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Newsletter of the

DIVECHA CENTRE FOR CLIMATE CHANGE

Infosys award ceremony

Review meeting

Dialogue on air pollution and health

Open day 2019

Impact of irrigation on Indian monsoon



Indian Institute of Science
Bengaluru
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FROM THE CHAIR

Greetings!

The “Water Solutions Lab” established at the Centre as a part of the “Sustainable Water Future Programme” of “Future Earth”, aims to address water sector challenges in India and adjacent nations and develop practical solutions by bridging the gap between science, policy and governance and between knowledge and practice. This falls under the aegis of the sustainable development goals of the “Future Earth” Programme, namely “Ensure availability and sustainable management of water and sanitation for all”. As a first initiative, the Lab will examine the problem of geogenic contaminants of ground water such as fluoride, arsenic, uranium and related radionuclides; followed by investigation on other contaminants such as high salinity, silica, heavy metals and sulphides.

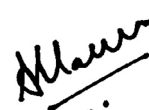
About 69% of the 1.35 billion Indians live in the rural sector. Their daily demand of 182 billion litres of water for domestic use (@ 200 litres per day per person), met mainly through ground water. About 67% of water demand in the irrigation sector is mostly dependent on ground water. Constantly increasing demand has pushed large areas of India in to critical and over exploited category of ground water exploitation. Nearly 30% of the country faces shortage of ground water availability and sinking of water table, with consequences on the quality and quantity of ground water. Water stress drives groundwater extraction from deeper zones, which are in contact with aquifer rocks for longer periods of time and are more susceptible to geogenic contamination.

Estimates show that about 40% of India’s population is subjected to higher fluoride contamination in ground water leading to dental or skeletal fluorosis. About 50 million people of 72 districts in Eastern India, 21 in Uttar Pradesh and large regions in Bangladesh face high threat of arsenic contamination in groundwater, leading to skin diseases, skin cancer, intestinal diseases etc. A very large area involving Punjab, Rajasthan, Haryana, Eastern Telangana, Western and south-western Andhra Pradesh, south-eastern Karnataka and Tamil Nadu have ground water with uranium contamination much greater than 30 ppb or 60 ppb, the limits prescribed by WHO and Atomic Energy Regulatory Board of India respectively. Consequent health implications are serious.

A holistic approach, consisting of delineation of contaminated groundwater zones, their geological setting, petro-mineragraphic and geochemical study of aquifer rocks, geochemistry of water, water rock interaction modelling, development of different sustainable technologies as applicable to different settings, medical and nutritional intervention for reversing the associated diseases are being undertaken in selected areas. Successful approaches, after trial over sufficient duration, would be passed on to Government agencies and policy makers for possible large-scale implementation.

On a brighter side, a recent research involving scientists from the Centre has shown a steady and significant decreasing trend in Black Carbon (BC) [soot particles emitted during all low-temperature combustion] mass concentration over India during the last decade (@ ~200 ng m⁻³ y⁻¹). The study based on long-term primary data from a dense network stations spread across India, has also emphasized the role of the Government’s emission control measures in this.

S. K. Satheesh



INFOSYS AWARD CEREMONY



Prof. S. K. Satheesh receiving the Infosys award on 5th January 2019 in Bengaluru.

The Infosys Prize is awarded by the Infosys Science Foundation (ISF), a not-for-profit trust set up in 2009. The award is given annually to honour outstanding achievements of contemporary researchers and scientists across six categories: Engineering and Computer Sciences, Humanities, Life Sciences, Mathematical Sciences, Physical Sciences and Social Sciences. The award intends to celebrate success in research and stand as a marker of excellence in these fields.

The Infosys Science Foundation (ISF) honoured the winners of the Infosys Prize 2018 at an awards ceremony in Bengaluru on 5th January 2019, while also celebrating its 10th year milestone. The winners were felicitated by the Chief Guest, Prof. Manjul Bhargava, Fields Medallist and R. Brandon Fradd Professor of Mathematics at Princeton University.

The event was attended by eminent

scientists and academicians from India and abroad, business leaders, young researchers and students. Trustees of the Infosys Science Foundation, Mr. K. Dinesh, President of the Board of Trustees, Mr. N. R. Narayana Murthy, Mr. Nandan Nilekani, Mr. T. V. Mohandas Pai, Mr. S. Gopalakrishnan, Mr. S. D. Shibulal and Mr. Srinath Batni, were also present at the event.

The laureates of the Infosys Prize 2018 in Physical Sciences is S.K. Satheesh, Professor, Centre for Atmospheric & Oceanic Sciences, Indian Institute of Science, and Chairman, Divecha Centre for Climate Change for his pioneering scientific work in the field of climate change. His studies on black carbon aerosols, the dark, light absorbing, microscopic particles in air which greatly influence the energy balance of the atmosphere over the Indian subcontinent have enabled a better understanding of the role of these particles on climate change, precipitation, and, human

health in the Indian subcontinent. Prof. Satheesh's work on measuring, quantifying, and analysing the impact of black carbon aerosols is important to not

only climate science but also, to society that must mitigate and cope with climate change, possibly the most important threat to humanity.

INFOSYS PRIZE LECTURE BY PROF. S. K. SATHEESH AT MOHALI

The Infosys Science Foundation (ISF) organized a public lecture by Prof. S.K. Satheesh, at Indian Institute of Science Education and Research (IISER), Mohali on 28th March 2019. In his lecture, Prof. S.K. Satheesh mentioned that there has been a substantial increase in interest in the climate impact of light-absorbing aerosols due to their high atmospheric warming potential. Of special significance is black carbon (BC) aerosol, the dark light-absorbing microscopic particles in air, which greatly influence the energy balance of the Earth-atmosphere system.

