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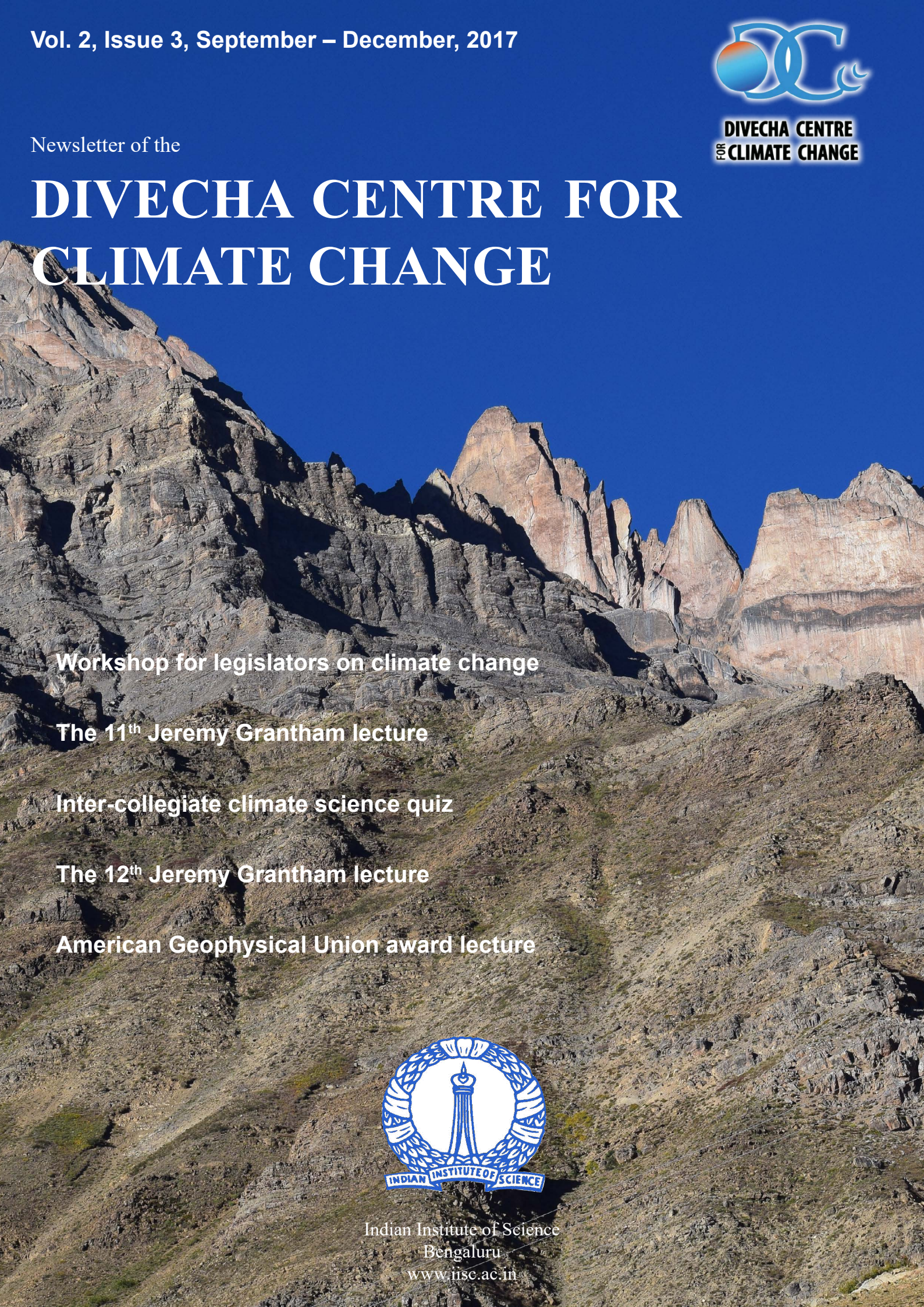
DIVECHA CENTRE FOR CLIMATE CHANGE

Newsletter of the

DIVECHA CENTRE FOR CLIMATE CHANGE



Workshop for legislators on climate change

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American Geophysical Union award lecture

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 seven 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.

The Intergovernmental Panel on Climate Change predicts rapid sea level rise, melting of glaciers, higher frequency of droughts and floods, increased stress on wildlife and plants. One major concern is the impact of climate change on India's precious biodiversity. India is committed to halt biodiversity loss by 2030 and this is a challenge as all our biodiversity is not yet documented. There is a need to generate a comprehensive biodiversity database using high resolution satellite data as well as through a network of volunteers from schools and colleges across the country. There is a need to establish several biodiversity study parks across different eco-zones and land-use types in order to understand the evolution of floral and faunal biodiversity in response to different stresses including climate change. This would provide a policy basis for incentives for biodiversity conservation. A balanced approach is required to carefully manage and conserve our forest resources. The centre will provide support to maintain several biodiversity study parks in natural forests which have three decades of data on biodiversity. A film on Divecha Centre for Climate Change was screened during the annual meeting of the American Geophysical Union held in New Orleans, USA in December 2017. You can watch the film by accessing our website (dccc.iisc.ac.in).

S. K. Satheesh

ORIENTATION WORKSHOP FOR LEGISLATORS AT SHIMLA, HIMACHAL PRADESH, INDIA

A two-hour orientation workshop for legislators on climate change and the need for adaptation in Himachal Pradesh, was organised at Hotel Peterhoff, Shimla on 24th August, 2017 by the Government of Himachal Pradesh. Honourable Chief Minister of Himachal Pradesh, Mr. Virbhadra Singh, and members of legislative assembly participated in the workshop.

