. The Monsoon Asia region spans South, East and South East Asia. The participants of the SSC meeting included academics and practitioners involved in science and policy research and project advisory services. The meeting involved review of activities related to three thematic research areas of MAIRS-FE namely Water-Energy-Food Nexus, Human Health, and Resilience to Natural Disasters, and discussion on the development of roadmap for future activities.

The first session of the meeting included a welcome address by the Dean of College of Environmental Sciences and Engineering at Peking University, Professor Tong Zhu, an introduction of Future Earth by MAIRS-FE vice chair Professor Tetsuzo Yasunari, introduction of the Future Earth Regional Centre in Kyoto, Japan by Professor Hein Malle and a talk on history of MAIRS by the Chair of MAIRS-FE SSC Professor Michael Manton. The next three sessions were dedicated to presentations by invited participants from India, China, Malaysia, Thailand and Mongolia on the three thematic areas of MAIRS-FE. The participants discussed activities developed by the organizations they represent and potential collaborative opportunities with MAIRS-FE.

Aditya Kaushik, a project scientist at Divecha Centre for Climate Change was invited to speak on the Water-Energy-Food nexus. Aditya gave a brief overview on the Water-Energy-Food nexus in Bengaluru, specifically talking about skewed supply-demand ratio, wastage of water, over exploitation of ground water use, problem of power generation, use of expensive energy intensive means to import water and impact of pollutants on food production. He introduced the newly instituted Water Solutions Lab, a major project of the Future Earth regional office, as a platform to generate sustainable and practical solutions to the complex and multidimensional problems resulting from the Water-Energy-Food nexus. Aditya also spoke about some of the recent activities that will be undertaken by the Water Solutions Lab such as the workshop on water quality to be held on 20th and 21st June, 2018 and the workshop on Urban Floods to be held from 27th to 29th June, 2018. He concluded the

presentation by describing how Divecha Centre can contribute to each of the three thematic areas of MAIRS-FE and specifically suggested conducting a joint comparative study exercise on the cities in the region. For example, a study on Bengaluru and Beijing on how the two cities survive the present, how they are planning for their water futures, and what cities can learn from each other. On the following day, the fifth session included presentations on Modelling and Observations. The participants discussed Earth system modelling techniques, regional climate downscaling techniques, and large sensor networks to acquire data on air pollution.

The final session was dedicated to developing a roadmap for future activities. It was decided to expand the original three thematic areas to include a fourth one on Modelling and Observation which would act as a link to other areas. A working group of participants from each area was created to identify the scope of future MAIRS-FE activities, links to other areas, roles of the two program offices, source of potential funding opportunities, types of long term and short term activities and potential leadership groups. The working groups will produce a report on plans for MAIRS-FE. Finally, it was also announced that Professor Tong Zhu would be the new chair and Professors Satheesh and Jiaguo Qi would act as new vice chairs of MAIRS-FE.

RESEARCH HIGHLIGHTS



SUPRAGLACIAL DEBRIS COVER MAPPING IN BASPA BASIN, WESTERN HIMALAYA

The Himalayan glaciers are valley glaciers, surrounded by steep rock walls. Weathering and erosion of these walls supply debris, which are transported down the glacier slope and are known as Supraglacial Debris Cover (SDC). This has profound influence on the glacier dynamics, since it alters the surface energy balance by insulating the glacier ice and hence influences the glacier melt, depending upon the thickness of debris. Generally, heavily debris-covered glaciers experience stable terminus and mass loss close to the Equilibrium Line Altitude. This eventually results in the reduction of glacier slope and leads

to the formation of supraglacial lakes. The debris covered glaciers with lakes lose more mass than clean glaciers. Therefore, a better understanding of SDC is necessary to predict future changes in glaciers. As monitoring of the SDC change in the field is challenging, there is a need to develop simple models for SDC.

We have developed a new method to modify the existing glacier boundary using satellite data. As seasonal snow cover on SDC causes hindrance in accurately quantifying SDC changes, it was removed using a maximum