Despite the general consensus among climate scientists on the significant role of light-absorbing aerosols on regional

and global climate, various studies and impact assessments provide widely differing and contrasting inferences and projections. Viewed in the above global backdrop, the South Asian region and India assume special significance due to the diverse geographical features, high population density, rapid urbanization and industrialization, leading to a highly complex aerosol system. He spoke on the enigma of light-absorbing aerosols and their impact on climate by using data from climate observatories, research ships, instrumented aircrafts and high-altitude balloons.



Prof. S. K. Satheesh delivering the lecture at IISER Mohali on 28th March 2019.

DIVECHA CENTRE FOR CLIMATE CHANGE REVIEW MEETING



(Left to Right) Prof. Thomas Stocker, Dr. Sailesh Nayak, Prof. Stephen Eggins, Prof. V. Ramaswamy, Prof. John Wallace.

The Indian Institute of Science reviews the performance of different departments and centres by inviting eminent experts in the field to visit the institute. The following committee was constituted to review the Centre for Atmospheric and Oceanic Sciences, Divecha Centre for Climate Change and the Centre for Earth Sciences. Dr. Sailesh Nayak, Director, National Institute for Advanced Studies, Bengaluru, Prof. John Wallace, University of Washington, Seattle, Washington, USA, Dr. V. Ramaswamy, Director, Geophysical Dynamics Laboratory, New Jersey, USA, Prof. Thomas Stocker, University of Berne, Switzerland, Prof. Stephen Eggins, Australian National University, Canberra, Australia

The committee visited the Indian Institute of Science from 23rd to 25th January 2019. The committee met all the faculty, students and staff and held detailed discussions on the research, teaching and training programs at DCCC. The committee indicated that DCCC

is a unique institution within the Indian Institute of Science and has reached full maturity in the 10 years of existence. They congratulated the leadership and the entire team for the continuous hard work that has helped creating a widely recognized centre. The uniqueness of DCCC is its interdisciplinary activity at the science-policy interface combined with its close association with the top research institutes in India and abroad. DCCC faculty and staff were working on a wide range of topics related to, and influenced by, anthropogenic climate change. Its interdisciplinary nature is a distinct strength and is very well reflected in the projects that are currently undertaken by the Centre. Over the years DCCC has developed a range of initiatives including workshop and training programs regular invitations to international speakers to deliver Grantham Lectures that enjoy wide attention.

ANNUAL CONFERENCE OF INDIAN COLLEGE OF ALLERGY ASTHMA APPLIED IMMUNOLOGY



(Left to Right) Prof. B. P. Karunakara (Org Secretary), Prof. Srinivas (Guest of Honour), Dr. Medha Y. Rao (Dean Ramaiah Medical College), Prof. Dr. H. Paramesh (Chairman) Prof. S. K. Satheesh (Chief Guest), Prof. A. K. Janmeja (President ICAAI), Dr. A. B. Singh (Secretary General ICAAI).

The 52nd Annual Conference of Indian College of Allergy Asthma Applied Immunology (ICAAICON – 2018-19) was organized by Lakeside Education Trust and South Zone at M.S. Ramaiah Institute of Medical Sciences, in Bengaluru from 13th to 17th February 2019. The conference was co-sponsored by Divecha Centre for Climate Change, Alliance for Health Promotion Geneva, Rajiv Gandhi University of Health Sciences, Adichunchinagiri University, IAP Allergy Chapter, Ramaiah Medical College and Aster CMI Hospital. There were 200 delegates from India, USA, UK and Sri Lanka in the workshop.

The conference was inaugurated by Prof. S. K. Satheesh, Chair, Divecha Centre for Climate Change. Prof. J. Srinivasan, Prof. Viraj and Prof. Dr. H. Paramesh delivered lectures during the workshop. A one-day workshop was

held prior to the conference to create awareness among children and adults on health-related topics. The conference highlighted the newer aspects of allergic diseases and its impact on psycho socio-economic disease burden. Air pollution, global warming and climate change was strongly emphasized as a major cause for allergic airway diseases. Food allergy, ear, nose, throat, eye, skin, and intestinal allergies were discussed in terms of causes, new clinical findings treatment and measures to prevent them. Researchers presented their scientific papers. There was a special open house session for the public and media.

Dr. H. Paramesh, Chairman of the organizing Committee concluded the session and sincerely thanked the delegates and Divecha Centre for Climate Change for co-sponsoring the program.



(Left to Right) Prof. Elizabeth C. Paramesh (Moderator), Prof. Dr. H. Paramesh, Prof. Maj. K. Nagaraju, Prof. J. Srinivasan, Mr. Mohan Gurjar and Mr. Zarir Batha (Panellist).

Dr. H. Paramesh gave a talk at the National Health Conclave on 23rd March 2019 organized by the Centre for Environmental Health, the Public Health Foundation of India. Air pollution is critical issue and can result in serious health effects as PM2.5 can enter blood stream and results in a spectrum of diseases, coagulopathy etc. Improving the greenery or green spaces by planting more trees could significantly improve the air quality.