Dr. Anil V. Kulkarni, distinguished visiting scientist, Divecha Centre for Climate Change, delivered a talk in Hindi about climate change and glaciers of Himachal Pradesh and also discussed with cabinet ministers and members of the legislative assembly. Dr. Kulkarni made a presentation giving current knowledge on the following issues: distribution of glaciers in Himachal Pradesh, contributions of glacier melt on stream runoff and its influence on water security, observed changes in climate and glaciers in Himachal Pradesh, annual loss in glacier mass, potential sites of glacier lakes and possible hazards due to retreating glaciers and finally influence of retreating glaciers on mountain communities. The talk highlighted the influence of climate change on small glaciers, and almost 70 percent of water stored in the glaciers has been lost from small and low altitude glaciers since the year 1984. These changes have already started to affect small mountain communities, as many regions are experiencing reduction in water availability and substantial reduction in distribution of springs.

The Chief Minister and members of the legislative assembly appreciated the contributions made by Divecha Centre for Climate Change to understand effect of climate change on glaciers of Himachal Pradesh and requested the Centre to suggest innovative techniques for adaptation.

Prof. Kulkarni interacting with Mr. Virbhadra Singh

IMPACT OF CLIMATE CHANGE ON PEOPLE IN THE BASPA AND PIN BASINS IN HIMACHAL PRADESH

Prof. Anil Kulkarni along with his students, Ms. Pratibha, Ms. Tejal and Mr. Pradeep went to Baspa and Pin Basins in Himachal Pradesh to understand effects of climate change in high-altitude regions. Their first stop was at village Raksham in Baspa valley. The village has a population of 765 and is at an altitude of 3100 m. Mr. Bhupendra Singh Negi, who is the owner of a small tea stall, has lived in this village for his entire life. In his lifetime he has observed that the thickness of the snow pack has reduced significantly, and the snow pack is melting early. He indicated that small springs here have vanished and they are now dependent upon big springs for water. He believes temperatures have increased and freezing takes place only in February rather than December as it used to.

Prof. Kulkarni discussed these issues with Mr. Sonam Gialson in village Mudh, a small hamlet of 250 people, located at the height of 3800 m in Pin valley. This is the last village in the valley before glaciated terrain starts. The village appears to be prosperous with good houses, electricity and water. The village is in a remote location but has good roads and a good school. The observations of villagers here are similar to that of Mr. Bhupendra Singh Negi from Raksham village. This village is a cold desert at high altitude and, therefore, snow remains here till end of March and villagers spray soil to melt snow early. The elderly people in this village migrate to lower altitudes during the entire winter period. This season is when pilgrimage occurs.

(Left to Right) Mr. Pradeep, Mr. Negi, Prof. Anil Kulkarni, Ms. Prathibha, Ms. Tejal

THE 11th JEREMY GRANTHAM LECTURE ON CLIMATE CHANGE BY THOMAS STOCKER

Professor Thomas Stocker delivering the lecture

Professor Thomas Stocker, Co-Chair, IPCC AR-5 (WG-I) and Professor, Climate and Environmental Physics, University of Bern, Switzerland, was invited to deliver the 11th Jeremy Grantham lecture on Climate Change on 14th September 2017 at J. N. Tata Auditorium in the Indian Institute of Science. The audience consisted of more than 1000 students and faculty from the colleges around Bengaluru. The summary from his lecture are give below.

Thirty years ago many scientists predicted that the concentration of carbon dioxide in the earth's atmosphere will exceed 0.04% in the first few decades of the 21st century. This prediction has become true and the carbon dioxide concentrations have relentlessly gone past 400 ppm last year. Today we are far beyond any concentration of carbon dioxide that we have measured in the past 800,000 years. In fact, the concentrations are 30% higher than that during the past 800,000 years. We see that the global mean temperature has been rising for the past 130 years. This warming of the climate system is unequivocal. The human influence on the climate system is clear. We know what is happening and who is responsible. The continued increase in greenhouse gas emissions will cause further warming and limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

Climate models predict that further warming will increase the likelihood of severe, pervasive and irreversible impacts. The temperature is not uniformly increasing in various parts of the world. The continents will warm faster. In particular the Arctic will show large increases in temperature (8 to 9 ^{0}C) in the businesses as usual scenario. The projections indicate that the ice cover in summer will disappear as early as 2035 for the high emission scenario. In the Mediterranean and in the dry areas in the southern hemisphere rainfall will decrease. This coincides with the areas that are now under stress because of

drought and shortage of water. Even more severe impact will be in countries exposed to sea level rise. This is already happening and the sea level rise is about 19 cm at present. There will be another 70 cm sea level rise during the 21st century with business as usual scenario. Climate change influences the mean temperature as well as the extremes. What we are more concerned is with the change of statistics of extreme events. The frequency of extreme events changes much faster than the mean temperature. The probability of experiencing heat waves increases by a factor of 20 in the next hundred years. The question then is whether adaptation is really possible? Heat waves affect our health, sea level rise reduces the land available and ocean acidification reduces food available from the oceans.

The Paris Agreement, signed on 12th December, 2015, is an important milestone because for the first time it identifies a temperature target explicitly. Climate models have shown that for every 1000 billion tons of carbon that is emitted into the atmosphere there will be a warming between 0.8 to 2.5 degrees Celsius. This directly links human activity of burning fossil fuels with the global temperature increase. So limiting temperature means also limiting the total emissions of carbon dioxide therefore limiting the burning the amount of fossil fuels. Any target climate that you ever define implies a limited carbon budget. We have emitted 565 billion tons of carbon since 1850, which means that 225 billion tons of carbon remains. The world emits about 10 billion tons of carbon every year and this budget will be exhausted by the year 2040.

The crucial question here is: what is the technology that would allow us to go negative in global emissions? This is a major technological requirement that says that we need to put in place technology that allows us to take out carbon dioxide at a global scale from the atmosphere. If we don't mitigate the climate change we would not be able to achieve many sustainable development goals. The science is clear. We know what is happening, who is responsible, and what options remain. Therefore the focus needs to be on carbon dioxide and its emission needs to be reduced if we want to reach these climate targets. Any delay in the reduction of carbon emissions is not a good recipe.