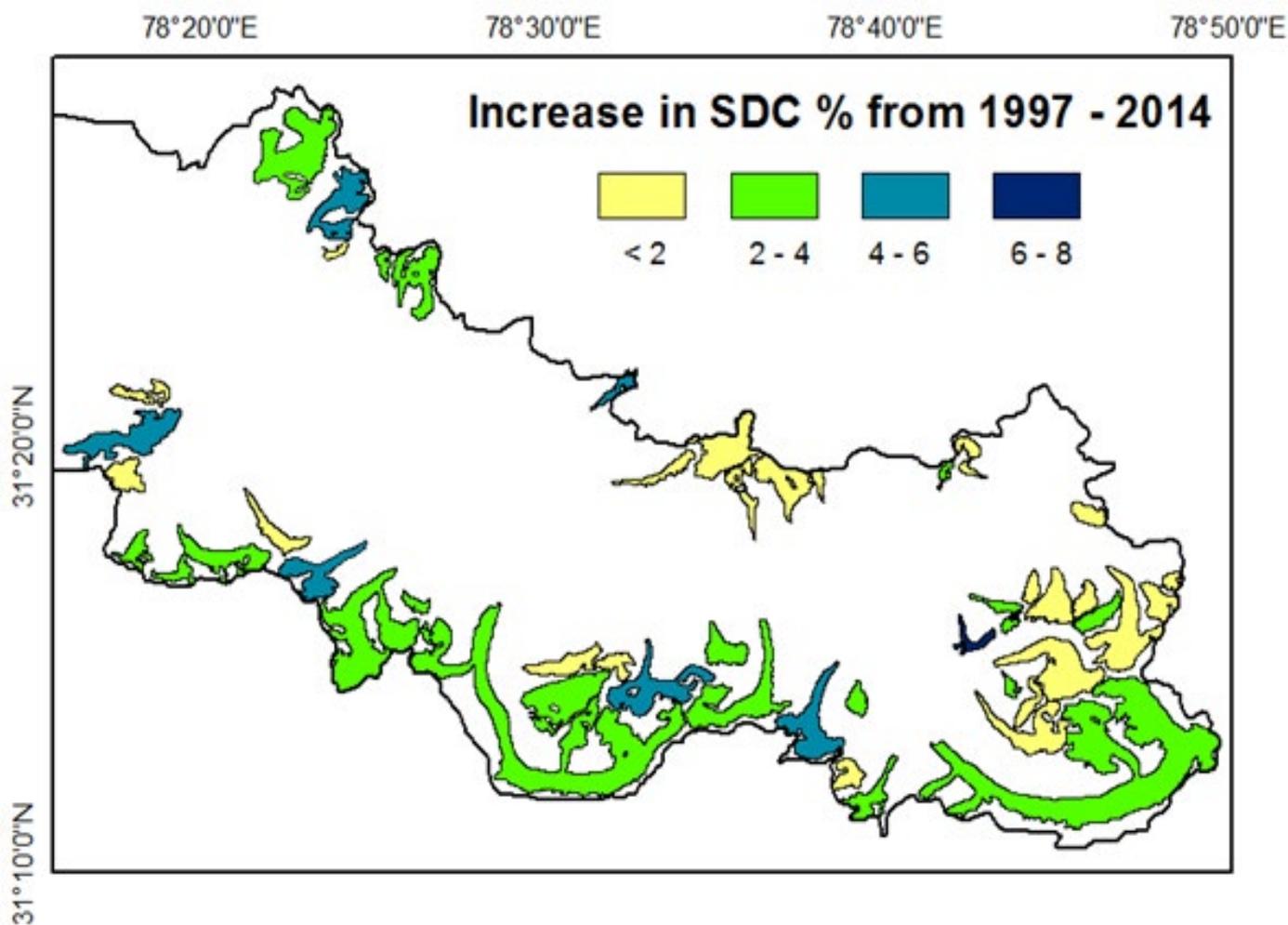


Figure 1: The figure shows increase in Supraglacial debris cover (SDC) for glaciers in Baspa basin.

likelihood based classification technique. Then, the changes in SDC was mapped using Normalized Difference Snow Index (NDSI).

The study was conducted on a glaciated region with an area of around 60 square kilometers. We found that SDC has steadily increased from 1997 to 2014 by around 2.8%. Naradu, a benchmark glacier in the basin, is one of the glaciers with highest increase in SDC by 5.6%. The reason for the high increase could be the prolonged negative mass balance.

Further, three of the glaciers in the basin have 60 to 85 % of SDC and if this trend continues, they have the potential to turn into rock glaciers. These rock glaciers can eventually develop into lakes. This can influence water supply for drinking, irrigation and hydro power generation.

Reference: S. Pratibha and A. V. Kulkarni, Decadal change in supraglacial debris cover in Baspa basin, Western Himalaya. Special Section: Himalayan Cryology. Current Science, 114, 792-799, 2018.