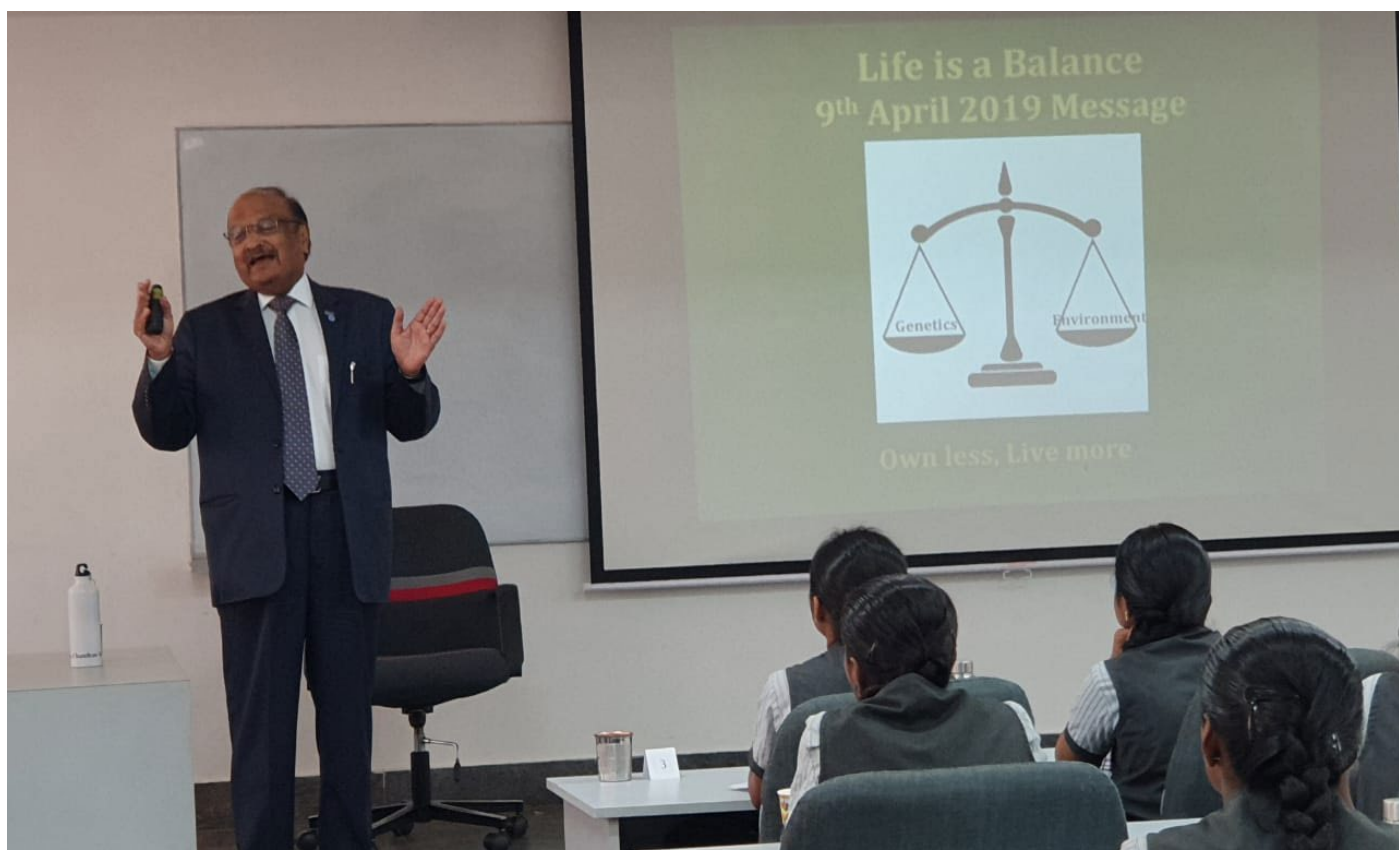
It's time to give serious thought to the effective implementation of mitigation measures such as use of indoor plants for air pollution reduction, Government policies on the regulation of industrial emissions, how to communicate with various government and private sectors and urban planners should include climate change in their agenda for effective solutions.



Prof. Dr. H. Paramesh with Malaysian delegates at Divecha Centre on 9th Jan 2019.



Prof. Dr. H. Paramesh participated as a panellist on air pollution and role of physician in advocating and educating in the society on ill health and taking measures in prevention, New Delhi on 23rd March 2019.



Prof. Dr. H. Paramesh addressing the high school students on environment pollution at ESSAE Foundation conference hall on 9th April 2019.

A TALK ON HIMALAYAN GLACIERS IN A REGIONAL LANGUAGE



Prof. Anil Kulkarni giving talk in Hindi on Himalayan Glacier at the Faculty Hall.

A one-day program on technical presentation in Hindi was organized by regional official language organizing committee on March 14th, 2019 at Indian Institute of Science.

Prof. Anil V. Kulkarni, Distinguished Scientist, Divecha Centre for Climate Change delivered a talk in Hindi on Climate Change and Himalayan Glaciers. He discussed the origin and distribution of glaciers in Himalaya and its contribution to river runoff. He discussed the observed and modelled changes in climate in the Himalaya.

In addition, techniques and models developed at Divecha Centre for Climate Change to estimate spatial distribution of glacier depth, glacier mass balance and glacier lakes were also discussed.

Case studies demonstrating application of these techniques to estimate future changes in glacier mass and extent in Satluj basin was also shown. He showed that retreating glaciers and early snow melt influence power generation and livelihood of people living in the Himalaya. Flash flood from glacier lake is a common disaster in the Himalaya.

The study carried out by the Centre in Sikkim on glacial lake outburst flood was presented. He concluded that Himalayan glaciers were retreating and can influence livelihood of mountain communities. He highlighted the need for timely action to mitigate future hardship.

PREPAREDNESS FOR AND RECOVERY FROM ABRUPT GLOBAL CATAclysm



Discussions during the workshop.

A workshop on “Preparedness for and recovery from abrupt global cataclysm” was held at Divecha Centre for Climate Change on 1st February 2019. Dr. Ray Taylor from Oxford University and Prof. Prosenjit Ghosh from Centre for Earth Sciences and Divecha Centre for Climate Change organized this workshop. Prof. John Ingram from Oxford University who introduced the topic and discussed the stresses due to famine, crisis in food production, dynamics of food systems, which include issues as diverse as global production and supply, politics and culture. Then Prof. David Denkenberger, author of “Feeding Everyone No Matter What” discussed some of the potential shocks, their likelihood and possible solutions.