Professor Thomas Stocker adressing the audience

CLIMATE CHANGE QUIZ CONTEST 2017

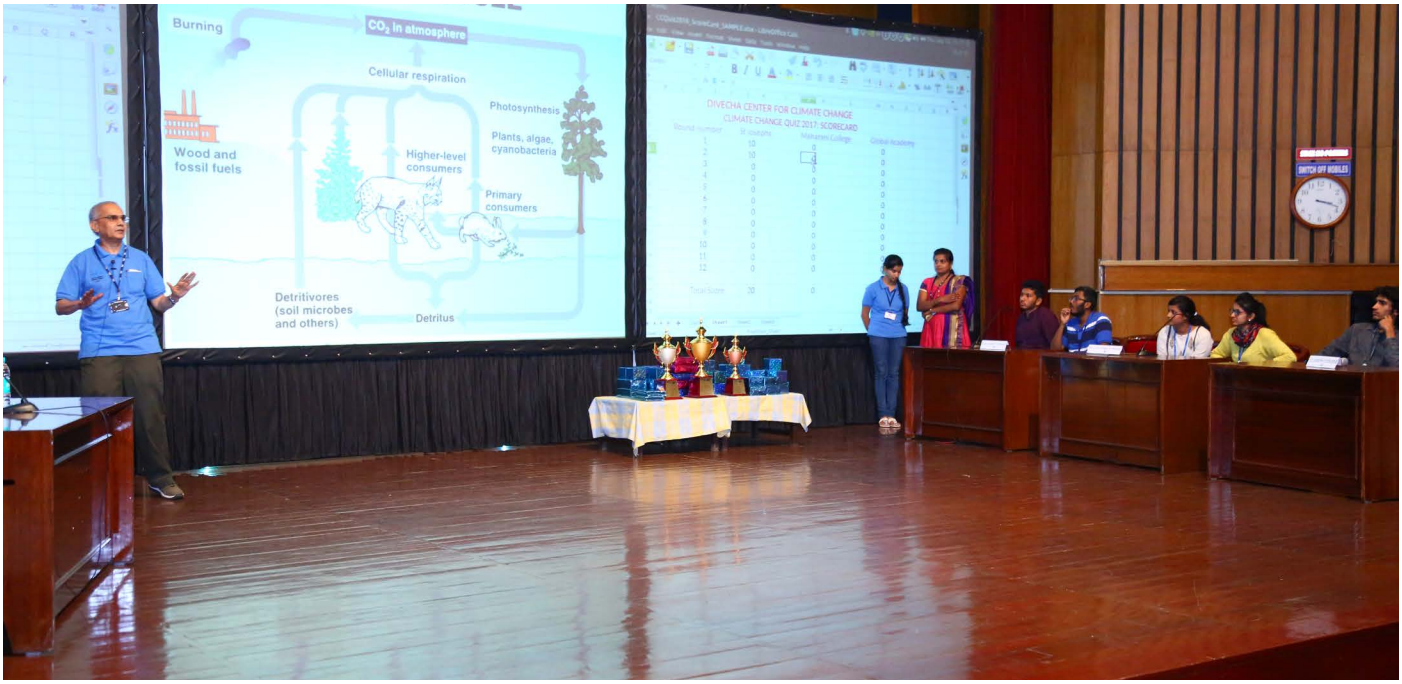
The annual Climate Science Quiz program for college students was held at J. N. Tata Auditorium, Indian Institute of Science on 14th September 2017. This event, which attracted more than 1000 students and faculty from 72 colleges across Karnataka, was conducted to create awareness about climate and climate change among the youth.

The research students and project staff of the center had created posters on glacier retreat in Himalayas, paleoclimate, water crisis and solutions, climate change and renewable energy. A few students provided live demonstrations of climate science through experiments. This created excitement and awareness among the students. Some of the experiments were on the greenhouse effect, cloud formation and micro physics and infrared measurements of carbon dioxide concentrations.

These experiences helped the students understand how climate science is relevant to everyday life. This provided an excellent learning experience for these youngsters who thronged the posters and demonstrations with great enthusiasm.

At noon, a preliminary written test on climate science was conducted for about 75 teams. The top three teams were St. Joseph's college, Global Academy of Technology and Maharani's College for Women. The format of the quiz involved ten rounds with three questions in each round. The question was passed on to the audience whenever the teams failed to answer the question. There was an

Students thronging to view the posters



Prof. J. Srinivasan conducting the quiz program

intense battle for the top spot in the quiz competition. The first prize was won by the students from the Global Academy of Technology. They retained their record winning the quiz for a second time in a row.

There was a tie between two colleges for the second and third place and a tie breaker round had to be invoked. Maharani's College for Woman won the second place followed by St. Joseph's college who secured the third spot. The winners were presented with trophies, certificates and cash prizes. Prof. Anurag Kumar, Director of Indian Institute of Science handed over the prizes.

The students of Global Academy of Technology receiving the first prize

THE 12th JEREMY GRANTHAM LECTURE ON CLIMATE CHANGE BY V. RAMASWAMY

Prof. V. Ramaswamy, Director, Geophysical Fluid Dynamics Laboratory in Princeton, USA delivered the 12th Jeremy Grantham lecture at Divecha Centre auditorium in Indian Institute of Science on 7th November 2017. The title of his talk was "Understanding of weather and climate from global to regional scales". The summary from his lecture are given below.

The Earth system consists of the atmosphere, oceans, biosphere, cryosphere and ecosystems. We need to understand the science of climate change but also use the science to provide early warnings about the disasters. We have powerful computers that can model the entire earth system with all its complexities. We divide the earth into million cubes and in each cube ensure that the laws of physics can be invoked. The equations we are concerned with are momentum conservation along with conservation of matter and energy. There are three attributes that are essential to solve these equations. A lot of weather phenomena extremes are dependent on the rotational motions. For hurricanes, rotation dynamics is important to capture.

Now let us talk about climate. We see that it is warm everywhere and in some places it is strikingly warmer compared to other regions and very few regions are cooling. One of the things that accompanies temperature change in the ocean, is sea level rise. Sea level is an important aspect of climate change and also detrimental to human society. There are three sets of factors that influence climate change. One is natural mechanisms. The changes in Sun's luminosity can change the climate. The volcanic explosions throw up dust in the atmosphere. The volcanic dust prevents

Prof. V. Ramaswamy delivering the lecture

sunlight from coming through which causes cooling of the surface. When we observe changes in temperature or sea level, we should ask if this is because of natural variability or because of human influence. The human influence is mainly through an increase in carbon dioxide, methane and other greenhouse gases. In addition to greenhouse gases, particulate matter has also increased on account of human actions. On account of global warming, heat waves will occur with higher frequency and have longer duration. In recent decades there have been major advances in climate science on account more observations, better computer models and a refinement of scientific understanding.