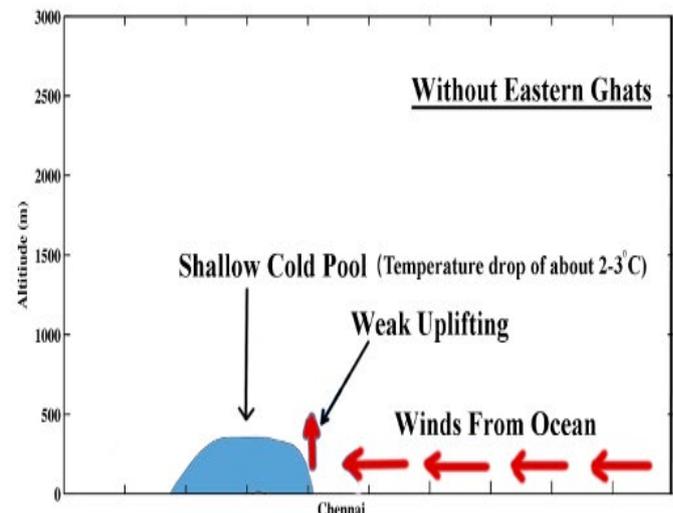
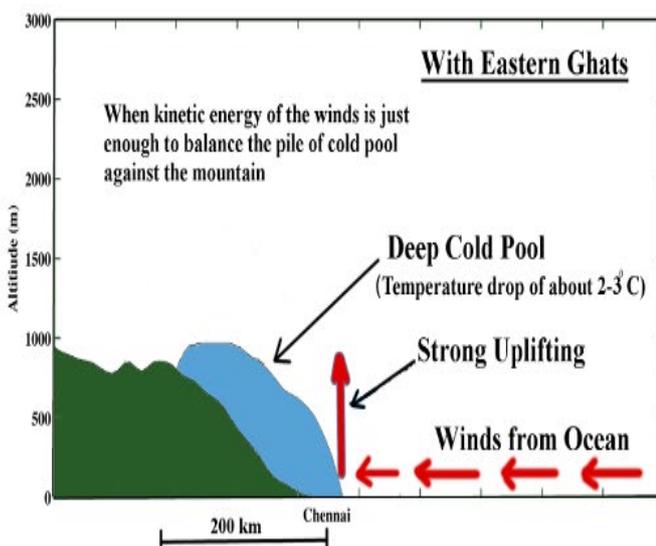
Figure 2: Field photograph of Supraglacial debris cover at Naradu glacier, Baspa basin. Glacier terminus is completely covered by debris and higher altitude regions are debris free.

WHAT CAUSED THE EXTREME RAINFALL OVER CHENNAI ON 1ST DECEMBER 2015

Extreme rainfall events in India have increased by 50 % over the past 50 years. Are all extreme rainfall events related to global warming? On 1st December, 2015, Chennai received a record breaking 494 mm of rain within 24 hrs. At least 250 people died in the ensuing floods. Was this related to global warming? In a recent paper Jayesh Phadtare , Jeremy Grantham fellow, has shown the impact of Eastern Ghats and a “cold pool” on extreme rainfall in Chennai. The Bay of Bengal is a rich breeding ground for tropical storms. Once formed, they move westwards and cause heavy rain over the east coast of India. During winter monsoon, rainfall accumulations of 100 to 200 mm in a day are normal over Chennai. The Eastern Ghats with a mean altitude of 750 m, are about 200 km inland. In the winter monsoon, winds blow from east towards the Eastern Ghats. The winds do not always rise over the mountains. They do so only when they have enough kinetic energy. Moreover, when it rains the raindrops evaporate, cooling the air in that region. This cold air near the surface, is known as the ‘cold pool’ (CP). It takes more energy to lift the

cold air over the mountains. At low wind speed the cold pool becomes stationary and its depth can reach around 1 to 2 km. The edge of the stationary cold pool can extend hundreds of kilometers ahead of the mountain. The warmer, and hence lighter, oceanic winds get uplifted well ahead of the mountain by the cold pool. Thus, winds get blocked even before they reach the mountain walls by the invisible walls of cold pool (see figure). This occurred on 1st December over Chennai. The uplifting of air by the stationary cold pool resulted in continuous rainfall over Chennai. The role of the cold pool and Eastern Ghats were explored by using a weather forecast model. In a computer simulation of this event (with no Eastern Ghats), the cold moved inland away from Chennai. With this understanding of the underlying mechanism, extreme rainfall over the coastal zone can be predicted with greater confidence.

Reference: J. Phadtare, Role of Eastern Ghats Orography and Cold Pool in an Extreme Rainfall Event over Chennai on 1 December 2015. Monthly Weather Review, 146, 943-965, 2018.



Climate Observatory in Challekere campus of Indian Institute of Science