Prof. Prosenjit Ghosh discussed the impact of Tambora volcanic eruption in 1816. Tambora eruption was quite

small. A super-volcanic eruption would be at least ten times larger. The larger Toba eruption coated India with more than 10cm of ash but importantly some humans survived.

Mehul Pandya from All India Disaster Mitigation Institute (AIDMI) proposed a draft road map in case of a major global shock. Dr. Mukesh Kumar, a senior lecturer in engineering at Cambridge University, explained some of the challenges that India could face regarding supply chain management. Dr. Peter Alexander from Edinburgh University discussed social and economic consequences of harvest loss.

Prof. Ghosh suggested that an all India workshop could be before or after the Future Earth Conference at Indian Institute of Science in September. Prof. Satheesh concurred with this suggestion.

SCIENCE WRITING WORKSHOP



Prof. S. K. Satheesh inaugurating the science writing workshop.

The 8th science writing workshop was held at Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru, during 3 to 10 February 2019. A total of 14 participants from different institutions across the country; ten scientists, one postdoctoral researcher, one senior research fellow and two Ramaseshan fellows attended the workshop.

The workshop was inaugurated by Mr. G. Madhavan (Executive Secretary, Current Science Association). The keynote speaker, Prof. S. K. Satheesh (Chief Editor, Current Science), Chair DCCC, provided a glimpse of the history and mandate of Current Science, and the types of research articles published in the journal. He also highlighted manuscript categories in the journal and some common problems from the editor's perspective.

Participants were tailored, to understand

and report natural phenomena using logic in a scientific manner. Mr. K. P. Madhu emphasized the need to overpower cultural, social and psychological barriers against asking questions. Mr. Madhu also drew attention to the use and effect of simple sentences and active voice on the readers. He stressed the importance of creativity while writing to inspire the readers.

Freelance science editor, Mr. Yateendra Joshi explained the norms and structure of science writing. He stated some of the common errors made by writers such as overlooking the aim and scope of the journal. He enlightened the participants about websites that provide a detailed list of authentic journals and cautioned them against predatory journals.

In the interactive session of the workshop, participants were exposed to the principle of search–research–

read—reflect before starting to write and revise—rewrite—restructure—reformulate after writing, for effective communication. Some of the factors involved in the flow of message from the author to the readers were transcribed, translated and terminated for the delight of reading.

Ms. Rohini Godbole (Centre for High Energy Physics, IISc, Bengaluru) deliberated the sensitive issue of gender parity in science, challenges faced by women in science and the policies implemented to safeguard the interests of women in India. She urged the participants to be mindful about gender bias and its long-term impact on shaping science. Ms. Godbole shared her experiences and discussed the need to devise policies which are gender neutral.

Mr. Karthik Ramaswamy from Archives and Publication Cell, Indian Institute of Science addressed the causes behind bad writing. He underscored the need for simple, clear sentences to meet the reader's expectations. He also provided participants some writing exercises to demonstrate how to write simple, coherent sentence for better clarity.

Mr. Sanjay Pai from Columbia Asia Referral Hospital, Bengaluru, explained the significance of following ethics in science writing and the cost that defaulters must pay. Malpractices in scientific research is not only a setback to the advancement of science, but also harm society at large. He spoke in depth about plagiarism and how it is frowned upon by the scientific community.

In the last session of the workshop, Ms. Gita Madhu stressed on the need for good input to foster good writing and demonstrated how anyone can enhance language learning using on-line resources. She also briefly discussed social media platforms as useful resources for researchers and provided a glimpse of blogging for science. Participants were shown how to access free-to-use images and to properly credit them. There was also, a session on obtaining relevant information and knowledge management.

The workshop provided a perspective to the participants, on various forms and techniques of science writing, such as, science papers, reviews, proposals, interviews, book reviews, and posters. (Adapted from Current Science)



Participants of the science writing workshop.

OPEN DAY 2019



Visitors and students viewing experiments.

The much-anticipated annual open day event organized by the Indian Institute of Science, Bengaluru was held this year on 23rd March 2019. The event, which takes place every year, marks the birth anniversary of J.N. Tata, founder of the institute.

This year over 2000 visitors, including school and college students, and science enthusiasts made their way to Divecha Centre for Climate Change to get an exposure of newer science-based technology. Research students showcased their work through live



School students taking part in quiz.



Research staff showcasing their work.

demonstrations and poster presentations. Simple experiments were shown depicting greenhouse effects caused by Infra-Red absorptions by gases such as carbon-dioxide in the atmosphere. The physics of the greenhouse effects were explained through posters. Real time measurements of black carbon aerosols were demonstrated. There was an interactive demo of a 3D forest scan. Children were very enthusiastic to view microbes in a microscope. The importance of planting plants to prevent soil erosion was demonstrated and explained through posters.

The melting of Himalayan glaciers due to global warming were screened at the Centre. Various posters related to these topics were also put up and research students explained the importance of climate change, its causes and consequences. The students interpreted the solutions to undo the damage already done and inspired the visitors to take necessary actions as an individual to contribute to help stop global warming. A quiz program was also conducted on

global warming and climate change to educate the visitors on the hazards and ill effects and how the Earth can be saved.

There was a special 'Kids Zone' at the Centre that focused on simple demonstrations such as laser beam propagation through atmosphere, influence of surface heating on vertical wind, and importance of water quality testing. This was very popular among the kids who came to visit. Some other posters include application of drones for effective pesticide spraying, groundwater contamination, 20 kW solar system at the main library in iisc, and the challenges of introducing electric vehicles in India.

The significance of Open Day is to attract children to help them understand the power of science, so they can contribute to the field in future. For many of the school and college students this event gave them an opportunity to rekindle a scientific temperament among them. It proved to be a great platform to explore, experience and enjoy the wonders of science.