In the Atlantic Ocean, a series of hurricanes usually occur from June to November. So the concept of using the weather model for climate purposes was put to test in this particular season. The performance of a model in the prediction of hurricanes is in terms of the difference between observed and predicted track. These errors come down as the hurricane comes closer to landfall. In a warmer climate the intensity of hurricanes will increase. Sea level rise occurs due to warming of oceans resulting in expansion of water. On top of that if there is a hurricane then a surge. Many sectors such as aviation, maritime, and energy infrastructure are affected by the changes in weather and climate. Vulnerability and exposure interact with climate change to subject some people to higher risk. In India, the risk of coastal flooding increases both on account of global warming and land subsidence along the coast. In America, a combination of high tide, sea level rise and storm surge caused by hurricane Sandy led to severe flooding in lower Manhattan in October 2012. So a unified modeling approach is necessary to address these situations and minimize risks and vulnerabilities. We need coupled assimilation systems to acquire more information about different phenomena.

Prof. V. Ramaswamy answering questions from the audience

INTERNATIONAL OCEAN DISCOVERY PROGRAM'S POST CRUISE MEETING

International Ocean Discovery Program's (IODP) Expedition 353 was conducted during December 2014 to January 2015 over the Indian Ocean region, and was aimed towards understanding the past climatological and biogeochemical history of the Indian monsoon across multiple timescales. Quantifying the variability of the salinity gradient in the Bay of Bengal on suborbital to orbital time scales was a major goal of the expedition. The IODP post cruise meeting at Divecha Centre for Climate change, organized during 6th to 8th November 2017 by Professor Prosenjit Ghosh, showcased the scientific progress made during the Expedition 353. The meeting comprised a host of international participants and speakers from institutions like: Brown University, USA; University of Bremen and GEOMAR-Kiel, Germany; and The Open University, UK. The presentations primarily dealt with reconstructing past variations in Indian Summer Monsoon and global climate through utilization of marine sedimentary archive. Attempts to reconstruct seasonal variability in physio-chemical conditions of the Northern Bay of Bengal through analyses of foraminifera was presented in the deliberation. Along with this, experts from India shared their contribution to the knowledge on monsoon variability based on ship data, and continental and marine archives. A total of 27 foregin and 7 Indian delegates participated in the meeting. The 35 talks spread over three days and the discussions provided new insights about variability of the Indian monsoon in the past.

The IODP expedition 353 post cruise meeting attendees

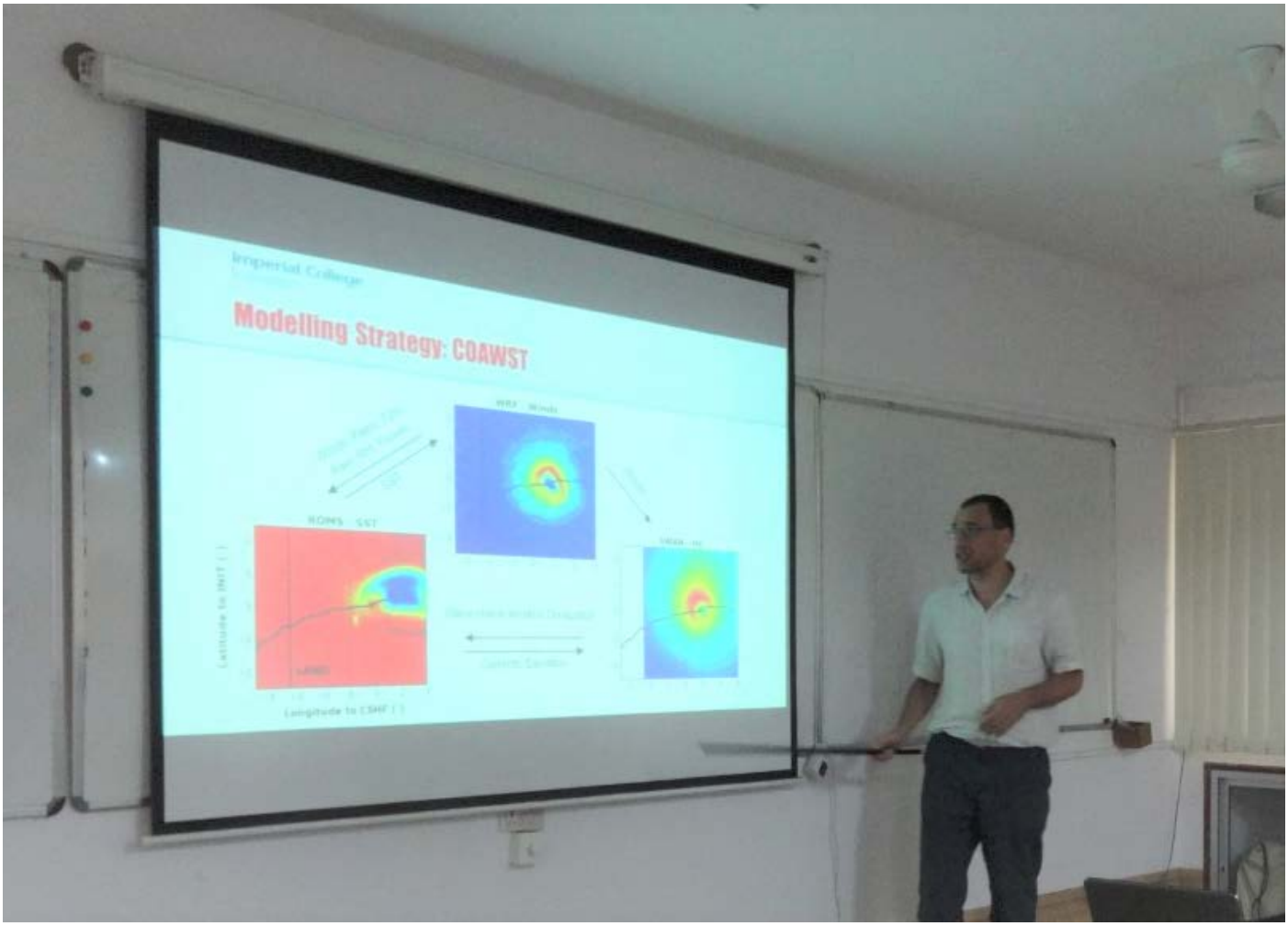
VISIT OF RALF TOUMI, IMPERIAL COLLEGE, LONDON

Prof. Ralf Toumi, Head of Space and Atmospheric physics, Imperial College, London, visited Divecha centre for Climate Change from 31st August to 2nd September 2017.

The main discussion during this visit was on the Global Challenges Research Fund (GCRF). Prof. Toumi highlighted the need for an interdisciplinary research hub to address intractable challenges faced by developing countries. During the discussion the need for an early warning system for various emergencies faced by developing countries was identified. Some these are extreme rainfall, drought, air quality and land degradation.

Prof. Toumi discussed the strategy for the prediction of the performance the wind power plants in Karnataka. He indicated that weather generators can be used to generate statistics and this can then be used for optimal siting of future power plants.

On Friday, Prof. Ralf Toumi gave a talk on “A wave-induced negative feedback between the stratified coastal ocean and tropical cyclones”. This was followed by a discussion on the accuracy of prediction of the tracks and intensities of cyclones.



Prof. Ralf Toumi delivering the lecture

VISIT OF THE PRESIDENT OF INDIA ON 24TH OCTOBER 2017

The Honourable President of India, Ram Nath Kovind, visited the Indian Institute of Science on 24th October 2017. During this visit Prof. S. K. Satheesh, Chairman, Divecha Centre for Climate Change met him and made a short presentation on "Environment and climate change". Some summary from this presentation is given below.

Climate change will be one of the major challenges for humanity in this century and India will be among the worst affected. Some recent devastating rain and consequent flash flood that affected India are those in Mumbai in 2005, Uttarakhand in 2013, and Chennai in 2015. Even though recent advances have made short-term prediction of rainfall more accurate, the prediction of its regional distribution, which is more important for farmers, still remains a challenge. To improve skill of prediction, it is necessary to integrate ground-based information and satellite data available with to develop region-specific parameterisations and incorporate those in climate or weather prediction models. To accelerate this process, climate science community will need access to exascale computing systems capable of running high resolution climate models. It is also important to predict and monitor moraine-dammed lakes in the Himalayas using high resolution satellite data, estimate the volume of water stored using location-specific algorithms, plan safe ways to drain them off during

The Honourable President of India, Ram Nath Kovind, in the meeting

emergency to prevent flash floods and take measures to prevent the loss of life and property in the Himalayan region. In addition to disaster management, the amount of stored water is also a crucial information as millions of people depend melt water from the Himalayan glaciers for their water supply and electricity.

Another major concern is the impact of climate change on India's precious biodiversity. The large human and cattle population along with land use changes have exerted significant pressure on India's biodiversity. In recent years, India's biodiversity is also facing additional pressure from climate change. India is committed to halt biodiversity loss by 2030 and this is a challenge as a fraction of our biodiversity is not yet documented and its change over time is rather poorly understood. A balanced approach is required to carefully manage and conserve our forest resources.

Policy making should depend on information derived from observation-based assessments. This requires an understanding of the implications that can help to design adequate strategies for management of resources. The current scientific understanding of the potential connections between climate change and society such as food production, water security and biodiversity conservation is not adequate enough to directly translate into policy decisions. It is important to pursue this, because India has made substantial commitments to reduce emissions in the Paris agreement. This has been initiated in Bangalore with a vision, "Science for the people" and with an objective of linking science to policy.

Round table discussion with the Director of IISc Prof. Anurag Kumar

AMERICAN GEOPHYSICAL UNION AWARD LECTURE

American Geophysical Union award lecture by Prof. S.K.Satheesh

Prof. S. K. Satheesh, delivered a lecture in the American Geophysical Union meeting on 12th December 2017. A summary of his lecture is given below.

A series of ground-based and airborne measurements of aerosols over the Indian region during summer and pre-monsoon seasons have revealed the presence of elevated absorbing aerosol layers over most of the Indian region. Subsequent measurements of black carbon (BC) using high-altitude balloons, showed layers with high concentrations in the middle and upper troposphere even at an altitude of 8 to 10 kms. Simultaneous measurements of the vertical thermal structure have shown localized warming due to BC absorption leading to large reduction in lapse rate and sharp temperature inversion, which in turn increases the atmospheric stability.

This aerosol-induced stable layer is conducive for maintaining the black carbon layer longer at that level, leading thereby to further solar absorption and subsequently triggering dry convection. These observations support the 'solar escalator' concept through which absorption-warming-convection cycles lead to self-lifting of BC to upper troposphere or even to lower stratosphere under favorable conditions in a matter of a few days.

An on-line regional chemistry transport model (WRF-Chem), incorporating aircraft emissions, showed that emissions from high-flying aircrafts as the most likely source of these elevated black carbon layers. These in-situ injected particles, produce significant warming of the thin air at those heights and can lift these layers to upper troposphere and lower stratosphere.

These simulations were further supported by extinction coefficient profiles obtained from the CALIPSO space-borne LIDAR. Based on these, it is hypothesized that such intrusions of black carbon to lower stratosphere and its consequent longer residence time in the stratosphere, can have significant implications for stratospheric chemistry, considering the known ozone depleting potential of black carbon aerosols.

AWARD OF DEVENDRA LAL MEMORIAL MEDAL

The presentation of the first Devendra Lal Memorial Medal

The Devendra Lal memorial Medal is named in honor of Professor Devendra Lal, a distinguished geophysicist whose work spanned diverse areas of the Earth and space sciences. He is best known for his role in founding and developing the field in which cosmic rays produced isotopes on Earth are used as tracers to investigate a wide range of Earth science problems.