DIALOGUE ON AIR POLLUTION AND HEALTH

On March 28th, 2019, Divecha Centre for Climate Change, conducted a one-day Dialogue on Air Pollution and Health with experts from the Indian medical community, including Dr. Sundeep Salvi, Chest Research Foundation Pune, and Dr. H. Paramesh, Lakeside Centre for Health Promotion, Bengaluru and Visiting Professor at DCCC. There was consensus that medical evidence confirms that outdoor and indoor air pollution contributes to poor and declining health and lowers life expectancy for all Indians. Consequently, the necessity to have greater involvement and association of medical experts in Central and State Pollution Control Boards was affirmed.

Prof. J. Srinivasan, Distinguished Scientist, DCCC, remarked that “In India, air pollution is considered as a mere nuisance, whereas it poses a serious health risk. Doctors need to help in raising awareness about air pollution by highlighting this health risk.” Dr. H. Paramesh elaborated some of these risks in his keynote address, noting that when certain pollutants are inhaled, they not only cause respiratory diseases, but

they can also cross the lung tissue and enter the blood stream. These pollutants contribute to a host of non-pulmonary diseases like blood coagulation, stroke, heart attack, BP, diabetes, cancer, autism, dementia and Alzheimer’s disease. “Our greed has brought us to this stage,” he said, “and it is essential that we act together to protect our politically powerless children – the future citizens of our country – from the effects of air pollution.” Viraj Kumar, Visiting Professor, DCCC noted: “This Dialogue has helped us identify opportunities to work with the medical community by linking reliable air pollution data in urban and industrial areas with medical data from these areas.”

Divecha Centre is coordinating efforts to translate the suggestions proposed during the dialogue into actions, which include:

- Developing an environmental questionnaire and smartphone app survey to assess health risk from air pollution.
- Identifying sub-populations at high risk from air pollution.



Participants of the air pollution and health workshop.

INDO-GERMAN WORKSHOP



German delegation at DCCC.

Helmholtz-Indian Platform on Science, Technology, Education and Research (HIPSTER) resulted from an agreement in May 2017 between Dr. Harsh Vardan, Hon'ble Minister of the Ministry of Science & Technology, Ministry of Environment, Forest and Climate Change, and Ministry of Earth Sciences, Government of India, and Prof. O. Wiestler, President of the German Helmholtz Association. HIPSTER will foster the bilateral collaboration with a special focus on young talent. This platform will enable both countries to work together to promote cross-disciplinary exchange and open new channels for research and innovation. The HIPSTER workshop was conducted during February 12-15, 2019 in Bengaluru. The workshop included keynote presentations and breakout sessions. The participants who took part in the session on "The Physics of the Atmosphere" were S.K. Satheesh, Chairman, Divecha Centre for Climate Change, (Co-Chair), Rolf Müller, Forschungszentrum Juelich GmbH, Germany (Co-Chair), Stefan Norra, Karlsruhe Institute of Technology, Germany (Co-Chair), Vinayak Sinha, Indian Institute of Science Education Research, Mohali, S. Suresh Babu, Space Physics Laboratory, Indian

Space Research Organisation, Thiruvananthapuram, Arindam Chakraborty, Centre for Atmospheric and Oceanic Sciences and Divecha Centre for Climate Change, Kirpa Ram, Institute of Environment and Sustainable Development, Banaras Hindu University, Varanasi, V. Vinoj, Indian Institute of Technology, Bhubaneswar.

During workshop, the participants had a very productive discussion. The participants decided to focus on topics, which are of interest to many research groups both in India and Germany. The committee also felt that at present, several atmospheric processes and mechanisms are neither clearly understood, nor modeled accurately, despite the large progress made in this direction over the last decades. This arises primarily due to the complexity of the processes and feedback mechanisms and the awareness of newer elements and processes that are significant. The committee recommended that comprehensive and continuous observations of state of the atmosphere is essential for evaluating model simulations at different scales and learn more about various atmospheric processes and mechanisms.