Prof. S. K. Satheesh, Chairman, Divecha Centre for Climate Change, Indian Institute of Science received the first Devendra Lal Memorial Medal of the American Geophysical Union in New Orleans on 13th December 2017 at the annual meeting.

This medal was given for outstanding earth science research by a scientist belonging to and working in a developing country. Prof. Satheesh is a pioneer in aerosol research and has contributed to our understanding of the impact of atmospheric aerosols on our climate. He used observations from aircraft and balloons to identify the presence of elevated layers of black carbon in many places across India.

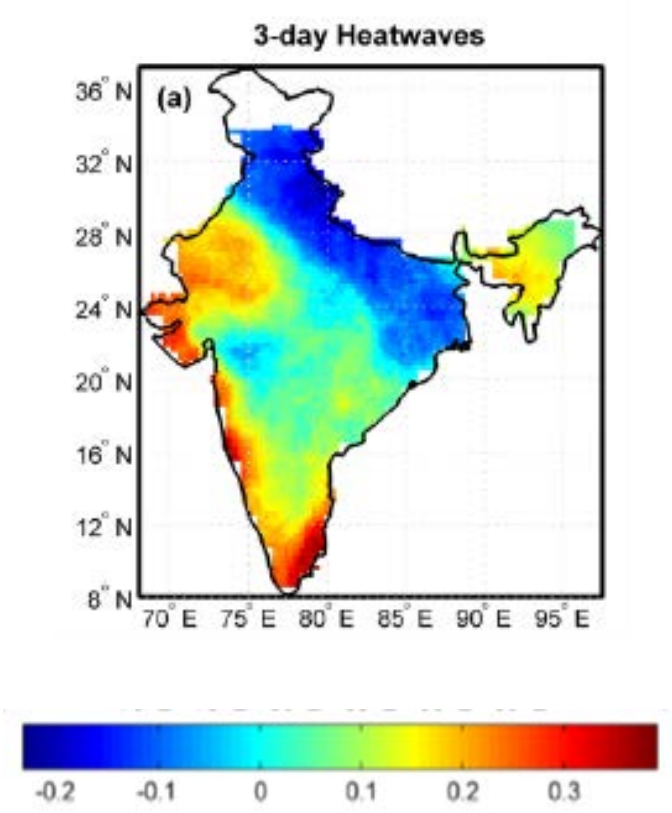
AGU medal

RESEARCH HIGHLIGHTS

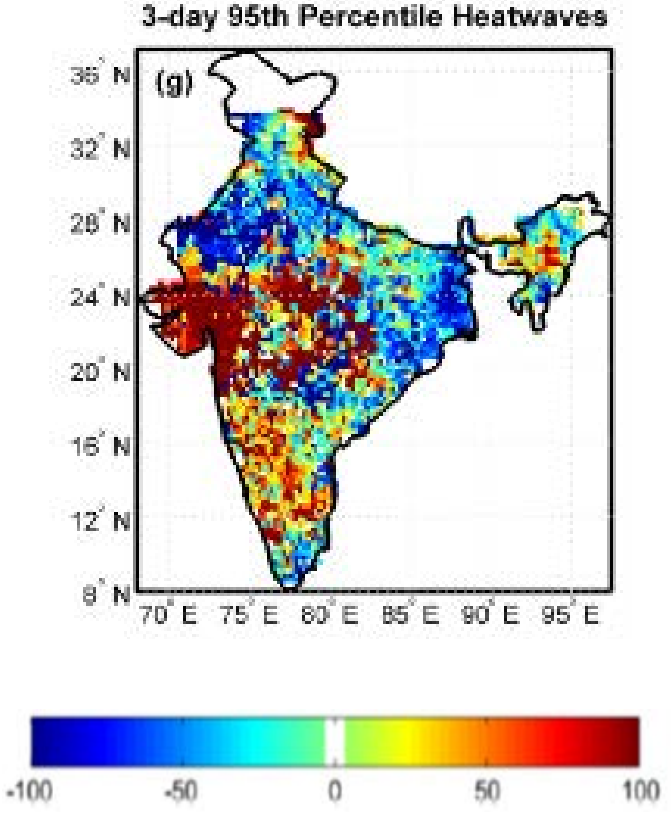
CONCURRENT HEAT WAVES AND DROUGHTS

A combination of low rainfall and high temperature has a more serious impact on society than when these occur separately. The yield of wheat crops decreases substantially when high temperature and low rainfall occur together. In a recent paper published in the journal Scientific Reports, Shialza Sharma and Pradeep Majumdar have examined the concurrent occurrence of heat waves and droughts during the period May to October in India. They used a heat wave magnitude index that combines the duration and magnitude of the heat waves. They have shown that during the period 1951-2010, heat waves with a duration of 3 days have increased in North West, North East, coastal and south India but decreased in the Indo-Gangetic plains. They used the Standardized Precipitation Index to define a meteorological drought. During this period the spatial extent of drought has increased in Central India. The number of concurrent heat waves and droughts increased during 1981-2010 compared to 1951-1980.

Reference: S.Sharma and P.Mujumdar, Increasing frequency and spatial extent of concurrent meteorological droughts and heat waves in India, Scientific reports, 17 November 2017



Trends in the frequency of 85 percentile heat waves in India



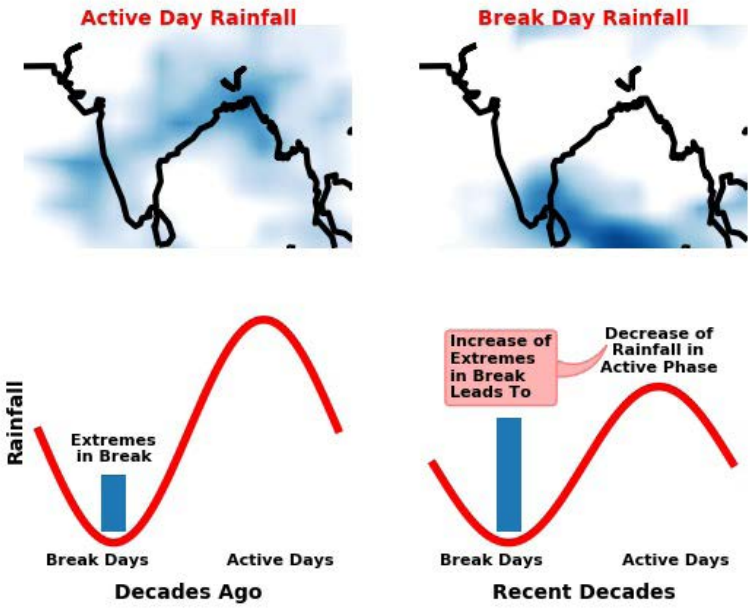
Percentage change in concurrent occurrence of heat waves and moderate droughts in 1981-2010 compared to 1951-1980

INCREASE IN EXTREME RAINFALL EVENTS DECREASE THE SEASONAL MEAN MONSOON RAINFALL

Indian summer monsoon rainfall has shown a small decline in the seasonal mean during the past 50 years. During the same period extreme rainfall events (rainfall greater than 100 mm/day) has increased by 50%. How can a decline in seasonal mean and increase in extreme rainfall occur at the same time? In a recent study published in the journal Scientific Reports, Karmakar, Chakraborty and Nanjundiah have investigated this apparent paradox using observational data and numerical models.

Indian summer rainfall alternates between phases with copious rainfall (called active) and quiescent phases (called breaks). These phases last for about a week or two over central India. Most of the contribution to seasonal mean rainfall comes from the active phase. This study found that extreme rainfall events have increased in the break phase during the last three decades. This increase in the extreme rain events during the break phase stabilizes the atmosphere, which weakens the subsequent phase of active rainfall. The evolution of active-break cycle of the Indian monsoon is not simulated well by the present climate models. How will Indian monsoon evolve in response to climate change? The climate models show large disagreement with regard how monsoon rainfall will change in the future. This may be partly on account of their inability to simulate accurately the active-break cycle of the monsoon.

Reference: Karmakar N, Chakraborty A, Nanjundiah RS (2017a) Increased sporadic extremes decrease the intraseasonal variability in the Indian summer monsoon rainfall. Sci Rep 7:7824, DOI 10.1038/s41598-017-07529-6 Article link: https://www.nature.com/articles/s41598-017-07529-6



Spatial pattern of rainfall during active and break monsoon

RAPID DEPLETION OF SMALL GLACIERS IN HIMACHAL PRADESH

During the past 50 years, the retreat of many Himalayan glaciers has been documented but these do not give us an idea about the volume of water that has been lost on account of the retreat. This knowledge is important to evaluate the impact of the retreat on availability of water to people living near the glaciers in the Himalayas. An accurate estimate of the decline in the volume of ice in a basin can be made if accurate field measurements are made in each glacier using stakes and snow pits. This is, however, difficult in the Himalayas since many glaciers are located in remote areas. Hence there is a need for an alternate method that uses satellite data and local data on temperature and snowfall.

The glaciology group, led by Anil Kulkarni has published a paper recently in the "Annals of Glaciology" on the mass and volume loss in the glaciers in the Chandra basin the Himalayas. This study examined about 146 glaciers spread over 660 square kilometres in the Chandra basin in Himachal Pradesh. The equilibrium line altitude of a glacier is the elevation at which the mass gained above that altitude is equal to the mass loss below that altitude in a given year (see figure 1).

In this paper the authors have shown that in the Chandra basin the equilibrium line altitude has increased at the rate of 113 meter per decade. For this work the authors used satellite data on snow lines and temperature and snowfall data from a weather station that is located about 25 km from the glacier. Glaciers in the Chandra basin have lost about 11.1 Gigatons of water between 1984 and 2012. This represents about 20% of the mass of glaciers in the entire basin. The smaller glaciers that are located at lower altitudes have lost 67% of their mass. Large glaciers at high altitudes will not disappear soon but small glaciers at lower altitudes will shrink rapidly and lead to water stress in villages located near these glaciers.

The changes in mass balance of a glacier depends upon the summer temperature and winter snowfall in that region. A 20% increase in snowfall can compensate for a 1 degree increase in summer temperature. In this region the impact of increase in temperature was more than the changes in snowfall. The rapid rise in temperature in the Himalayas in the past 40 years is the main contributor to the rapid melting of small glaciers at low altitudes.

Many small communities located close to the smaller glaciers have faced serious water stress on account of the disappearance of the smaller streams. There is a need, therefore, to find innovative methods to reduce the impact of water stress on these communities. Some of these innovations involve storing the winter snow in an ice pond. The melt from these ice ponds can be used for summer irrigation.

Reference: Sayli,A.T., Kukarni,A.V., and Bala,G.. An estimate of glacier mass balance for the Chandra basin, western Himalaya, for the period 1984–2012, Annals of Glaciology, August, 2017.