RESEARCH HIGHLIGHTS

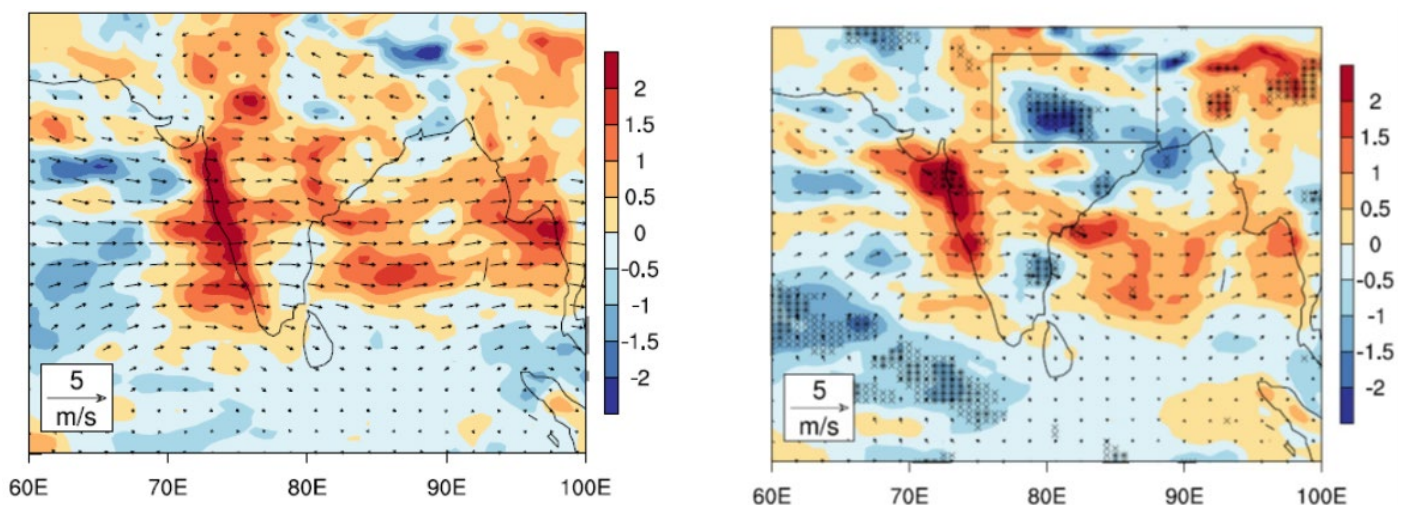


THE IMPACT OF IRRIGATION ON INDIAN MONSOON

The impact of human activities on the Indian monsoon has been examined by many scientists. The effect of global warming, aerosols and deforestation has been studied extensively. The advent of agriculture has changed the land use pattern in India. In the past 100 years there has been a large increase in land that is irrigated by surface or ground water. What impact will irrigation have on the Indian summer monsoon?

About 70% of the global freshwater withdrawal is used for irrigation. In the last 100 years the amount of water used globally for irrigation has increased from about 500 cubic kilometres to 2500 cubic kilometre. Most of this increase has occurred in Asia. Irrigation will increase surface evaporation and reduce the soil and air temperature near the ground. The amount of water vapor in the atmosphere will increase, when compared to no irrigation and hence increase cloudiness and the greenhouse effect due to water vapor.

This issue has been examined in a recent paper by Shubhi Agrawal et al. published in the journal Climate dynamics in February 2019. They have used a coupled atmosphere-land climate model developed by the National Centre for Atmospheric Research in Boulder, Colorado, USA. They used the soil moisture data from JULES (Joint UK Land and Environment Simulator). Among the many cases discussed in this paper, the most interesting is the impact of winter irrigation in the Indo-Gangetic plains on the summer monsoon rainfall. The figure below shows the difference in summer monsoon rainfall (in mm/day) with and without winter irrigation. We find that in many parts of central India rainfall increases by 1 to 2 mm/day and winds have also increased in strength. The largest increase in rainfall is seen in the month of May and June. How does the winter irrigation influence the summer monsoon rainfall? The major parameter is the total amount of water vapor in the vertical column of the atmosphere. The



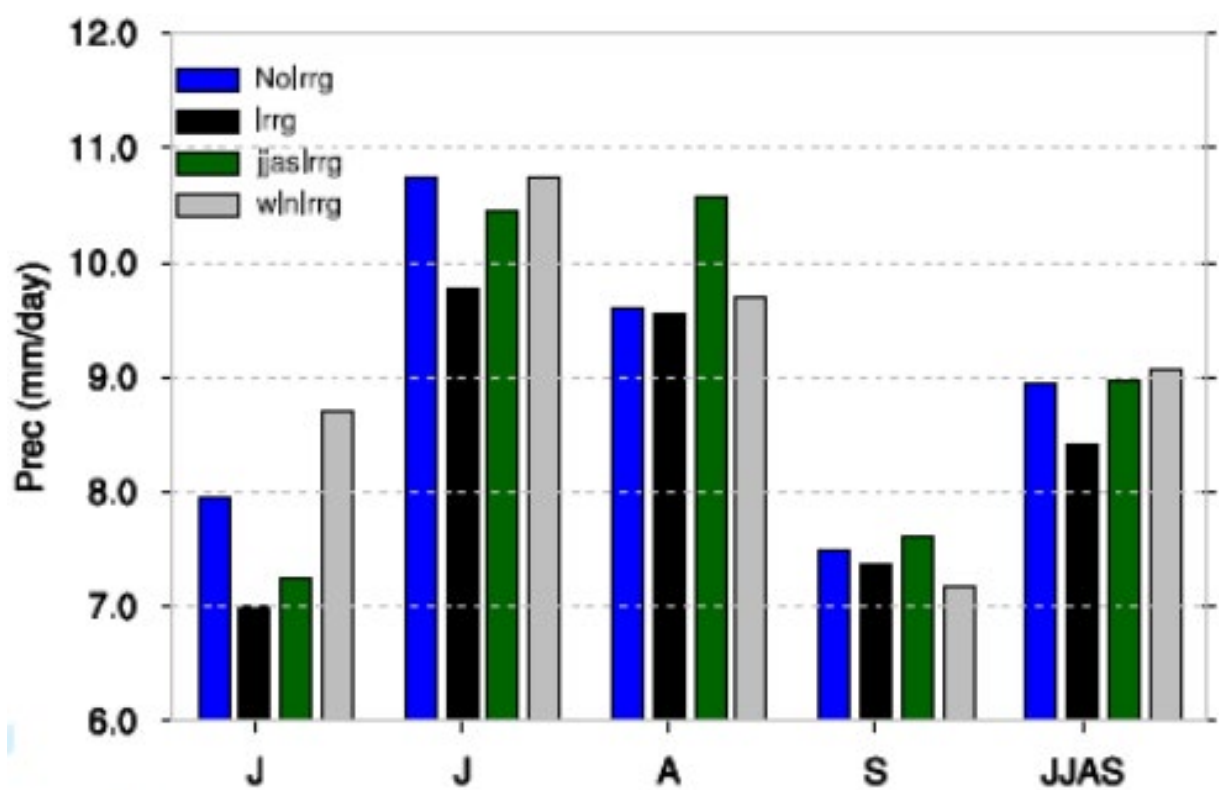
The figure on the **left** shows the difference in summer rainfall between winter irrigation and no irrigation simulations. The figure on the **right** shows the difference in summer rainfall between summer irrigation and no irrigation simulations.

irrigation in winter increases the amount of water vapor in the atmosphere during May and June. Water vapor is lighter than air and hence a higher amount of water vapor promotes vertical motion and this leads to higher rainfall.

When irrigation is undertaken throughout the year, Agrawal et. al., (2019) find that Indian monsoon rainfall decreases in the Indo-Gangetic plains. This unusual pattern of rainfall changes can be attributed to local changes in circulation on account lower surface temperature in the Indo-Gangetic plains when irrigation is undertaken throughout the year. The changes in seasonal cycle of rainfall in the Indo-Gangetic plains shows a more complex pattern. There is an increase in rainfall in June with winter irrigation but

not in summer or annual irrigation.

Reference: Shubhi Agrawal, Arindam Chakraborty, Nirupam Karmakar, Simon Moulds, Ana Mijic, and Wouter Buytaert, Effect of winter and summer-time irrigation over Gangetic plain on mean and intra-seasonal variability of Indian summer monsoon, Climate Dynamics, 2019, <https://doi.org/10.1007/s00382-019-04691-7>

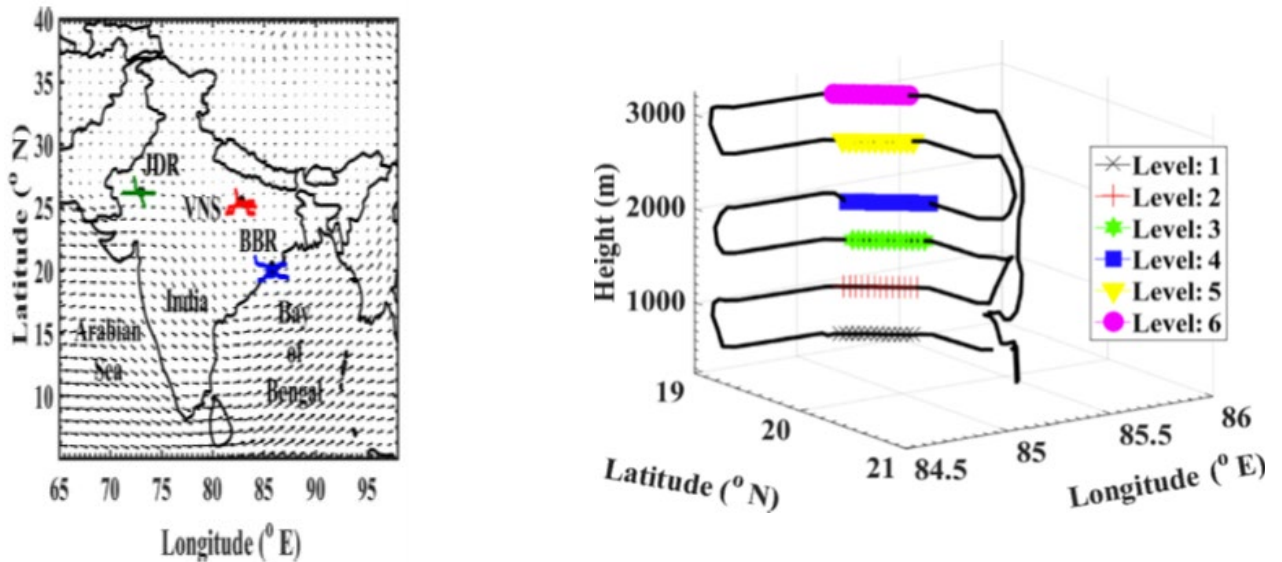


Seasonal cycle of rainfall in the Indo-Gangetic plains in different simulations. Irrg refers to annual irrigation, jjasIrrg to summer irrigation, winIrrg to winter irrigation.