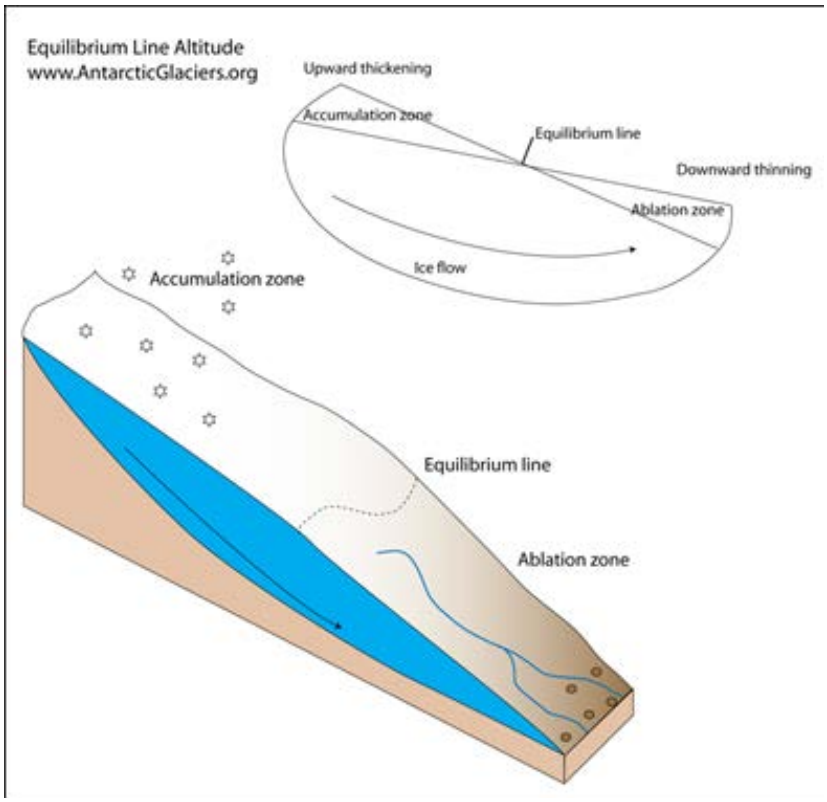


Figure 1: The equilibrium line altitude of a glacier

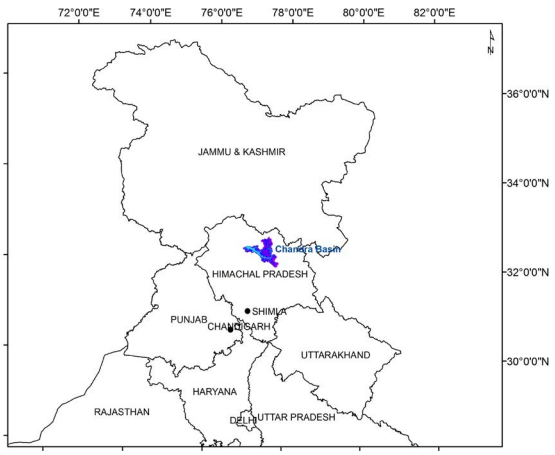


Figure 2: Location of Chandra Basin

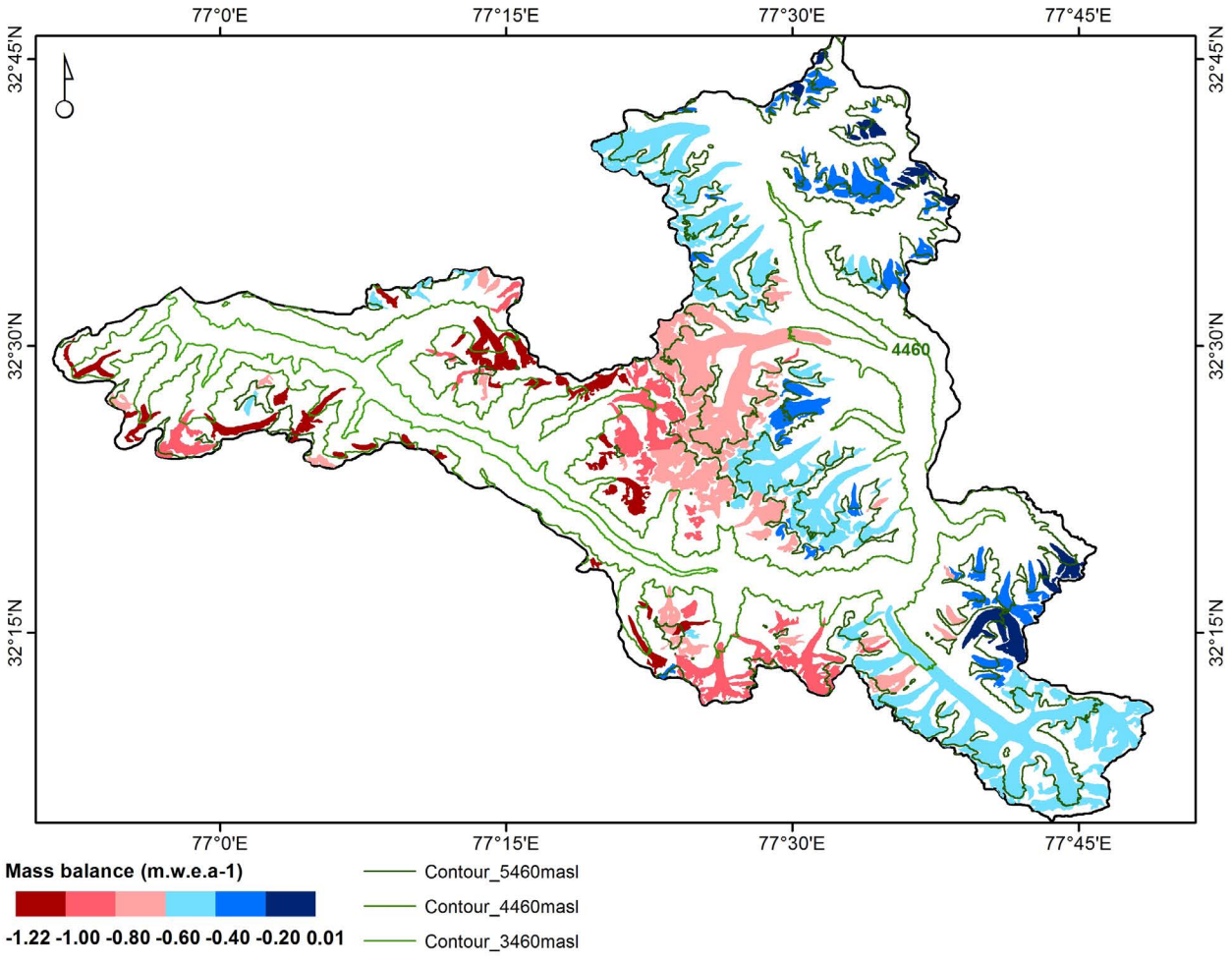


Figure 3: Change in mass balance of the glacier in the Chandra Basin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