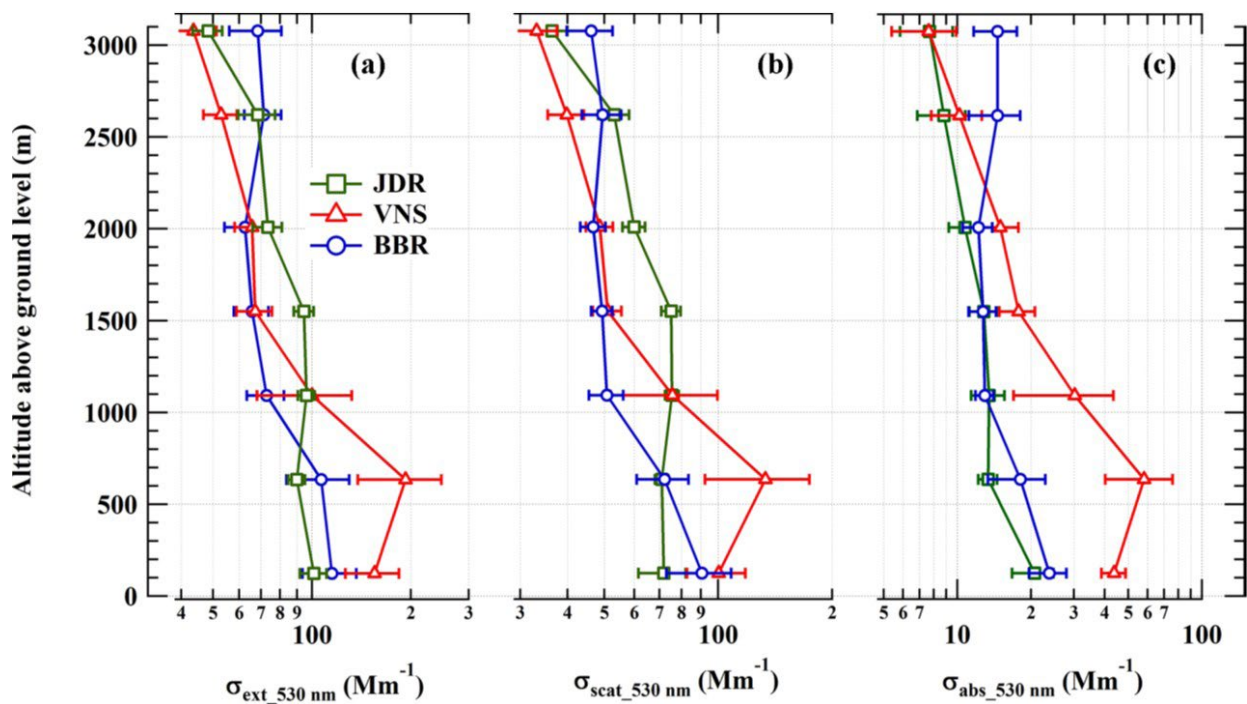
VERTICAL PROFILE OF HEATING BY AEROSOLS IN NORTH INDIA

Natural and anthropogenic aerosols occur in significant amounts over the Indian region, especially over Indo-Gangetic Plains (IGP). They are known to strongly influence the Indian Summer

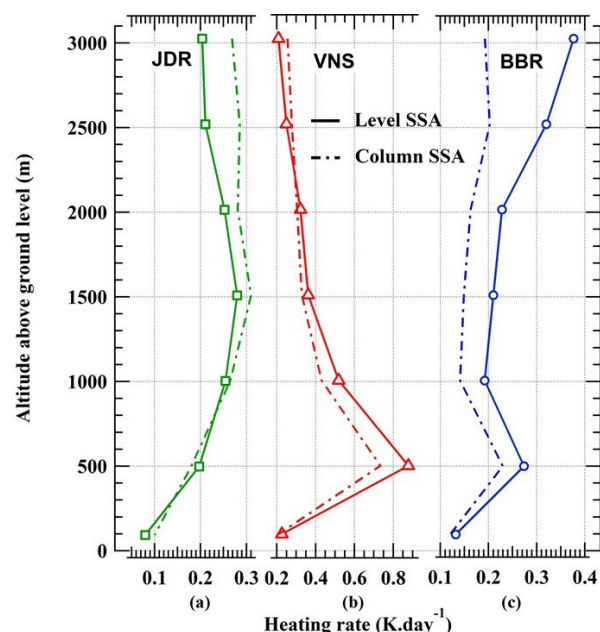
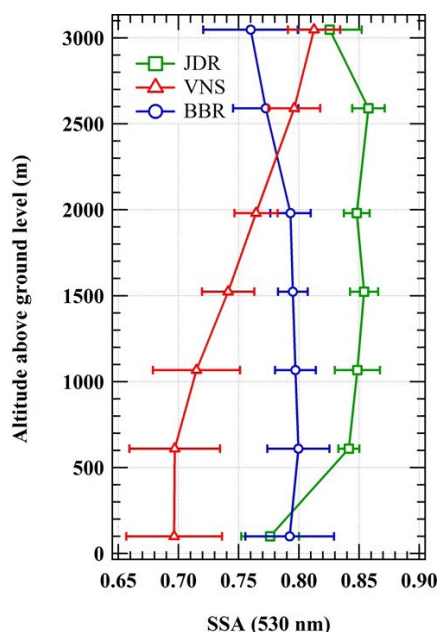
Monsoon. A joint Indo-UK field campaign SWAAMI (South West Asian Aerosol Monsoon Interaction) was been carried out to characterize these aerosols. There were extensive measurements



The figure on the **left** shows the stations where measurements were made by aircraft. JDR=Jodhpur, VNS= Varanasi and BBR=Bhubaneshwar. The figure on the **right** shows how the aircraft traversed different layers of the atmosphere.



The figure above shows the variation of extinction, scattering and absorption coefficient at different levels. Note that the absorption coefficient is much higher in Varanasi (Central IGP) than in the other two stations.



The figure on the **left** shows the vertical variation of single scattering albedo (SSA) which is the ratio of scattering to extinction coefficient. A low value of SSA indicates the presence of absorbing aerosols such as soot. Important points to note are (a) very low value of SSA at Varanasi close to the surface, (due to local anthropogenic activities) and a rather rapid increase in SSA above the local boundary layer showing the impacts of elevated dust aerosols (with SSA values going close to those over Jodhpur). In contrast, at BBR, where the marine aerosols are significant in the lower altitudes, SSA remains fairly high, and surprisingly decrease above 2 km due to mixing of aerosols of different origins. The figure on the **right** shows the heating rate of the clear atmosphere by these aerosols, estimated using the earlier data. Note the high heating over Varanasi on account of the presence of more soot in Varanasi when compared to Jodhpur which has more dust.

using Indian and UK aircrafts and data from ground-based observatories and satellites. The altitude profiles aerosol extinction, absorption and single scattering albedo were measured in Jodhpur, Varanasi and Bhubaneswar using a Beechcraft (B200) aircraft of the Indian Space research Organization, during June 2016.

Based on these measurements the vertical profile of extinction (sum of absorption and scattering) coefficient was calculated and SSA was derived. Jodhpur lies close to the arid region and is strongly under the influence of locally generated and long-range transported mineral dust during this season, Varanasi

in the Central IGP represents regions with strong anthropogenic emissions and Bhubaneswar represents the aerosols at the outflow region, being modulated by the marine component.

Reference: “Large contrast in the vertical distribution of aerosol optical properties and radiative effects across the Indo-Gangetic Plain during the SWAAMI–RAWEX campaign”, Aditya Vaishya, Surendran Nair Suresh Babu, Venugopalan Jayachandran, Mukunda M. Gogoi, Naduparambil Bharathan Lakshmi, Krishnaswamy Krishna Moorthy, and Sreedharan Krishnakumari Satheesh, Atmospheric Chemistry and Physics, 18, 17669–17685, 2018



